Microwave Vacuum & Freeze Drying


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Motivation

- In the time we developed Microwave Vacuum Driers, conventional freeze drying was always the quality reference for texture, appearance, color etc.
- Conventional freeze driers were developed in an incremental way, but no real innovation happened in the past decades
- Due to extreme long drying times conventional freeze driers are economical under pressure (especially as steel prices are increasing significantly)
- Due to the long drying time, volatile compounds like aromas, antioxidants etc. get lost
- Shelf based material handling is difficult for full automated processes.

40-70h FD Drying Time based on Shelf Logistic

The CONRAD™ Process

2-4h FD Drying Time based on Drum Logistic

24kW MW FD

Conventional Heating

Microwave Heating
Application Categories in Mw-Vacuum Drying

**Inorganic Inert Chemicals**
like Drying of Si-Powder

- Ability to absorb microwave energy:
  - Not critical

**Organic Chemicals**
Biotec and Food

- Like Drying pharmaceutical raw materials:
  - Not critical
- becomes critical at MC < 5-10%

**Active Chemicals**
Like Drying of Graphite and SiC-Powders

- High
- Medium
- Low
  - Very critical
Application Categories
Mw-Vacuum Drying versus Mw-Freeze Drying

Organic Products under Mw Vacuum Drying Conditions

<table>
<thead>
<tr>
<th>H2O</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td></td>
</tr>
<tr>
<td>medium</td>
<td></td>
</tr>
<tr>
<td>low</td>
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</tr>
</tbody>
</table>

- In frozen conditions water molecules cannot move and the dielectric losses are low.
- Dielectric products losses mainly determined by product itself.

Dielectric constant $\varepsilon'$

Loss factor $\varepsilon''$
Microwave Vacuum Drying

- Vacuum [mbar]
- MW-Power [W]
- Temp [°C]
- Weightloss [g]

Graphs showing drying and end drying stages:
- Vacuum: 100 to 20 mbar
- MW-Power: Max
- Temp: 40°C
- Weightloss: Decreasing

Biotec and Food

- H2O Product
- High, Medium, Low

Turntable with online loadcell
IR camera
Mode Stirrer
Vacuum Pump
Microwave System
PC
PLC

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Microwave Freeze Drying System based on Rotating Drums

**Food under Mw FD Conditions**

- **P mw**
- **vacuum**
- **temp**
- **weight**
- **mechanical stability**

- **high**
- **medium**
- **low**

- **H2O**
- **Product**

- Evaporation temperature
- Verdampfungspump

- 24kW
- 1mbar
- 0 to -20
- 85%
- 15%
- 10%
- 5%

- Varies on product

50 liter
In order to avoid Arcing & Plasma an excellent Microwave Design is required.
Different Configurations of the Lab \( \mu \text{WaveVacxx50} \)

- **Lab Setup \( \mu \text{WaveVac0250-FD} \)**
  - 2kW/2450MHz Mw FD with 2kW @ -50°C chiller/condenser for vacuum levels of 1mbar

- **Turntable Operation**

- **50 ltr Open PP Drum**

- **50 ltr Closed PP Drum**
Mw FD of Horse Radish on Turntable

<table>
<thead>
<tr>
<th>Param</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start weight</td>
<td>346g</td>
</tr>
<tr>
<td>Initial MC</td>
<td>68%</td>
</tr>
<tr>
<td>End weight</td>
<td>110g</td>
</tr>
<tr>
<td>End MC</td>
<td>3-10%</td>
</tr>
<tr>
<td>Drying Time</td>
<td>2h</td>
</tr>
<tr>
<td>Max Temp</td>
<td>5°C</td>
</tr>
</tbody>
</table>
### Mw FD of Radish on Turntable

<table>
<thead>
<tr>
<th></th>
<th>Combi MW FD &amp; VD</th>
<th>MW FD</th>
<th>Conv FD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry Time</strong></td>
<td>2h</td>
<td>4h</td>
<td>40h</td>
</tr>
<tr>
<td><strong>Max Temp</strong></td>
<td>40°C</td>
<td>10°C</td>
<td>40°C</td>
</tr>
<tr>
<td><strong>Weight per piece</strong></td>
<td>0.58g</td>
<td>0.59g</td>
<td>0.52g</td>
</tr>
<tr>
<td><strong>Ratio Dehyd</strong></td>
<td>2:3</td>
<td>6:8</td>
<td>10.0:14.0</td>
</tr>
<tr>
<td><strong>Aroma</strong></td>
<td>good</td>
<td>Very good</td>
<td>Poor</td>
</tr>
</tbody>
</table>
Mw FD of Raspberries in open Drum

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brix</td>
<td>8-13%</td>
</tr>
<tr>
<td>Initial Weight</td>
<td>3kg</td>
</tr>
<tr>
<td>End Weight</td>
<td>0.45kg</td>
</tr>
<tr>
<td>Drying Time</td>
<td>3.5h</td>
</tr>
<tr>
<td>Max Temperature</td>
<td>35°C</td>
</tr>
<tr>
<td>Applied Mw Energy</td>
<td>2.94kWh</td>
</tr>
</tbody>
</table>
Mw FD of Strawberries in open Drum

- Homogenous Freezing of Fruits very important
- Fruits have to be calibrated

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Weight</td>
<td>3kg</td>
</tr>
<tr>
<td>End Weight</td>
<td>0.51kg</td>
</tr>
<tr>
<td>Drying Time</td>
<td>3.0h</td>
</tr>
<tr>
<td>Max Temperature</td>
<td>42°C</td>
</tr>
<tr>
<td>Applied Mw Energy</td>
<td>2.81kWh</td>
</tr>
</tbody>
</table>
Mw FD of Raspberries in closed Drum

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brix</strong></td>
<td>8-13%</td>
</tr>
<tr>
<td><strong>Initial Weight</strong></td>
<td>5kg (83% MC)</td>
</tr>
<tr>
<td><strong>End Weight</strong></td>
<td>0.82kg (7-10% MC)</td>
</tr>
<tr>
<td><strong>Drying Time</strong></td>
<td>3.4h</td>
</tr>
<tr>
<td><strong>Max Temperature</strong></td>
<td>35°C</td>
</tr>
<tr>
<td><strong>Applied Mw Energy</strong></td>
<td>4.64kWh</td>
</tr>
</tbody>
</table>
Further Application Examples

- Strawberries in MW FD
- Broccoli in MW Vacuum Drying
- Herbs in MW Vacuum Drying in fluidized bed conditions
- Banana in MW FD conditions
- Cranberries in MW FD conditions
- Fresh Ginger
- MW FD Ginger
- MW Vacuum dried Ginger

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Microwave Freeze Drying of chemical Raw Material

Microwave Heating Power has to balance Cooling Power @ -30°C.
Summery

Huge Potential for Mw FD Technology in Food, BioTec & Pharma Applications

Much more shorter Drying times with better Quality Parameters gives good economical.

Mw FD Technology will develop with niche application.

\textit{\textbf{\muWaveVac xx50}} offers Multipurpose Conditions and is ideal Entrance into Microwave Freeze Drying Technology

All Processes have to be proven before in small scale using an appropriate Micro-wave Concept which can be up-scaled later to Production Scale

Thank you for your attention

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