Understanding Smoke Color

Chad Anderson
Sales Manager
Red Arrow Products

Bob Hanson
VP of Research & Technology
ALKAR - RapidPak
Why do we cook meat?

Primary goal: Kill bacteria
Secondary goal: Quality characteristics
ULTIMATE FOOD SAFETY SYSTEM

$1,000,000,000

WHAT'S IT DO TO THE MEAT?

IT COOKS IT.
Smoked Sausage, natural casing, 32-34mm, traditional smoke

<table>
<thead>
<tr>
<th>Step</th>
<th>Time</th>
<th>Dry-Bulb</th>
<th>Wet-Bulb</th>
<th>R.H.</th>
<th>Dampers</th>
<th>Smoke</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 min</td>
<td>110°F</td>
<td>100°F</td>
<td>68%</td>
<td>Auto</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>90 min</td>
<td>120°F</td>
<td>0°F</td>
<td>---</td>
<td>Auto</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>30 min</td>
<td>120°F</td>
<td>0°F</td>
<td>---</td>
<td>Closed</td>
<td>On</td>
</tr>
<tr>
<td>4</td>
<td>30 min</td>
<td>145°F</td>
<td>120°F</td>
<td>47%</td>
<td>Auto</td>
<td>On</td>
</tr>
<tr>
<td>5</td>
<td>30 min</td>
<td>165°F</td>
<td>140°F</td>
<td>50%</td>
<td>Auto</td>
<td>On</td>
</tr>
<tr>
<td>6</td>
<td>to 158°F</td>
<td>170°F</td>
<td>160°F</td>
<td>78%</td>
<td>Auto</td>
<td></td>
</tr>
</tbody>
</table>
Smoke Composition

• Phenols
• Carbonyls
• Acids
Smoke Color

- Carbonyls + amines + dry heat
- Hot, dry conditions promote Maillard browning
Maillard Reaction

Reducing Sugar + Protein (N) → Schiff’s Base

- The Amadori Rearrangement
- Yield Several Products
  - including 5 Hydroxymethyl 2 Furaldehyde
  - Different pathways based on the ability to dehydrate
- Brown Pigments
  - Melanoidins
Factors Affecting Smoke Color

- Concentration of browning components
- Surface temperature
- Surface dryness
Factors Affecting Smoke Color

Concentration of browning components

- Absorption of liquid smoke
  - Application method
    - Atomized or drenched
  - Concentration of drench solution
    - Liquid smoke or Maillose
    - Atomization time
  - Surface dryness

- Absorption of traditional smoke
  - Surface dryness
  - Smoke density
Factors Affecting Smoke Color

*Surface Temperature & Surface Dryness*

- Air velocity
- Dry heat
- Humidity
- Surface drying before smoke application
- Surface drying after smoke application
- Product formulation
  - Water content influences surface dryness
- Product shape
Test Equipment and Procedures

Batch Oven
- Air velocity = 100-600 fpm
- Dry-bulb = 120-200°F
- Used typical processes

Belt Oven
- Air velocity = 1800 fpm
- Dry-bulb = 400°F
- Accelerated color development
Test Equipment and Procedures

**Batch Oven**
- Air velocity = 100-600 fpm
- Dry-bulb = 120-200°F
- Used typical processes

**Belt Oven**
- Air velocity = 1800 fpm
- Dry-bulb = 400°F
- Accelerated color development
Factors Affecting Smoke Color

*Concentration of browning components*
- Absorption of liquid smoke
  - Application method
    - atomized or drenched
  - Concentration of drench solution
    - Liquid smoke or Maillose
    - Atomization time
  - Surface dryness

- Absorption of traditional smoke
  - Surface dryness
  - Smoke density
Effect of liquid-smoke concentration -- molded hams

Pre-cooked hams: 10-min pre-dry, drench, 10-min final dry

Air velocity = 1800 ft/min  Dry-bulb = 400°F
Effect of Maillose concentration -- Turkey breast

Pre-cooked turkey: 5-min pre-dry, drench, 5-min final-dry
Air velocity = 1800 ft/min  
Dry-bulb = 400°F
Factors Affecting Smoke Color

