Mathematical Modelling of time based Shrinakge of different shaped food particulates

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Desbiolles
What is fluidization?
Drying

- Preservation technique
- Complex process
- Drying condition
- Drying rate
- Phase transformations
- Chemical/biochemical and physical changes
Physical changes during drying

- Shrinkage (diffusional properties)
- Density changes (thermophysical, transport, packaging, energy)
- Alteration of shape, size (packaging)
- Porosity (diffusional properties)
- Pore size
- Pore size distribution (bulkiness, rehydration capacity, rehydration rate)
Quality aspects associated with physical changes

- Change of solubility
- Reduced rehydration
- Change of organoleptic properties
- Textural changes
- Reconstitutability
Why it is important?

- design of process and material handling equipment
- resistance to air flow (ambient drying, fluid bed drying, energy in drying)
- structural loads in bulk storage systems
- mixing, transport, packaging
- predict drying times
- optimise storage conditions
- obtain best product quality
- design aeration and ventilation systems
- modelling of mass/heat transfer operations
Drying conditions

- **Temperatures**
  30, 40, 50\(+2^\circ C\)
- Fluidized bed dryer
- connected to heat pump dehumidifier system
Laboratory fluid bed dryer

Exit Air

U-tube manometer

Drying chamber

Material
Porous plate

Air distributor plate

Pitot tube

Air from heat pump

By-pass
Fluid bed dryer set up
Raw material properties

- Material
  - green beans (cylindrical)
    - L:D ratio
      - 3:1
      - 2:1
      - 1:1
  - potato (cuboidal)
    - Aspect ratio
      - 3:1
      - 2:1
      - 1:1
  - green peas (sphere)
Equation used for modelling shrinkage constant

\[ VR = A \, e^{-B \, t} \]

where, \( VR = \text{Volume ratio} \)
\( A, B = \text{constants} \)
\( t = \text{drying time (s)} \)
Shrinkage behaviour of Beans

Bean 1:1/30 °C

\[ y = 0.5183e^{-0.3945x} \]

\[ R^2 = 0.947 \]
# Potato Shrinkage Constants

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30°C</td>
<td>40°C</td>
</tr>
<tr>
<td>3:1</td>
<td>0.438</td>
<td>0.390</td>
</tr>
<tr>
<td>2:1</td>
<td>0.513</td>
<td>0.470</td>
</tr>
<tr>
<td>1:1</td>
<td>0.758</td>
<td>0.496</td>
</tr>
</tbody>
</table>
## Bean Shrinkage Constants

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th></th>
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<th>B</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30°C</td>
<td>40°C</td>
<td>50°C</td>
<td>30°C</td>
<td>40°C</td>
<td>50°C</td>
</tr>
<tr>
<td>3:1</td>
<td>0.906</td>
<td>0.692</td>
<td>0.557</td>
<td>0.270</td>
<td>0.350</td>
<td>0.380</td>
</tr>
<tr>
<td>2:1</td>
<td>0.805</td>
<td>0.603</td>
<td>0.539</td>
<td>0.320</td>
<td>0.310</td>
<td>0.320</td>
</tr>
<tr>
<td>1:1</td>
<td>0.518</td>
<td>0.356</td>
<td>0.263</td>
<td>0.320</td>
<td>0.390</td>
<td>0.450</td>
</tr>
</tbody>
</table>
### Peas shrinkage constants

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>30</th>
<th>40</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>0.863</td>
<td>0.794</td>
<td>0.563</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>0.230</td>
<td>0.180</td>
<td>0.240</td>
</tr>
</tbody>
</table>
CONCLUSIONS

- There is a relation between shrinkage constant and drying time.
- Simple mathematical models can be derived for this relation.
- Simple models can be further improved by considering structural changes.
- Further experiments are necessary to validate this assumption.
Thank You for your time