Equilibrium moisture content of rice and rice products

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Objectives

- Determine rice component mass fractions
- Equilibrium moisture content
- Desorption and adsorption isotherms
EMC concept
Equilibrium Moisture Content

The MC grain will come to when there is no moisture transfer between the grain and surrounding air.
Equilibrium moisture content...no moisture transfer from the air to the kernel or vice versa.
Factors Affecting EMC …

- Air conditions
  - Temperature
  - Relative humidity
EMC Relations:

- If RH remains constant; T $\Uparrow$ EMC $\Downarrow$

- If T remains constant; RH $\Uparrow$ EMC $\Uparrow$
Equilibrium Moisture Content (% w.b.)

Factors Affecting EMC ...

Relative Humidity (%)

- 32°F
- 50°F
- 68°F
- 122°F
### Equilibrium Relative Humidity

Table 4.2.3. Equilibrium moisture content (EMC) of rough rice as a function of temperature and MC<sup>a</sup>

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Relative Humidity %</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>45</td>
<td>12.0</td>
</tr>
<tr>
<td>45</td>
<td>11.5</td>
</tr>
<tr>
<td>60</td>
<td>11.0</td>
</tr>
<tr>
<td>75</td>
<td>10.5</td>
</tr>
<tr>
<td>90</td>
<td>10.1</td>
</tr>
</tbody>
</table>

<sup>a</sup>Based on the Modified Henderson Equation (ASAE, 1997)
Factors Affecting EMC ...

- Air conditions
- Chemical constituency
Factors Affecting EMC …

Different grains and forms have different EMCs.

At 70ºF and 80% RH:

<table>
<thead>
<tr>
<th>Grain Type</th>
<th>Corn</th>
<th>Hard Wheat</th>
<th>Soybean</th>
<th>Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC(%w.b.)</td>
<td>16.3</td>
<td>16.6</td>
<td>15.2</td>
<td>15.0</td>
</tr>
</tbody>
</table>

(Calculated based on Chung Equation)
Different components of grains have different EMCs.

At 77°F and 75% RH:

<table>
<thead>
<tr>
<th>Rice</th>
<th>Rough rice</th>
<th>Brown rice</th>
<th>White rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC (%w.b.)</td>
<td>11.89</td>
<td>13.01</td>
<td>13.04</td>
</tr>
</tbody>
</table>

(Measured based on laboratory observations)
Factors Affecting Rice EMC …

- Varieties
- Types (long-, medium-, short-grain)
- Harvest MC
Importance of EMC …

• Drying:

\[
\text{MC (w.b.)} \quad \text{T, RH} \quad \text{EMC}
\]

\[
\begin{align*}
20\% & \quad \text{EMC} \\
\end{align*}
\]

Drying Duration
If EMC were 14%, Kernel MC = 12%, kernel would gain MC

If EMC were 10%, Kernel MC = 12%, kernel would dry and decrease MC
Fissuring in rice kernels
Materials

- Rice
  - Jupiter (medium-grain)
  - Wells (long-grain)
  - CL730 (long-grain, hybrid)
  - Parboiled

- Kellogg’s cereals process end-product
Materials

- **Rice components/products:**
  - Rough
  - Brown
  - Head
  - Brokens
  - Hulls
  - Bran
Platinous Temperature & Humidity Chamber
Chamber Test Area
Schematic of the EMC apparatus

- Linear actuator
- Load cell
- Load connector
- Sample baskets (19)
- PC
- Data logger
- Actuator control
- Thermocouple (9)
- Cover
Procedures
Temperature profiles inside the oven @ 60°C/20%RH

