Common Foodborne Pathogens

- *Bacillus cereus*
- *Campylobacter jejuni*
- *Staphylococcus aureus: ham, tongue, poultry, dressing, gravy, eggs, potato salad, cream sauces, sandwich fillings*
- *Listeria monocytogenes: RTE meats*
- *Norovirus, Norwalk virus: most common: raw oysters, shellfish, water, ice, salads*
- *Salmonella: Chicken, Pet Food*

Red = highest concern in meat, Purple = concern in meat

www.extension.iastate.edu/foodsafety/pathogens

Main 3: Foodborne Pathogens in Meat Products

- Listeria: RTE
- *E. coli: Ground beef*
- *Salmonella: Poultry*

Listeria monocytogenes: RTE meats

Gram positive, facultative anaerobic, psychrotroph
- Stops growing at <14 F/-10 C
- Resistant to high salt, low pH & high temperatures.

Listeriosis:
- Occurs in immune compromised individuals and pregnant women.
- Can result in: Septicemia, Meningitis, Miscarriage

Why? Pathogen of concern:
- Slow growing: Incubation of 2 days - 3 weeks
- Tolerant of refrigeration, salt, low Aw, low pH.
- Often outcompeted by spoilage microorganisms.

Meat industry/consumer desires have created an environment for growth:
- Cleaner products: lower initial micro counts
- Longer shelf life: 60-120 days
- Extended refrigerated distribution and storage
- *Lm is ubiquitous (it is everywhere)*

Antimicrobials: The Times They Are A-Changin’

Agenda:
- Meat Pathogens: *Lm, Salmonella, E. coli*
- Foodborne Illness
- Factors influencing microbial growth
- Antimicrobials in Processed Meat
  - Organic Acids, non-organic Acids
  - Bacteriocins
  - Bacteriophages
  - Free Fatty Acids
- Types of Antimicrobials—A-Changin’ Times
  - Market Leading “Gold Standard” antimicrobials—lactates/diacetates/acetates
  - Low Cost antimicrobials: new spin on traditional inhibitors
  - Natural inhibitors: Vinegars
  - Clean label inhibitors: Cultured sugars
- Listeria Control Model: R&D and QA tool

Lm: Growth Factors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Critical limit of Listeria m growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>&lt;= 4.4</td>
</tr>
<tr>
<td>Salt</td>
<td>&gt;= 13% liquid phase salt</td>
</tr>
<tr>
<td>Water activity</td>
<td>&lt;= 0.92</td>
</tr>
<tr>
<td>Temperature</td>
<td>Freezing (28F), Cooking (&gt;160F)</td>
</tr>
<tr>
<td>Cure (nitrite)</td>
<td>Regulatory guidelines (150 ppm or 200 ppm)</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Low oxygen (facultative anaerobe)</td>
</tr>
</tbody>
</table>
### Salmonella

- **Main concern in Meat Industry!**
- Gram negative, rod-shaped bacteria in Enterobacteriaceae family
- Motile, non-spore forming
- *S. enterica*: Serotypes: *S. Enteritidis* & *S. Typhimurium* most prevalent in US.
- Prevalent on raw poultry.
- New issue: **Beef lymph nodes**
- USDA performance standards in poultry.

### US Top 5 Pathogens: Reported cases

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Estimated number of illnesses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norovirus</td>
<td>5,461,731</td>
<td>58</td>
</tr>
<tr>
<td><em>Salmonella</em>, nontyphoidal</td>
<td>1,027,561</td>
<td>11</td>
</tr>
<tr>
<td><em>Clostridium perfringens</em></td>
<td>965,958</td>
<td>10</td>
</tr>
<tr>
<td>Campylobacter spp.</td>
<td>845,024</td>
<td>9</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>241,148</td>
<td>3</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>8,541,422</strong></td>
<td><strong>91</strong></td>
</tr>
</tbody>
</table>

