AMSA Educational Webinar:
An Update on Alternative Curing Systems with Food Safety Considerations

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Purpose of Sodium Nitrate / Nitrite

- Cured meat color

- Cured meat aroma and flavor

- Powerful antioxidant
  - Effective in controlling fat oxidation

- Preservative/antimicrobial properties
  - *Clostridium botulinum, Clostridium perfringens, Listeria monocytogenes*
Cured Meat Color Chemistry

- Sodium nitrate from vegetables = NaNO₃
- Purified sodium nitrate = NaNO₃
- Sodium nitrite from vegetables = NaNO₂
- Purified sodium nitrite = NaNO₂
Cured Meat Color Formation

Addition of Sodium Nitrite

Nitric oxide (gas)

Oxymyoglobin

Nitrosomyoglobin/Nitrosometmyoglobin

Heat

Nitrosohemochrome (Pink cured meat color)
Natural, Organic and Conventional Labeling Claims

- **Organic**
  - 100% organic
  - Organic
  - Made with organic
  - Less than 70% organic

- **Natural**

- **Uncured**

More Restrictive

Less Restrictive
Natural Labeling

- USDA, Food Standards and Labeling Policy Book
- 21 CFR 101.22

‘(1) the product does not contain any artificial flavor or flavoring, coloring ingredient, or chemical preservative (as defined in 21 CFR 101.22), or any other artificial or synthetic ingredient; and (2) the product and its ingredients are not more than minimally processed....’
Organic Meat and Poultry Products

- National Organic Program (NOP)
  - Agricultural Marketing Service (AMS)

- The National List of Allowed and Prohibited Substances
  - 7 CFR
    - § 205.605 Nonagricultural (nonorganic) substances allowed as ingredients in or on processed products labeled as “organic” or “made with organic (specified ingredients or food group(s)).”
    - § 205.606 Nonorganically produced agricultural products allowed as ingredients in or on processed products labeled as “organic” or “made with organic (specified ingredients or food group(s)).”
USDA Definition of **Uncured** Meat Products

- **Definition found in 9 CFR 317.17 and 9 CFR 319.2**
  - Normal cured products that can be made without nitrites or nitrates added
  - Other normal ingredients are allowed

- **Statements/words that must be added**
  - “Uncured” before common name
    - i.e. *Uncured Frankfurters*
  - “No Nitrate or Nitrite Added …..” statement must be added
  - “Not Preserved – Keep Refrigerated Below 40°F At All Times” statement must be added
Exceptions to Labeling for Uncured Meat Products

- “Not Preserved – Keep Refrigerated Below 40°F At All Times” not required if:
  - Thermal processed to $F_o \geq 3$
  - Final pH $\leq 4.6$
  - Water activity $\leq 0.92$

- No labeling changes are needed if brine concentration greater than 10%

- Product not covered by curing regulations
Types of Natural / Organic Meat Products

- Fresh Products
- Traditionally uncured, cooked products
Types of Natural / Organic Meat Products

- Traditionally cured, cooked products
  - No intention of replacing nitrate/nitrite
    - Uncured appearance and flavor
Types of Natural / Organic Meat Products

- Traditionally cured, cooked products
  - Intention to replace nitrate/nitrite
    - Cured appearance and flavor
New Approach: Clean Label

- Traditionally cured, cooked products
- Intention to replace nitrate/nitrite
- Cured appearance and flavor
“Alternative Curing”
Systems-“Cultured”

- Vegetable juice powders and juices
  - Standardized up to 30,000 ppm nitrate (ion)
  - Can be labeled as “celery powder”, “flavoring” or “natural flavoring”

- Lactic Acid Starter Cultures
  - Staphylococcus carnosus
  - Staphylococcus carnosus / vitulinus
  - Staphylococcus carnosus / utilis
  - Staphylococcus carnosus / Micrococcus varians

- Cure Accelerators
  - Cherry /Acerola Powder (Ascorbic acid)
  - Lemon powder (pH reducer)
“Alternative Curing”
Systems-“Pre-Converted”

- Pre-converted vegetable powders and juices
  - Standardized up to 10,000-15,000 + ppm nitrite (ion)
    - 20,000 – 25,000+ sodium nitrite
    - nitrite ion vs. sodium nitrite

