Energy consumption in grain drying
Why do we dry grain?

- The grain moisture content after harvesting is in most cases so high that spoiling of grain starts if the grain is not dried

- High moisture content makes possible for the microbes to start their work

- Moisture content is the key factor in microbe growth
  - Low moisture content of material prevents vital functions of microbes
  - When air moisture content is higher than 62% molds start to grow
  - When air moisture content is higher than 90% bacteria start to grow
Drying demand in European countries

Harvest moisture content and drying need

<table>
<thead>
<tr>
<th>Country</th>
<th>Harvest moisture %</th>
<th>Need for drying %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td></td>
<td></td>
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<tr>
<td>Sweden</td>
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<tr>
<td>Denmark</td>
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<tr>
<td>Germany</td>
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</tbody>
</table>
Microbes and water

Moisture% vs. Intensity of growth

- Sieni
- Bakteeri
Crop storage

Crop temperature

Storage time, weeks

crop moisture content
• When biomas is kept in a constant air moisture content after some moisture movement between the material and the air there is a balance between the material and air
• Hysteresis makes the moisture balance figures different depending on if the material is drying or wetting
• Temperature has an effect on balance, the curves are called moisture isotherms
Moisture balance

Hay and straw moisture balance

Material moisture content % vs. Air relative humidity %

- Hay
- Straw

- Heinä 20 C
- Heinä 25 C
- Olki 10 C
- Olki 25 C
Crop moisture balance

Barley, rye, wheat

Crop moisture content %

Air moisture content %

Ohra   Ruis   Vehnä
Air

• Air is a gas mixture
• Besides gases air embodies water vapour (moisture)
• Air density in normal conditions (1 atm, 0°C) is 1.29 kg/m³

<table>
<thead>
<tr>
<th>Alkaine</th>
<th>Tilavuus %</th>
<th>Paino %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happi O₂</td>
<td>20,95</td>
<td>23,14</td>
</tr>
<tr>
<td>Typpi N</td>
<td>78,09</td>
<td>75,53</td>
</tr>
<tr>
<td>Argon Ar</td>
<td>0,93</td>
<td>1,28</td>
</tr>
<tr>
<td>Hiilidioksid CO</td>
<td>0,03</td>
<td>0,05</td>
</tr>
<tr>
<td>Neon Ne</td>
<td>0,002</td>
<td>0,001</td>
</tr>
</tbody>
</table>

### Graph
- Others
- Nitrogen
- Oxygen

---

**Note:** The data provided is a simplified representation and may not fully encompass all known components of air.
**Air moisture contents**

**Relative humidity** expresses how near air is to saturation, 100 % = saturation

\[s = \frac{p_h}{p'_h}\]

- \(s\) = relative humidity
- \(p_h\) = water vapour partial pressure
- \(p'_h\) = water vapour partial pressure at saturation

**Humidity ratio (absolut humidity)** expresses how much the air has water in

\[x = \frac{m_h}{m_i}\]

- \(x\) = humidity ratio
- \(m_h\) = mass of water
- \(m_i\) = mass of dry air
This is an approximate way to calculate air heating power

\[ P_k = \dot{V} i \rho c_i \Delta T \]

- \( c_i \): air heat capacity, \( 1,006 \text{ kJ/kgK} \)
- \( \Delta T \): temperature change
Example

Grain dryer furnace air flow value is 21 000 m3/h and the temperature change is 60 C. What is the heating power of the furnace?
Grain drying

In boreal conditions crops must be dried. Drying consumes energy!

In grain drying the moisture in the grain moves to the air, which is blown through the grains.
During drying different phases can be seen

- Drying starts with rapid moisture removal, the free water on the grain surface is removed
- When the free water has been removed water inside the grain must move to the surface, the moisture removal speed is decreased
- Temperature has an effect of water moving speed, high temperatures give higher moving speeds
Drying

- Grain moisture content
- Grain core temperature
- Constant speed
- Decreasing speed
- Drying speed
- Drying time
Drying

Removed water amount:

\[ M_{RW} = M \frac{w_h - W_d}{1 - w_h} \]

- \( M_{RW} \) = mass of evaporated water
- \( M \) = mass of the dried grain
- \( w_h \) = moisture content of harvested grain (wb)
- \( W_d \) = moisture content of dried grain (wb)
Example

• Barley yield of Finland is 1 700 milj. kg. What is the evaporated water amount when harest moisture content is 25, 20 or 18%.
Drying energy need

• The minimum energy need is got from the water evaporation energy and vapour heat content

\[ E = h_{vh} + c_v T_v \]

- \( h_{vh} \) = water evaporation energy at 0°C, 2502 kJ/kg
- \( c_v \) = water vapour heat content, 1.87 kJ/kg C
Example

• What is the minimum energy needed to remove 1 kg of water at 50 °C?
Drying

In grain drying

- 120 g of burning oil is needed per evaporated water kg
- This corresponds to 5.1 MJ/kg H₂O
- Besides this energy (electricity) is needed to run the fan, elevator and other dryer equipments
Example

- A farm has 210 ha of grain with average yield of 3,5 t. What is the average oil consumption in grain drying?
This material has been produced in ENPOS project. ENPOS is acronym for *Energy Positive Farm*.

The project partners are
- University of Helsinki, department of Agricultural Sciences – Agrotechnology
- MTT Agrifood Research Finland - Agricultural Engineering
- Estonian University of Life Sciences

Project home page is at [http://enpos.weebly.com/](http://enpos.weebly.com/)

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