**US top five pathogens acquired foodborne illnesses, 2011**

**Source:** CDC, 2011 Estimates of Foodborne Illness

### US Top 5 Pathogens: Hospitalization

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Estimated number of hospitalizations</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salmonella</em>, nontyphoidal</td>
<td>19,336</td>
<td>35</td>
</tr>
<tr>
<td>Norovirus</td>
<td>14,663</td>
<td>26</td>
</tr>
<tr>
<td>Campylobacter spp.</td>
<td>8,463</td>
<td>15</td>
</tr>
<tr>
<td><em>Toxoplasma gondii</em></td>
<td>4,428</td>
<td>8</td>
</tr>
<tr>
<td><em>E.coli</em> (STEC) 0157</td>
<td>2,138</td>
<td>4</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>49,028</strong></td>
<td><strong>88</strong></td>
</tr>
</tbody>
</table>

**US top five pathogens resulting in hospitalization, 2011**

**Source:** CDC, 2011 Estimates of Foodborne Illness

### US Top 5 Pathogens: Death

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Estimated number of deaths</th>
<th>90% Credible Interval</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salmonella</em>, nontyphoidal</td>
<td>378</td>
<td>0–1,011</td>
<td>28</td>
</tr>
<tr>
<td><em>Toxoplasma gondii</em></td>
<td>327</td>
<td>200–482</td>
<td>24</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>255</td>
<td>0–733</td>
<td>19</td>
</tr>
<tr>
<td>Norovirus</td>
<td>149</td>
<td>84–237</td>
<td>11</td>
</tr>
<tr>
<td>Campylobacter spp.</td>
<td>76</td>
<td>0–332</td>
<td>6</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>1185</strong></td>
<td></td>
<td><strong>88</strong></td>
</tr>
</tbody>
</table>

**US top five pathogens resulting in death, 2011**

**Source:** CDC, 2011 Estimates of Foodborne Illness

### Salmonella

**Broiler Percent positives for Salmonella during FSIS HACCP Verification Testing, 2004-2012**

**Source:** USDA 2012 Annual Report
Factors Influencing Microbial Growth

- Moisture / Aw
- Ionic strength
- pH
- Temperature
- Available food source: sugar, proteins, etc.
- Antimicrobial ingredients influence safety via their effect on these factors.

Food Preservation Hurdle Technology

- Each hurdle affects the growth of microorganisms
- More hurdles mean more restrictions for bacteria growth
- Lower Water Activity
- Higher Salt
- Use of Nitrite/Nitrate
- Reduced processing, storing and distribution temps
- Freezing

Multiple Interventions to protect meats during processing:

1. Use of lactic acid or other natural acids or chemicals to spray on carcass during slaughter
2. Use of similar sprays on primal/sub primal
3. Use of antimicrobial ingredients inside product formulations - raw or cooked
4. Use of surface treatments to protect against the growth of listeria and other pathogens
   Ingredients - Lauric arginate, Acidified Calcium Sulfate, Phages
5. Equipment - HPP, Post Pasteurization, Irradiation

Treatment of Meat Trimmings: Acids

- Peroxyacetic Acid (PAA):
- Acidified Sodium Chlorite (ASC):
- Lactic Acid:
- Hypobromous Acid:
- Lauric Arginate (LEA, lauramide arginine ethyl ester):

RTE Surface Treatments: Acids

- Peroxyacetic Acid (PAA):
- Acidified Sodium Chlorite (ASC, Sanova):
- Hypobromous Acid:
- Lauric Arginate (LAE): Sprayed lethality in Container
- Octanoic Acid (OA, Caprylic Acid)
- Bacteriophages:
**Antimicrobial Results:**

- **Shelf Life Extension**
  - Inhibition of spoilage organisms, days to $10^6$ or $10^7$.

- **Food Safety - Pathogen Control**
  - Inhibition of *Lm, Salmonella, E. coli*.

**Antimicrobial Categories**

- **Bactericidal**
  - Kills bacterial cells
  - Commonly applied topically
  - Post lethality microbial reduction

- **Bacteriostatic**
  - Inhibits bacterial cells
  - Commonly formulated as an ingredient
  - Microbial suppressor

**Types of Antimicrobials: Processed Meats**

- **Organic Acid salts**: lactate, acetate, sorbate, propionate, benzoate
- **Bacteriocins**: Nisin, lactacin, sakacin, pediocin
- **Fatty Acids**: Lauric Arginate
- **Bacteriophages**: virus that infects and replicates within a bacterium.
- **Other**: Natamyacin (yeast and mold)

**Organic Acids & Their Salts** *(Bactericidal >> Bacteriostatic)*

- **Lactic** - lactate
  - Hydrophilic - a good inhibitor in meats, widely used, water binding effects.