- Cure Accelerators
  - Cherry /Acerola Powder (Ascorbic acid)
  - Lemon powder (pH reducer)
Available/Generated Nitrite Comparison Between Pre-converted & Cultured System

- **Ingoing nitrite via “cultured system”**
  - 45,000 ppm (sodium nitrate) x 0.40% = 180 ppm
    - 50% conversion = 90 ppm sodium nitrite
    - 75% conversion = 135 ppm sodium nitrite

- **Ingoing nitrite via “pre-converted system”**
  - 22,500 ppm (sodium nitrite) x 0.50% = 112 ppm

**Nitrate/nitrite vs. Sodium nitrate/nitrite**
- Nitrate vs. Sodium nitrate=1.37:1 conversion
- Nitrite vs. Sodium nitrite=1.50:1 conversion
Proper Use of Ingredients

**Vegetable Juice or Powder**
- Goal is to maximize levels
  - Minimum of 0.2%
  - Maximum of 0.4% ...
  - Depends on amount of spices in product

**Starter Culture**
- Per manufacturer’s recommendations
  - *e.g.* 25 g per 225 kg recommended
“Alternative Cured” Product Manufacture – Cultured System
Step # 1:

Addition of ingredient containing naturally occurring nitrates & Nitrate reducing starter culture
Curing Ingredient Activity

- Sodium/Potassium Nitrate = **INACTIVE COMPOUND**

- Sodium/Potassium Nitrite = **ACTIVE COMPOUND**
Natural Sources of Nitrate

Vegetable sources of “natural” nitrate (avg. ppm):

- Radishes 2600
- Celery 3151
- Lettuce 2330
- Spinach 2470
- Carrots 274
- Beets 3288
- Cabbage 712
- Beans 466
- Tomatoes 80
- Potatoes 150
- Turnip Greens 9040
- Onions 235
- Melon 4932
- Rhubarb 2900
- Broccoli 1014

R. Walker (1990), Food Add. Contam. 5:717-768.
“Alternative Curing” Cured Meat Color Development

Addition of nitrate source and starter culture.

Myoglobin

Nitric oxide (gas)

Incubation reduces nitrate to nitrite

Nitrosomyoglobin

Heat

Nitrosohemochrome (Pink cured meat color)
Nitrate and Nitrite Found in “Alternative Cured” Sausages

<table>
<thead>
<tr>
<th>TRT Description</th>
<th>PPM Residual Nitrite</th>
<th>PPM Residual Nitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Incubate</td>
<td>Post-Incubate</td>
</tr>
<tr>
<td>1 (0.20% VJP + 30 min)</td>
<td>0&lt;sup&gt;h&lt;/sup&gt;</td>
<td>5.6&lt;sup&gt;ij&lt;/sup&gt;</td>
</tr>
<tr>
<td>2 (0.20% VJP + 120 min)</td>
<td>0&lt;sup&gt;h&lt;/sup&gt;</td>
<td>24.5&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>3 (0.40% VJP + 30 min)</td>
<td>0&lt;sup&gt;h&lt;/sup&gt;</td>
<td>7.7&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>4 (0.40% VJP + 120 min)</td>
<td>0&lt;sup&gt;h&lt;/sup&gt;</td>
<td>46.0&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>C (156 ppm nitrite)</td>
<td>59.1&lt;sup&gt;g&lt;/sup&gt;</td>
<td>NA</td>
</tr>
<tr>
<td>SEM</td>
<td>0.62</td>
<td>1.22</td>
</tr>
</tbody>
</table>

<sup>g-j</sup> Means within same column with different superscripts are different (P<0.05).

