WALNUT DRYING PROCESS

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Introduction

- For optimal quality, nuts have to be treated with care by means of harvesting, drying, storage and transporting.
- Experiences and practice through the decades of walnut cultivation showed there are approaches that gave the best results.
- The most famous varieties: Chandler, Howard, K82, Serr and others.
- In Serbia: Novosadski kasni, Srem, Tisa and others. Prescribed quality of inshell walnuts are formed by United Nations organs by standard “UNECE STANDARD DDP-01, Inshell Walnuts”
- According to this standard walnut quality can be classified in three categories.
Brief review of walnut drying requirements

- Satisfactory level of final moisture content is usually taken as 8% of moisture on dry basis of walnut mass.

\[
\log \left[ \log \left( \frac{1}{1 - rh} \right) \right] = 1.77 \log(M_e) - 2.05
\]

- Long-term exposure of walnuts to temperatures larger than 43°C may cause the walnuts to become rancid. Short-term exposure to higher temperatures, even those that are extremely high, should not cause such an advent, but the experiments showed that this approach doesn’t decrease drying time almost at all.
Mathematical model and numerical analysis of bin drying systems

- For simulation of drying process of nuts (and grain materials as well) the thin layer drying model is used

- When effects of TLD are known, one can access to deep bed drying modeling where the mass and heat balances of moisture and air (as the drying agent) are included. This kind of model is hard for analytical solving so the numerical approach is used (finite difference method).
\[
\frac{\partial T}{\partial t} = -\frac{G_a(c_a + c_v X)}{\rho_p(c_p + c_w M)} \frac{\partial T}{\partial x} - \frac{G_a h_f g}{\rho_p(c_p + c_w M)} \frac{\partial x}{\partial x}
\]

\[
\frac{\partial X}{\partial x} = \frac{-\rho_p}{G_a} \frac{\partial M}{\partial t}
\]

\[
\frac{\partial M}{\partial t} = -k(M - M_e)
\]

\[
k = \exp(-0.681 + 0.11 M_o 0.952 \ln M_o + 0.000152(1.8T + 32.2)^2)
\]
<table>
<thead>
<tr>
<th>Process parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter, $D$</td>
<td>mm</td>
<td>35</td>
<td>K82 variety</td>
</tr>
<tr>
<td>Specific heat dry air, $C_{pa}$</td>
<td>kJ/(kgK)</td>
<td>1.01</td>
<td>general</td>
</tr>
<tr>
<td>Density of dry air, $\rho$</td>
<td>kg/m$^3$</td>
<td>588</td>
<td>average</td>
</tr>
<tr>
<td>Specific heat dry solids, $C_p$</td>
<td>kJ/(kgK)</td>
<td>1.26</td>
<td>general</td>
</tr>
<tr>
<td>Initial walnut temperature, $T_g$</td>
<td>K</td>
<td>303</td>
<td>ambient</td>
</tr>
<tr>
<td>Initial walnut moisture, $M_0$</td>
<td>% d.b.</td>
<td>39.76</td>
<td>K82 variety</td>
</tr>
<tr>
<td>Inlet air temperature, $T_a$</td>
<td>K</td>
<td>315</td>
<td>ambient</td>
</tr>
<tr>
<td>Inlet air relative humidity, $rh$</td>
<td>%</td>
<td>40</td>
<td>ambient</td>
</tr>
<tr>
<td>Inlet air pressure, $p_a$</td>
<td>Pa</td>
<td>101325</td>
<td>ambient</td>
</tr>
<tr>
<td>Distance step, $\Delta x$</td>
<td>cm</td>
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<td></td>
</tr>
<tr>
<td>Time step, $\Delta t$</td>
<td>min</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Start

Setting up zero matrix, i x j dimension

Calculating $M_{i+1,j}$ by using TLD equation

Calculating $T_{ai+1,j+1}$ by using heat balance equation

Calculating $X_{i+1,j+1}$ by using mass balance equation

Calculating $rh_{i+1,j+1}$ by using absolute humidity $X$

If $rh<0.9$ then NO, if $rh>0.9$ then YES

Next depth $i$ and time $j$ step

Checking if final depth and time are reached (if all matrix elements are filled)

End
Numerical results analysis

- Numerical simulation was made by using Matlab code, which was prepared according to the mentioned procedure. Bed depth was 0.5 m, and total drying time 30 h. As showed in figure, it takes about 16 h for the process to decrease its average moisture content below 1% of moisture (dry basis).
Conclusion

- The drying approach proposed in this paper is similar to those that are used for any other grain drying (wheat, corn, rice, etc.).

- Based on the literature survey it can be concluded that there are no such results for walnut cultivars in Serbia, while internationally published results are also pretty poor.

- Developing such numerical approaches with different discretization algorithms might result in even more accurate information.
In this paper the approach for synthesis of important sub-processes is proposed, so the overall process observation could be simplified. That could provide a better environment for more frequent investigation, designing and investing in walnut cultivation and post-processing actions.
Thank you!