- **Citric** - citrate
  - Hydrophilic - not a good inhibitor in meats (synergy with lactic)

- **Propionic** - propionate
  - Good inhibitor, recently approved in US meats, sweet, musky flavor

- **Acetic** - acetate/diacetate
  - Lipophilic, good inhibitor, vinegar flavor, widely approved

- **Benzoic** - benzoates
  - Lipophilic, good inhibitor, recently approved in US meats

- **Sorbic** - sorbates
  - Not approved for use in meats, surface mold inhibitor only

- **Cultured sugar or dairy products (ferments)**
  - Naturally fermented organic acid blends, effective and widely approved.

- **Nisin, propionate, lactate, acetate**
Potassium and Sodium Lactates

- The salt of L(-) lactic acid
- Natural- minimally processed
- Not for use in “Natural” b/c approved as antimicrobial
- Neutral pH
- Mild saline taste
- Naturally present in meat products
- Bacteriostatic properties
- Hygroscopic salt, yield benefit
- Available as a Liquid or Powder

Lactic Acid is Present in Many Food Products

<table>
<thead>
<tr>
<th></th>
<th>% Lactic Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pork</td>
<td>0.9</td>
</tr>
<tr>
<td>Beef</td>
<td>0.9</td>
</tr>
<tr>
<td>Cheese</td>
<td>1.3</td>
</tr>
<tr>
<td>Veal</td>
<td>0.9</td>
</tr>
<tr>
<td>Mutton</td>
<td>0.9</td>
</tr>
<tr>
<td>Ferm. Sausage</td>
<td>1.7</td>
</tr>
<tr>
<td>Yogurt</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Lactic acid is produced in the rigor phase present as (L+) lactic acid

Bacteriocins

- Bacteriocins are protein-based antimicrobials produced by bacteria to inhibit the growth of similar or closely related bacterial strain(s).
- Nisin – US and Canada very common in deli salads containing meat. Cannot be used directly in meat.
- Bind easily with fat.
- Expensive
- Cause holes to form in bacterial cell walls

Phages = Virus

- A bacteriophage is a Virus that infects and replicates within a bacteria
- Bacteriophages are highly specific to their target organism, and upon adhesion, the target organism will be eliminated without any side effects regarding taste, flavor or visual appearance.
- The term is derived from Greek word “to devour”
- Composed of proteins that encapsulate a DNA or RNA genome
- Phage replicate within bacteria following the injection of their genome into the cytoplasm of the host
- Gaining traction as both pre and post harvest intervention
- Spray on cattle before slaughter - E coli
- Spray in package RTE – Lm

Free Fatty Acids

- Lauric arginate (esterified FFA + Amino acid Arginine)
- Used as topical on RTE products often applied via spray in package, sliced as well
- Weak detergents, work like soap
- Terminates cells ability to generate energy by damaging cell walls

Antimicrobial Categories in Processed Meats
General Product Categories: Processed Meats

Product Categories:
- **Market Leading**:
  - Lactate, diacetate
  - K or Na lactate, blended with Na diacetate
- **Low Cost**:
  - Lactate, acetate, diacetate blends
  - Propionate
  - Benzoate
- **Natural**:
  - Vinegar
  - Citrus juices
  - Celery powder
  - Natural oleoresins: rosemary, tea tree, green tea,
- **Clean Label**:
  - Cultured corn sugar or cultured dextrose
  - Cultured sugar
  - Fermented cane sugar or fermented sugar

Market Leading Antimicrobials: Lactate/diacetate

- balance antimicrobial performance, cook yield, flavor, texture and sliceability.