Residual Nitrite in
“Alternative Cured” Sausages

<table>
<thead>
<tr>
<th>TRT</th>
<th>0</th>
<th>14</th>
<th>28</th>
<th>56</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (0.20% VJP + 30 min)</td>
<td>r16.1&lt;sup&gt;e&lt;/sup&gt;</td>
<td>r10.6&lt;sup&gt;f&lt;/sup&gt;</td>
<td>r8.8&lt;sup&gt;fh&lt;/sup&gt;</td>
<td>r4.9&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>r4.9&lt;sup&gt;gh&lt;/sup&gt;</td>
</tr>
<tr>
<td>2 (0.20% VJP + 120 min)</td>
<td>pq24.7&lt;sup&gt;e&lt;/sup&gt;</td>
<td>pq21.7&lt;sup&gt;e&lt;/sup&gt;</td>
<td>pq17.2&lt;sup&gt;f&lt;/sup&gt;</td>
<td>pq12.0&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>pqr9.1&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td>3 (0.40% VJP + 30 min)</td>
<td>qr21.3&lt;sup&gt;e&lt;/sup&gt;</td>
<td>q16.6&lt;sup&gt;f&lt;/sup&gt;</td>
<td>qr12.9&lt;sup&gt;fh&lt;/sup&gt;</td>
<td>qr9.9&lt;sup&gt;gh&lt;/sup&gt;</td>
<td>qr8.5&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>4 (0.40% VJP + 120 min)</td>
<td>n58.5&lt;sup&gt;e&lt;/sup&gt;</td>
<td>n44.3&lt;sup&gt;f&lt;/sup&gt;</td>
<td>n33.1&lt;sup&gt;g&lt;/sup&gt;</td>
<td>n22.3&lt;sup&gt;h&lt;/sup&gt;</td>
<td>n16.3&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>C (156 ppm nitrite)</td>
<td>o46.9&lt;sup&gt;e&lt;/sup&gt;</td>
<td>o31.4&lt;sup&gt;f&lt;/sup&gt;</td>
<td>op22.0&lt;sup&gt;g&lt;/sup&gt;</td>
<td>opq12.4&lt;sup&gt;hi&lt;/sup&gt;</td>
<td>opqr8.7&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

SEM = 1.02

<sup>e-i</sup> Means within same row with different superscripts are different (P<0.05).

<sup>n-r</sup> Means within same column with different superscripts are different (P<0.05).

Step #2:

Incubation - Conversion of nitrate to nitrite
Requirements for Nitrate Conversion

- **Proper incubation of product essential**
  - Goal is to convert as much nitrate to nitrite as possible
  - Internal temperature held for optimum starter culture function
    - i.e.: 50-113 °F (86 °F optimum)
    - ~ 1-2 hours
    - Depends on product diameter
      - Frankfurters = 2 hours
      - Ham = 1 hour (or less)

- **Optimum time for starter culture function**
  - Nitrate reductase enzymes reduce nitrate to nitrite
Step #3: Cooking
Cooking Requirements

- Besides the addition of an incubation step, no other changes are necessary.
“Alternative Cured” Product Manufacture – Pre-converted System
Process Adjustments

- **Step 1—Ingredients**
  - Pre-converted juice or powder
  - Alternative cure accelerator

- **Step 2 – Incubation Step**
  - None needed

- **Step 3 – Cooking**
  - No changes necessary
Quality Discussion
Quality Considerations

- Water and protein binding
  - Control of raw materials
  - Control of pH
  - Ingredient choices
  - Modifications to processing
# Raw Material Considerations

