Modeling the drying and sorption behaviour of yam (*Dioscoreaceae rotundata*)

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Yam is an important food crop for many people in the yam zone of West Africa

- MC: about 70%
- Uses: when boiled, roasted or fried
- Losses: 10-50%
- Production: Ghana is a main producer (third to Nigeria)
- Export: Ghana is leading in West Africa
Yam as a food product

- Nutrition:
  - 4 times more protein as in cassava
  - the only root crop that exceeds rice in protein
  - overall rating of essential amino acids relatively high and superior to sweet potato

- Drying into powders may increase its variability of uses
  - In soups
  - composite products
  - baby foods
Drying properties

- Moisture fits: Classical empirical/black-box models are often used
  - High R-square values
- The challenge: To understand moisture transport
- Is a mass driven equation an option?
Sorption isotherms

- Indicates equilibrium conditions of a food product under varying conditions of RH and temperature
  - useful for optimization
  - design of drying equipment
  - predictions of quality parameters
  - shelf-life study
  - storage investigations.

- How is it affected by temperature?
Dynamic Vapour Sorption analyser (DVS)
Sorption model

Sorption

- Henderson, Halsey, Oswin and GAB equations

- The GAB equation is

\[ X_e = C_1 C_2 C_3 RH [(1 - C_2 RH)(1 - C_2 RH + C_2 C_3 RH)]^{-1} \]
Drying rate measurements

- Yam variety and cultivar: *D. rotundata, Dente*
  - Cut size: 3x3x1 cm
- Drying procedure/ equipment
Drying model

Diffusion

\[
\frac{dX}{dt} = D \frac{d^2 X}{dx^2}
\]

Approximated by

\[
MR = \frac{X - X_e}{X_0 - X_e} = \frac{8}{\pi^2} \exp \left( -\frac{\pi^2}{L^2} Dt \right)
\]

Specifying the drying rate as

\[
drying rate = \frac{dX}{dt} = -k(X - X_e)
\]

Gives

\[
\frac{X - X_e}{X_0 - X_e} = \exp(-kt)
\]

Then

\[
k \approx \frac{\pi^2}{L^2} D
\]
Results on sorption isotherms

- 25°C desorption
- 50°C desorption
- 25°C sorption
- 50°C sorption

Equilibrium moisture content (kg/kg db (%))

Relative humidity (%)

Desorp (50°C)  Desorp (25°C)
Sorption curve model

At 50°C

<table>
<thead>
<tr>
<th></th>
<th>C₁</th>
<th>C₂</th>
<th>C₃</th>
<th>K</th>
<th>n</th>
<th>MSe</th>
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<tbody>
<tr>
<td>GAB</td>
<td>8.28</td>
<td>0.76</td>
<td>10.14</td>
<td>-</td>
<td>-</td>
<td>0.0027</td>
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<td>Henderson</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.012</td>
<td>1.65</td>
<td>0.09</td>
</tr>
</tbody>
</table>
Drying model

- Using
  \[
  \frac{X_0 - X_e}{X_0} = \exp(-kt)
  \]
- R-square values \(\approx 0.995\) are good...
- ... but systematic errors
Drying rate Vs moisture

\[ \frac{dX}{dt} = rate = -k(X - X_e) \]
Drying rate Vs moisture

\[ \frac{dX}{dt} = \text{rate} = -k(X - X_e) \]
Cont. drying rate

- Rate, $k$ is not constant
- This behaviour could not be detected by the empirical models
- Region of phase transition is well defined
- Probably may be the glass transition region coupled with shrinkage
- There is progressive increase in temp with decreased moisture content
Conclusion

The present work reveals that:

- Both drying rate and diffusion approximation models exhibit two drying phases with a shift between 1.2-1.3 kg water/kg dry matter.
- This can be explained from shrinkage behavior of yam during drying.
- There was no shift in EMC at different temperatures as reported in literature.
- The GAB model fitted well the sorption isotherms.
Thanks for your attention

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