Surface Temperature & Surface Dryness

- Air velocity
- Dry heat
- Humidity
- Surface drying before smoke application
- Surface drying after smoke application
- Product formulation
  - Water content influences surface dryness
- Product shape
Effect of air velocity on browning

Pre-cooked turkey: 5-min pre-dry, drench, 5-min final-dry

Dry-bulb = 400°F    Concentration = 30% Maïllose
Factors Affecting Smoke Color

Surface Temperature & Surface Dryness

- Air velocity
- Dry heat
- Humidity
- Surface drying before smoke application
- Surface drying after smoke application
- Product formulation
  - Water content influences surface dryness
- Product shape
Effect of dry heat on smoke color -- molded hams

*Pre-cooked ham:* 10-min pre-dry, drench, 10-min final-dry

Air velocity = 1800 ft/min  Dry-bulb = 400°F  Liq smoke = 30%
Effect of dry heat on smoke color -- turkey breast

*Pre-cooked turkey:* 5-min pre-dry, drench, 5-min final-dry

Air velocity = 1800 ft/min  
Dry-bulb = 400°F  
Maillose = 30%
Effect of dry heat on smoke color -- pre-cooked hams

**Effect of Heat Treatment on Surface Temperatures of Hams**
Pre-cooked molded hams, Virginia molds, 6.0" dia x 15.0"., 14-15 lb

**Process**
1. Pre-Dry = 10-min @ 200 or 400°F dry-bulb temperature
2. Drench = 30-sec in 30% liquid smoke, 90-sec drip-off
3. Final-Dry = 10-min @ 200 or 400°F dry-bulb temperature

**Graph**
- Surface temperature 400°F process
- Surface temperature 200°F process

**Axes**
- Temperature °F
- Time - Minutes

**Legend**
- 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
- 0 20 40 60 80 100 120 140 160 180 200 220
Effect of Heat Treatment on Surface Temp of Turkey
Pre-cooked turkey breast, 4.5"x 8"x 10", 9-10 lb

Process:
Pre-dry = 5 min @ 400°F dry-bulb temperature
Drench = 30 sec in 30% Maillose, drip-off = 90 secs
Final-dry = 5 min @ 400°F dry-bulb temperature

Effect of Dry Heat on Smoke Color -- Turkey Breast
Factors Affecting Smoke Color

*Surface Temperature & Surface Dryness*

- Air velocity
- Dry heat
- Humidity
- Surface drying before smoke application
- Surface drying after smoke application
- Product formulation
  - Water content influences surface dryness
- Product shape
### Pre-smoked casings

#### Oven Cook

<table>
<thead>
<tr>
<th>Time</th>
<th>DB</th>
<th>WB</th>
<th>RH%</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 min</td>
<td>160</td>
<td>115</td>
<td>26</td>
</tr>
<tr>
<td>to 152</td>
<td>180</td>
<td>160</td>
<td>60</td>
</tr>
<tr>
<td>10 min</td>
<td>shower</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Steam Cook

<table>
<thead>
<tr>
<th>Time</th>
<th>DB</th>
<th>WB</th>
<th>RH%</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 min</td>
<td>130</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>to 152</td>
<td>160</td>
<td>160</td>
<td>100</td>
</tr>
<tr>
<td>10 min</td>
<td>shower</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Effect of humidity on smoke color -- boneless hams

Pre-smoked fibrous casings -- steam vs dry cook
Factors Affecting Smoke Color

Surface Temperature & Surface Dryness

- Air velocity
- Dry heat
- Humidity
- Surface drying before smoke application
- Surface drying after smoke application
- Product formulation
  - Water content influences surface dryness
- Product shape
Effect of pre-drying on smoke color--atomized smoke

Natural-casing sausage, 32mm, batch oven, atomized liquid smoke

<table>
<thead>
<tr>
<th>Time</th>
<th>0, 30, 60 min</th>
<th>15 min</th>
<th>15 min</th>
<th>15</th>
<th>to 160</th>
<th>10 min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DB</strong></td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WB</strong></td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RH%</strong></td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Atomization with Supreme