Thermocouple

LC-load cell

RH Sensor

<table>
<thead>
<tr>
<th>Location</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>61.3</td>
</tr>
<tr>
<td>T2</td>
<td>62.9</td>
</tr>
<tr>
<td>T3</td>
<td>62.4</td>
</tr>
<tr>
<td>T4</td>
<td>62.5</td>
</tr>
<tr>
<td>T5</td>
<td>62.9</td>
</tr>
<tr>
<td>T6</td>
<td>61.4</td>
</tr>
<tr>
<td>T7</td>
<td>62.5</td>
</tr>
<tr>
<td>T8</td>
<td>61.2</td>
</tr>
<tr>
<td>T9</td>
<td>61.3</td>
</tr>
<tr>
<td>T10</td>
<td>63.3</td>
</tr>
<tr>
<td>T11</td>
<td>62.7</td>
</tr>
</tbody>
</table>

RH Sensor: RH1 = 16.1%
Temperature profiles in the oven @60°C/20%RH
19 Products/samples locations inside the oven

- #5 CL730 - rough
- #13 Wells - rough
- #2 Parboiled - brown
- #1 Parboiled - rough
- #19 Wells - rough
- #16 Wells - brokens
- #15 Wells - head
- #14 Wells - brown
- #13 Wells - rugged
- #12 Jupiter - bran
- #11 Jupiter - head
- #10 Jupiter - brown
- #9 Jupiter - rugged
- #8 Jupiter - brokens
- #7 CL730 - head
- #6 CL730 - brown
- #5 CL730 - rugged
- #4 EP1
- #3 Parboiled - milled
- #2 Parboiled - brown
- #17 Parboiled - rugged
- #18 Wells - hulls
- #19 Wells - rough
- #16 Wells - brokens
- #15 Wells - head
- #14 Wells - brown
- #13 Wells - rugged
- #12 Jupiter - bran
- #11 Jupiter - head
- #10 Jupiter - brown
- #9 Jupiter - rugged
- #8 Jupiter - brokens
- #7 CL730 - head
- #6 CL730 - brown
- #5 CL730 - rugged
- #4 EP1
- #3 Parboiled - milled
- #2 Parboiled - brown
- #17 Parboiled - rugged
- #18 Wells - hulls
Clean Rough rice

400 g @ 12.5% MC

Boerner divider

150 g

Oven MC

Dehull/THU

Brown rice

Head

Brokens

Bran

Rough

Hulls

Head Brokens

Mass & Oven MC

Oven MC

Dehull/THU

Brown rice

Mill, McGill#2

150 g

Oven MC

Dehull/THU

Brown rice

Mill, McGill#2

15 g

5 g

15 g

15 g

15 g

5 g
Drying curves
Example of EMCs
Example of rice components

Jupiter (medium-grain)
- Hull: 17.0%
- Brown rice: 83.0%

Wells (long-grain)
- Hull: 16.1%
- Brown rice: 83.9%
Example of rice components

CL730 (long-grain)

Hull, 16.5%

Brown rice, 83.5%
Example of rice components

Brown rice, 83.5%

Hull, 16.5%

Parboiled (long-grain)
Wells (long-grain)

- Wells, 9%
- Wells, 5%
- Bran, 9.8%
- Brokens, 4.6%
- Head rice, 68.6%
Acknowledgement

We are grateful to Kellogg’s for providing the specialized oven and the Rice Processing Program Industry Alliance Sponsors for the financial support of this project.
Thank you!
Jupiter and Wells rough rice

400 g @ 12.5%MC

Boerner divider

150 g

Oven MC

Dehull/Kett

Rough

Hulls

Brown rice

150 g

Oven MC

Dehull/THU

Mill, McGill#2

Head

Brokens

Bran

15 g

5 g

15 g

15 g

15 g

5 g
CL730 and Parboiled rough Rice

400 g @ 12.5%MC

Boerner sample divider

150 g

Oven MC → Dehull w/ Kett

Hulls

Oven MC → 5 g

Brown rice

Oven MC → 5 g

150 g

Oven MC → Dehull w/ THU

Mill w/ McGill#2

Head rice

Oven MC → 15 g