<table>
<thead>
<tr>
<th>Meat</th>
<th>Protein</th>
<th>Moisture</th>
<th>Fat</th>
<th>Collagen²</th>
<th>Color³</th>
<th>Bind⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull meat, full carcass</td>
<td>20</td>
<td>68</td>
<td>11</td>
<td>20</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Cow meat, full carcass</td>
<td>19</td>
<td>70</td>
<td>10</td>
<td>21</td>
<td>95</td>
<td>100</td>
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<tr>
<td>Beef shank meat</td>
<td>19</td>
<td>73</td>
<td>7</td>
<td>66</td>
<td>90</td>
<td>80</td>
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<tr>
<td>Beef chucks</td>
<td>18</td>
<td>61</td>
<td>20</td>
<td>30</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Beef trimmings, 90% lean</td>
<td>17</td>
<td>72</td>
<td>10</td>
<td>30</td>
<td>90</td>
<td>85</td>
</tr>
<tr>
<td>Beef trimmings, 75% lean</td>
<td>15</td>
<td>59</td>
<td>25</td>
<td>38</td>
<td>85</td>
<td>80</td>
</tr>
<tr>
<td>Beef plates</td>
<td>15</td>
<td>34</td>
<td>50</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Beef flanks</td>
<td>13</td>
<td>43</td>
<td>42</td>
<td>—</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td>Beef head meat</td>
<td>17</td>
<td>68</td>
<td>14</td>
<td>73</td>
<td>60</td>
<td>85</td>
</tr>
<tr>
<td>Beef cheeks, trimmed</td>
<td>17</td>
<td>68</td>
<td>14</td>
<td>59</td>
<td>10</td>
<td>85</td>
</tr>
<tr>
<td>Poultry meat (dark)</td>
<td>19</td>
<td>67</td>
<td>12</td>
<td>—</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Pork trimmings, 80% lean</td>
<td>16</td>
<td>63</td>
<td>20</td>
<td>24</td>
<td>57</td>
<td>58</td>
</tr>
<tr>
<td>Pork trimmings, 50% lean</td>
<td>10</td>
<td>39</td>
<td>50</td>
<td>34</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>Pork blade, 95% lean</td>
<td>19</td>
<td>75</td>
<td>5</td>
<td>23</td>
<td>80</td>
<td>95</td>
</tr>
<tr>
<td>Picnic trimmings, 85% lean</td>
<td>17</td>
<td>67</td>
<td>15</td>
<td>24</td>
<td>60</td>
<td>85</td>
</tr>
<tr>
<td>Pork jowls</td>
<td>6</td>
<td>22</td>
<td>72</td>
<td>43</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>Pork cheeks, trimmed</td>
<td>17</td>
<td>67</td>
<td>15</td>
<td>72</td>
<td>65</td>
<td>75</td>
</tr>
</tbody>
</table>
Focus on Myofibrillar Proteins

- **Salt soluble**
  - 32-34 °F

- **Contractile proteins**
  - Myosin
  - Actin

- **Functions in Meat**
  - Texture
  - Water holding capacity (WHC)
  - Form strong heat-set gels
pH Considerations

![Graph showing pH changes with time postmortem for PSE, Normal, and DFD meat samples.](image)

<table>
<thead>
<tr>
<th>pH</th>
<th>PSE</th>
<th>Normal</th>
<th>DFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Water Holding Capacity (WHC)

- Isoelectric point (pI)
  - Occurs when positive charges equal negative charges
  - pI of meat is approximately 5.2

Ingredient Considerations

**Challenges**

- Identifying functional ingredients that meet labeling requirements
- Replacing/removing ingredients and impact on meat system and finished product

**Important to understand function of each ingredient and impact on system.**
Salt/Water Relationship

- Isoelectric point shift
  - Myofibrillar swelling for improved water binding
    - Theoretical swelling capacity = 2.8x diameter & 8x volume
    - Change in ionic strength
  - Effect due to Cl⁻ ion

![Graph showing water holding capacity vs pH with and without salt](chart.png)
Myosin Solubility in NaCl

% Soluble

100

0

1.5% [NaCl w/w] 3.0%

Courtesy - Everett Bandman
Department of Food Science & Technology
University of California, Davis
adapted from Samejima et al., 1984
pH Manipulation/Water Relationship: Phosphate Example

- Phosphates dissociate actomyosin
  - Mimic ATP
  - Allow for more room for added water to bind
- Increases ionic strength
  - More negative charges available to bind water
  - Swelling of the proteins
Binders & Extenders

- A broad group of non-meat ingredients used to improve water binding and retention or to extend a product for economical reasons

- Understanding function
  - Moisture absorption
  - Protein, fat, moisture interaction
  - Gelation properties
Binders & Extenders

- **Examples**
  - Cereal products/
    - e.g. starches, flours
  - Carbohydrates
    - e.g. starches, hydrocolloids, gums
  - Carrageenan
  - Alginate
  - Milk products
    - e.g. Casein, nonfat dry milk

