Superheated steam drying

Identification

Key words: superheated steam, low pressure, drying
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How does it work?

Primary objective: Drying of food products
Working principle:

This closed-system drying method is based on the vapourization of water in the product by contact with superheated steam. This water in its turn becomes part of the superheated steam. The superheated steam allows good heat transfer to the product that needs to be dried. (1,2).

Superheated steam is steam that has a temperature above the boiling point. Up to the boiling point, the term saturated steam is used, while above the boiling point, the steam is referred to as unsaturated or superheated. As long as the temperature remains higher than the saturation temperature (i.e. boiling point), a drop in temperature does not cause condensation of the steam (1,2).

The drying cycle using superheated steam consists of 3 periods (1,2):

1. Initial drying period in which the product moisture content increases because of the heat initially being transferred through condensation. This increase in moisture content increases the drying time, but is only important for food products with low initial moisture content.

2. Constant-rate period in which the water from the product moves as bulk flow from the product, without diffusive resistance at the boundary layer. The heat transfer coefficient for superheated steam is higher than for hot dry air, if the degree of superheating is high enough. For the same drying medium temperature, the product reaches a higher temperature in saturated steam (i.e. saturation temperature), than in hot air (i.e. the wet bulb temperature). However, the drying rate in superheated steam is lower than in dry air if the temperature is below the inversion temperature. Above the inversion temperature, superheated steam is a more effective drying agent than humid air or even than dry air (3). The period of drying at a constant rate is longer for superheated steam drying.

3. Falling-rate period in which because of the dry layer forming at the surface of the product, the rate of drying drops. In this period, the temperature of the product increases to that of the superheated steam. The drying rate in this period is also higher than for hot air drying.

To minimize the thermal damage to the product, superheated steam drying can be performed at reduced pressure. A lower pressure is accompanied by a lower saturation temperature. Although this also lowers the drying rates due to poorer convective heat transfer under reduced pressures, the products obtained are superior compared to conventional vacuum drying (4). Superheated steam drying can also be performed at elevated pressures. This is mostly interesting for products that are not heat sensitive and when energy recovery is essential. The constant rate drying temperature then exceeds 100°C.
### Additional effects
- Because of higher heat transfer coefficients and higher drying rates, energy savings of 50-80% can be attained. High thermal efficiency is obtained only if the exhaust steam is collected and condensed. Its energy can than be reused in the process or elsewhere in the factory. The steam emitted is at the pressure of the drying process.
- The inert, oxygen free atmosphere during drying overcomes the risk of oxidative or combustion reactions (e.g. in drying of coal), and also improves product quality.
- Because of the high drying rates, food products may become more porous.
- The closed design allows toxic or expensive compounds to be removed or collected in the condensate before they reach the environment.
- The process allows concurrent blanching, pasteurisation, sterilisation (5,6), and deodorisation of food products during drying.

### Important process parameters
- Superheat of the steam, pressure (although for low-pressure superheated steam drying, the superheat is more important for the drying rate). Both affect the shape of the drying curve (4).

### Important product parameters
- Thermal diffusivity, initial moisture content

### What can it be used for?

<table>
<thead>
<tr>
<th>Products</th>
<th>Sugar beet pulp, vegetables, noodles, wheat flour, meat, ....</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations</td>
<td>Drying</td>
</tr>
<tr>
<td>Solutions for short comings</td>
<td>energy savings in drying (7)</td>
</tr>
</tbody>
</table>

### What can it NOT be used for?

<table>
<thead>
<tr>
<th>Products</th>
<th>Heat sensitive food products. In that case, low-pressure superheated steam drying needs to be applied.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations</td>
<td></td>
</tr>
</tbody>
</table>
| Other limitations       | • Superheated steam drying needs to be performed at reduced pressure when drying heat-sensitive products, as this lowers the boiling point of water and thus the thermal damage.  
                          | • The drying system is more complex with regard to feeding and discharge of products as air leaking and steam leaking out, respectively, need to be prevented. This is especially the case when drying under reduced pressure. This requires good sealing.  
                          | • The system also requires good insulation as all parts that come into contact with the superheated steam need to be kept above the condensation temperature at the given pressure.  
                          | • In some cases, moisture condensation in the beginning of drying might increase the drying time  
                          | • to achieve low moisture end levels, the superheat of the drying steam needs to be high |
| Risks or hazards        | not applicable                                                                                     |


Implementation

**Maturity**
Superheated steam drying is already in industry (both in food and other), although the number of different commercial equipments available and industrial applications is limited (2).

**Modularity**
All dryer types (both continuous and batch) that are used for hot air drying can also be used for superheated steam drying. Pneumatic, flash and fluid bed dryers are the most common (2).

**Consumer aspects**
No issues expected

**Legal aspects**
No issues expected

**Environmental aspects**
Superheated steam drying is more environmentally friendly because of energy savings compared to hot air drying up to 50-80% (1).

Facilities that might be interesting for you

<table>
<thead>
<tr>
<th>Title</th>
<th>Institute/company</th>
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<tbody>
<tr>
<td>B-290- Mini spray dryer-HES-SO Valais-HEI</td>
<td>University of Applied Sciences and Arts Western Switzerland Valais</td>
</tr>
<tr>
<td>GPCG1-Fluidized bed dryer-HES-SO Valais-HEI</td>
<td>University of Applied Sciences and Arts Western Switzerland Valais</td>
</tr>
<tr>
<td>IRTAsim</td>
<td>IRTA</td>
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<tr>
<td>MP41/60, Zs240- Drum dryer- HES-SO Valais-HEI</td>
<td>HES-SO Valais-HEI</td>
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<tr>
<td>Microwave vacuum drying pilot system KEKI</td>
<td>NAIK EKI</td>
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<tr>
<td>QDS system IRTA</td>
<td>IRTA</td>
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<tr>
<td>Spray Dryer - TTZ</td>
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</tr>
<tr>
<td>Spray dryer - HES-SO Valais-HEI</td>
<td>University of Applied Sciences and Arts Western Switzerland Valais</td>
</tr>
</tbody>
</table>

Further Information

**Institutes**
TNO Institute, AgroParisTech, Karlstad University, University of Manitoba - DBE

**Companies**
GEA Barr-Rosin, Techniprocess, BMA Group, Eirich

**References**