Effect of material state gradients on head rice yield reduction during cross-flow drying

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On-farm cross-flow dryer

Cross-flow drying

Symmetry line
Rice column
Rice inlet
Heated-air plenum
Air exhaust
Rice outlet

Rice Processing Program

Goal

Improve the rice drying process = drying + tempering

Milling yield
Energy-use efficiency
Dryer performance
Dryer throughput

Tempering

- Commercial drying processes comprise multiple passes, with periods of “tempering” between passes holding the rice in a bin
- Allows intra-kernel moisture and material state gradients to subside

The glass transition (Tg) line

Glassy region
High viscosity: modulus of elasticity and density; low diffusivity, specific heat, specific volume, and thermal volumetric expansion coefficient

Rubbery region
Low viscosity: modulus of elasticity and density; high diffusivity, specific heat, specific volume, and thermal volumetric expansion coefficient

Glass transition line
$T_g = 100.5 - 334 \times MC; R^2 = 0.81$
Objectives

1. Quantify the effects of drying and tempering treatments on moisture contents (MCs) and HRY reductions (HRYRs) as a function of location within the drying column

2. Study the effects of intra-kernel material state gradients on HRYRs within the drying column

Experimental design (full factorial)

1. Drying air conditions
   i. To maintain kernels in the glassy state: 40°C/32% RH
   ii. To induce different extents of intra-kernel material state gradients:
      - 50°C/18% RH,
      - 60°C/12% RH,
      - 70°C/8% RH

2. Tempering approaches

FACTORS

RESPONSES

1. T/RH of the drying air
2. MC of rice after 60 min of drying
3. MRY and HRY
Tempering approaches

i. TA1 - Bulk column; not tempered

- Contents of all ten baskets mixed; 500-g sample spread into a 5-cm-deep tray, conditioned to 12.5% MC, then milled

ii. TA2 - Bulk column; tempered

- Duplicate, 150-g samples
- Dehulled in laboratory huller, milled to 0.4% surface lipid content
- Data presented as MRY and HRY

Milling analyses

- Rough rice was conditioned to 12% MC using air at 26°C/56% RH
- Five, 150-g samples were milled, and the yields averaged

Bulk-column milling yields

- Milled rice yield (%)
- Drying air condition

Control

- Rough rice was conditioned to 12% MC using air at 26°C/56% RH
- Five, 150-g samples were milled, and the yields averaged

Tempering approaches

iii. TA2 – Individual baskets; not tempered

- Contents of each basket spread into a 5-cm-deep tray, conditioned to 12.5% MC, then milled

iv. TA4 – Individual baskets; tempered

- Contents of each basket spread into a 5-cm-deep tray, conditioned to 12.5% MC, then milled
HRYs within the column

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Humidity</th>
<th>Head rice yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C/21% RH</td>
<td>Control</td>
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HRY reduction in light of the Tg line

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<td>40°C/21% RH</td>
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<td>Final bulk MC and grain T of each basket</td>
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Relevant considerations

1. Bulk MC vs. individual-kernel MCs

- Individual-kernel behavior

2. The "Tg line"

- $T_g = 100.5 - 334 \times \text{MC} \quad (R^2 = 0.81)$

HRY reduction in light of Tg line

- Tempered vs. Not tempered
Summary and conclusions

Final MCs
1. Increased with distance from HAP; large variations in MC within the column
2. Decreased with increasing severity of drying air condition

Milling yield
1. MRY decreased only at the most severe drying air condition; MRY was not affected by whether or not the rice was tempered after drying
2. HRYs
   - Kernel in glassy state: Negligible HRY regardless if samples were tempered after drying or not
   - Kernel with material state gradients: Negligible HRY if samples were tempered at an elevated temperature after drying

Thank you