<table>
<thead>
<tr>
<th>Time</th>
<th>160</th>
<th>180</th>
<th>10 min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DB</strong></td>
<td>145</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td><strong>WB</strong></td>
<td>115</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td><strong>RH%</strong></td>
<td>38</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

shower

No pre-dry

30-min pre-dry

60-min pre-dry
Effect of pre-drying time on smoke color
Atomized vs traditional smoke -- natural-casing sausage

Liquid smoke

Traditional smoke

No pre-dry  30-min pre-dry  60-min pre-dry
Effect of pre-drying time on smoke color -- drenching

Skinless smoked sausage, 28mm, cellulose casing, drenched liquid smoke

<table>
<thead>
<tr>
<th>Time</th>
<th>DB</th>
<th>WB</th>
<th>RH%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0, 15, 30 min</td>
<td>150</td>
<td>105</td>
<td>22</td>
</tr>
<tr>
<td>1 min</td>
<td>170</td>
<td>130</td>
<td>32</td>
</tr>
<tr>
<td>15 min</td>
<td>180</td>
<td>150</td>
<td>46</td>
</tr>
<tr>
<td>15</td>
<td>180</td>
<td>180</td>
<td>100</td>
</tr>
<tr>
<td>to 165</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 min</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No pre-dry | 15-min pre-dry | 30-min pre-dry

Drench (30% liquid smoke)
Factors Affecting Smoke Color

Surface Temperature & Surface Dryness

- Air velocity
- Dry heat
- Humidity
- Surface drying before smoke application
- Surface drying after smoke application
- Product formulation
  - Water content influences surface dryness
- Product shape
Surface drying *after* smoke application--pre-cooked ham

**Process Steps**

1) *Drench*

2) **10-minute** final-dry

1) *Drench*

2) **20-minute** final-dry

Concentration = 15% 30% 45%

Air velocity = 1800 fpm  Dry-bulb = 400°F
Process Steps

1) Drench
2) 10-minute final-dry

1) 10-minute pre-dry
2) Drench
3) 10-minute final-dry

Concentration = 15% 30% 45%

Effect of surface drying -- pre-dry vs no pre-dry

Air velocity = 1800 fpm  Dry-bulb = 400°F (pre- and final-dry)
Factors Affecting Smoke Color

Surface Temperature & Surface Dryness

- Air velocity
- Dry heat
- Humidity
- Surface drying before smoke application
- Surface drying after smoke application
- Product formulation
  - Water content influences surface dryness
- Product shape
### Drying time after smoke application – boneless ham

Process: 60, 90, and 120-minute post-dry, batch oven

<table>
<thead>
<tr>
<th>Time</th>
<th>DB</th>
<th>WB</th>
<th>RH%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 min</td>
<td>160</td>
<td>115</td>
<td>26</td>
</tr>
<tr>
<td>60, 90, 120 min to 152</td>
<td>180</td>
<td>160</td>
<td>60</td>
</tr>
</tbody>
</table>
Factors Affecting Smoke Color

Surface Temperature & Surface Dryness

- Air velocity
- Dry heat
- Humidity
- Surface drying before smoke application
- Surface drying after smoke application
- Product formulation
  - Water content influences surface dryness
- Product shape
Effect of product shape on smoke color

Process: 60, 90, and 120-minute post-dry

<table>
<thead>
<tr>
<th>Time</th>
<th>DB</th>
<th>WB</th>
<th>RH%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 min</td>
<td>Drench (30%)</td>
<td>160</td>
<td>115</td>
</tr>
<tr>
<td>60, 90, 120 min</td>
<td>180</td>
<td>160</td>
<td>60</td>
</tr>
<tr>
<td>to 152</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Effect of product shape on temperatures of boneless hams
2.0" vs 4.6" diameter, fibrous casings, 20% water-added formula

Effect of product shape on smoke color -- hams
Factors Affecting Smoke Color -- Process Variables

Surface dryness

Pre-dry

Humidity

Air velocity

Post-dry

Concentration
Influence of Equipment Design

**Batch Oven**
- Large cabinet cross-section
- Variation in three dimensions
- Variable air velocity and drying
- Readily over-loaded

**Continuous Ovens**
- Higher airflow and drying
- Fixed loading prevents over-loading
- Less variable air velocity and drying
- Variation in only one or two dimensions