- Soy protein
  - e.g. Flour, concentrate, isolate

- Protein-enzyme
  - e.g. Transglutaminase

- Proteins
  - e.g. Fibrinex, gelatin, collagen
Limited Functional Ingredients

- “Natural” binders and extenders
  - Sodium carbonate
  - Sodium bicarbonate
  - Carageenan
  - Guar gum, locust bean gum
  - Potato starch
  - Rice starch
  - Potato fiber
  - Etc.
Quality Considerations: Antioxidants

- **Antioxidant protection**
  - ~ 50 ppm sodium nitrite
  - Dependent on amount of unsaturated lipids

- **Antioxidant replacement**
  - BHT and BHT replaced with rosemary, green tea, etc.
  - Removal of other catalysts
    - Oxygen, light, etc.
Quality Considerations: Color

- **Maintaining cured color**
  - 2-14 ppm sodium nitrite induces cured color
  - 40-50 ppm sodium nitrite generally considered adequate for maintaining for shorter shelf-life
  - 70+ ppm sodium nitrite needed for longer shelf-life

- **Cure accelerator inclusion**

- **Important to follow good meat curing procedures**
  - Hold time for curing
  - Removal of oxygen and light post processing
Cure Accelerators - Reductants/Acidulants

- **Reductants**
  - Sodium ascorbate/Sodium erythorbate
    - Accelerate nitrite reduction to nitric oxide (NO)
    - Provide reduced environment Fe+2 for NO binding
    - Improves flavor stability, shelf life

- **Acidulants**
  - Sodium acid pyrophosphate / Citric acid
    - A decrease of 0.2-0.3 pH units can result in a doubling of nitrite-to-nitric oxide
## Sarcoplasmic Proteins

<table>
<thead>
<tr>
<th>Species</th>
<th>Color</th>
<th>Myoglobin Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow/Bull</td>
<td>Dark red</td>
<td>16-20 mg/g</td>
</tr>
<tr>
<td>Beef</td>
<td>Bright cherry red</td>
<td>4 mg/g</td>
</tr>
<tr>
<td>Veal</td>
<td>Brownish pink</td>
<td>0.7 mg/g</td>
</tr>
<tr>
<td>Chicken Leg</td>
<td>Dull red</td>
<td>0.4 mg/g</td>
</tr>
<tr>
<td>Pork</td>
<td>Grayish pink</td>
<td>0.3 mg/g</td>
</tr>
<tr>
<td>Chicken Breast</td>
<td>Grayish white</td>
<td>0.01 mg/g</td>
</tr>
</tbody>
</table>
Processing Considerations

- Grinding
- Mixing
- Macerating
- Tumbling/massaging
- Thermal processing
Food Safety Discussion
Safety Considerations

- Clostridium botulinum inhibition
  - 50-60 ppm ingoing nitrite?
  - Difficult to assess without challenge studies
    - Difficult to quantify true amount of nitrite generated

- Clostridium perfringens
  - 100 ppm + ?

- Listeria monocytogenes
  - 70-80 ppm minimum?
Figure 2. Growth of *L. monocytogenes* over time in uncured, nitrite cured, "naturally cured", and nitrite-cured-antimicrobial (control) added turkey slurries.

- Slurry only = 2% salt
- Traditional NO2 = 2% salt + 156 ppm nitrite + 547 ppm erythorbate
- Starter = 2% salt + 0.4% vegetable juice powder + starter culture + 0.28% cherry powder
- Preconverted = 2% salt 0.3% preconverted vegetable juice powder + 0.28% cherry powder
- Control 1N/L/D = 2% salt + 156 ppm nitrite + 547 erythorbate + 2.8% lactate/diacetate
### Clostridium botulinum Growth in “Alternative Cured” Frankfurters

Time until botulism toxin was detected during vacuum-packed storage of inoculated frankfurters at various storage temperatures

<table>
<thead>
<tr>
<th>Products stored at:</th>
<th>72°F</th>
<th>50°F</th>
<th>40°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>uncured control (no nitrite)</td>
<td>5 days</td>
<td>14 days</td>
<td>63 days</td>
</tr>
<tr>
<td>conventional cure (156 ppm)</td>
<td>14 days</td>
<td>none/84 days</td>
<td>none/84 days</td>
</tr>
<tr>
<td>natural cure</td>
<td>5 days</td>
<td>14 days</td>
<td>63 days</td>
</tr>
<tr>
<td>natural cure + VS507</td>
<td>5 days</td>
<td>none/84 days</td>
<td>none/84 days</td>
</tr>
<tr>
<td>natural cure + VD55</td>
<td>none/84 days</td>
<td>none/84 days</td>
<td>none/84 days</td>
</tr>
</tbody>
</table>

Sebranek et al. (2010; unpublished data)
### Reduced Levels of Nitrite Impacting *Clostridium Botulinum*

**Keto-Timonen, et al. (2012), J. Food Prot. 75(7): 1346-1349**

<table>
<thead>
<tr>
<th>Product</th>
<th>Inoculation level (log CFU/g)</th>
<th>Storage time (wk)</th>
<th>C. botulinum count</th>
<th>Toxigenesis</th>
<th>C. botulinum count</th>
<th>Toxigenesis</th>
<th>C. botulinum count</th>
<th>Toxigenesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bologna-type sausage</td>
<td>2.0</td>
<td>1</td>
<td>2.11 (1.32–2.85)</td>
<td>0/5</td>
<td>2.48 (2.04–2.85)</td>
<td>ND</td>
<td>2.34 (1.90–2.66)</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>2.08 (1.49–2.69)</td>
<td>5/5</td>
<td>2.12 (0.52–4.20)</td>
<td>0/5</td>
<td>1.93 (1.52–2.38)</td>
<td>0/5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>2.80 (2.11–3.73)</td>
<td>ND</td>
<td>1.63 (1.23–2.04)</td>
<td>0/5</td>
<td>2.02 (1.38–2.52)</td>
<td>0/5</td>
</tr>
<tr>
<td>Wiener-type sausage</td>
<td>2.0</td>
<td>1</td>
<td>0.73 (0.52–1.23)</td>
<td>ND</td>
<td>0.50 (−0.47–1.38)</td>
<td>ND</td>
<td>1.04 (0.69–1.52)</td>
<td>ND</td>
</tr>
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<td></td>
<td>&gt;4.0 (&gt;4.0)</td>
<td>0/5</td>
<td>−0.44 (−0.96–0.11)</td>
<td>ND</td>
<td>0.36 (0.11–0.69)</td>
<td>ND</td>
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<tr>
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<td></td>
<td>3</td>
<td>3.23 (0.11–5.38)</td>
<td>−0.50 (−0.89–0.60)</td>
<td>0/5</td>
<td>0.34 (−0.10–0.66)</td>
<td>0/5</td>
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<tr>
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<td></td>
<td>5</td>
<td>1.93 (1.52–2.38)</td>
<td>ND</td>
<td>1.41 (0.90–1.85)</td>
<td>0/5</td>
<td>1.64 (1.23–2.04)</td>
<td>0/5</td>
</tr>
<tr>
<td>Cooked ham</td>
<td>2.0</td>
<td>1</td>
<td>2.49 (2.23–2.69)</td>
<td>ND</td>
<td>2.59 (1.90–3.23)</td>
<td>ND</td>
<td>2.58 (2.32–3.04)</td>
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</tr>
<tr>
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<td></td>
<td>3</td>
<td>3.27 (2.66–3.96)</td>
<td>0/5</td>
<td>2.13 (1.67–2.52)</td>
<td>ND</td>
<td>1.96 (1.34–2.45)</td>
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<td>5</td>
<td>1.93 (1.52–2.38)</td>
<td>3/5</td>
<td>1.41 (0.90–1.85)</td>
<td>0/5</td>
<td>1.64 (1.23–2.04)</td>
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</tr>
<tr>
<td></td>
<td>4.0</td>
<td>1</td>
<td>2.61 (2.11–3.04)</td>
<td>0/5</td>
<td>2.23 (1.65–2.52)</td>
<td>ND</td>
<td>2.50 (2.36–2.69)</td>
<td>ND</td>
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<tr>
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<td>3</td>
<td>2.93 (2.38–3.38)</td>
<td>5/5</td>
<td>1.84 (1.32–2.23)</td>
<td>ND</td>
<td>1.66 (1.15–2.11)</td>
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<td>5</td>
<td>1.93 (1.49–2.90)</td>
<td>ND</td>
<td>1.14 (0.65–1.34)</td>
<td>0/5</td>
<td>1.35 (0.30–2.79)</td>
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</tbody>
</table>

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*a* Mean log MPN estimate of cell count (CFU per gram); minimum and maximum cell counts are shown in parentheses.

*b* Number of toxin positive samples/total number of samples analyzed.

*c* ND, not determined.
Natural Growth Inhibitors, *Listeria* on Ham

40°F, 1.6-1.7% NaCl; ~70% moisture, pH 6.2-6.4

Change in populations of *L. monocytogenes* (Log CFU/ml rinse)

- Natural Ham Control-No Antimicrobials
- Natural Ham - 1.5% lemon/cherry/vinegar blend
- Natural Ham - 3.0% cultured sugar/vinegar blend
- Natural Ham - 2.0% buffered vinegar
- Traditional Ham Control with 2.8% lactate/diacetate

Natural Growth Inhibitors, *Listeria* on Roast Beef
40°F, 0.5% NaCl; ~65-67% moisture, pH 5.7-5.9

Impact of “Natural” Ingredients on Frankfurters

“Alternative Cured” System

<table>
<thead>
<tr>
<th>TRT</th>
<th>Vegetable Juice Powder (nitrate or nitrite source)</th>
<th>Antimicrobial (cherry/lemon/vinegar or cultured sugar/vinegar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2% pre-converted</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>0.2% pre-converted</td>
<td>1.4% cherry/lemon/vinegar (c/l/v)</td>
</tr>
<tr>
<td>3</td>
<td>0.2% pre-converted</td>
<td>3.0% cultured sugar/vinegar (cs/v)</td>
</tr>
<tr>
<td>4</td>
<td>0.45% nitrate source</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>0.45% nitrate source</td>
<td>1.4% cherry/lemon/vinegar (c/l/v)</td>
</tr>
<tr>
<td>6</td>
<td>0.45% nitrate source</td>
<td>3.0% cultured sugar/vinegar (cs/v)</td>
</tr>
<tr>
<td>Control</td>
<td>156 ppm Na nitrite</td>
<td>2.5% Potassium lactate/sodium diacetate</td>
</tr>
</tbody>
</table>

Impact of “Natural” Ingredients on Frankfurters

Figure 9. Growth of *L. monocytogenes* on uncured, no-nitrate-or-nitrite-added (TRT 1-4) and nitrite added control (C+) uncured control (C-) EFSC sausages.

TRT 1 (nitrite-NA); TRT 2 (nitrite-c/l/v); TRT 3 (nitrite-cs/v)
TRT 4 (nitrate-NA); TRT 5 (nitrate-c/l/v); TRT 6 (nitrate-cs/v)

**Antimicrobial Ingredients with Mixed Results**

1. 150 ppm purified nitrite
2. No nitrite
3. NaNO₂ + 1% cranberry
4. NaNO₂ + 2% cranberry
5. NaNO₂ + 3% cranberry
6. NaNO₂ + 0.5% grape seed extract

Xi et al. (2011), Meat Sci. 88: 503-511
Inhibition of Listeria monocytogenes in Deli-Style Turkey

- Uncured, No antimicrobials
- Uncured, 3.8% PD4
- PC Celery (80 ppm nitrite) + 3.8% PD4
- Na Nitrite (80 ppm nitrite) + 3.8% PD4

PD4 = commercial blend containing 56% potassium lactate + 4% sodium diacetate

UW-Madison, 2012, unpublished data
Need for Change in Food Safety Approach?

- Important to evaluate products
  - Fresh
  - Not Fully Cooked
  - Fully Cooked
  - Shelf Stable

- Important to evaluate processes
  - A change in food safety risk?
  - Need for adjustment?
Alternative Curing Next Steps

- A need to understand/confirm equivalence
  - Food safety
  - Labeling change

- Additional ingredient work
  - “Natural”, organic, and clean label antimicrobials
    - Improved effectiveness and cost consideration
  - Nitrate/nitrite sources
    - Increased concentration and cost consideration
Questions?