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Composition (%)</th>
<th>Use level (%)</th>
<th>Application guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>OptiForm PD 4</td>
<td>K Lactate (56%), Na Diacetate (4%)</td>
<td>2.5-3.5</td>
<td>Cooked Cured applications</td>
</tr>
<tr>
<td>OptiForm SD 4</td>
<td>Na Lactate (56%), Na Diacetate (4%)</td>
<td>2.5-3.5</td>
<td>Cooked Cured applications</td>
</tr>
<tr>
<td>OptiForm Powder 100</td>
<td>Na Lactate (88%), No Diacetate (12%)</td>
<td>1.0-2.0</td>
<td>Powder + Cooked Cured applications</td>
</tr>
<tr>
<td>OptiForm Lite 4</td>
<td>No Lactate (30%), K Lactate (38%), Na Diacetate (32%)</td>
<td>2.5-3.5</td>
<td>Reduced Na ● Lactate portion: half Na, half K ● + Cooked Cured applications</td>
</tr>
</tbody>
</table>

Lactate/Diacetate: MODE OF ACTION

**Internal Cell Acidification**
- Lactate and sodium diacetate is in equilibrium with Lactic Acid and acetic acid
- Undissociated lactic acid and acetic acid penetrate into organism
- Acids dissociate, resulting in a lower internal pH of the cell
- Cell needs energy to raise the pH
- Cell stops growing and multiplying

**Feed Back Mechanism**
- Micro organism derives energy from glycolysis (energy metabolism)
- Due to concentration of lactate or acetate outside the cell, the proton pump pathway is blocked
- Slows down glycolysis (interference with energy metabolism)

Lactate/Diacetate: MODE OF ACTION

**Reduce water activity**
- Lower water potential ($\Psi$) leads to lower turgor pressure. High turgor pressure is essential for cell growth and cell division
- $\Psi_s + \Psi_p$ ($\Psi_s$: solute part, $\Psi_p$: hydrostatic pressure part/turgor pressure)
Low Cost Meat Antimicrobials

Switch to Low Cost Solutions

Cons:
- Poor labeling: Slightly worse than traditional
- Processing issues: reduced dry matter, lower pH, reduced cook yield
- Flavor, texture changes

Pros:
- Savings for customer
- Solution for low cost products previously without antimicrobial.

Lactate, Acetate and Di-acetate

- **Lactate:**
  - Salt of lactic acid
  - K or Na
  - Does NOT lower pH
  - Use up to 3.5%
  - Low flavor impact
  - Potent
  - Hygroscopic

- **Acetate:**
  - Salt of acetic acid
  - K or Na
  - Does NOT lower pH
  - Use up to 0.25%
  - Potent
  - Potential odor
  - Hygroscopic

- **DiAcetate**
  - Dissociates to 60% sodium acetate and 40% acetic acid
  - Lowers pH
  - Use up to 0.25%
  - Potent
  - Hygroscopic

Low Cost Product Overview

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Composition (%)</th>
<th>Use level (%)</th>
<th>CIU savings</th>
<th>Positioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opti.Form PD4</td>
<td>K Lactate (56)</td>
<td>2.5-3.5</td>
<td>±30%</td>
<td>Reference/control</td>
</tr>
<tr>
<td>Opti.Form Ace P13</td>
<td>K Lactate, Na diacetate (4)</td>
<td>1.5-1.9</td>
<td>±30%</td>
<td>No label change vs PD4 (K+6% prop/1.5% P+0.5% D)</td>
</tr>
</tbody>
</table>
| Opti.Form Ace P40   | K Lactate | 1.2-1.7 | ±15% | No max use level or regulatory limit | Balanced flavor impact
| Opti.Form Ace P37   | K Lactate, Na diacetate | 1.0-1.5 | ±60% | High product stability at T<45F |
| Opti.Form Pro P24   | K Acetate, Na prop | 0.8-1.2 | ±15% | High efficacy
| Opti.Form Powder Ace SE1 | Lactate, Acetate, Diacetate | 0.4-0.6 | ±15% | For powder preference |

Est. use levels based on typical parameters, contact Corbion technical services for individual projects.
Beef Hot Dog: High Fat (37%)

**Study 1**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Antimicrobial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>None</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>PD4 3.00%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>PD4 1.70%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>PD4 1.25%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>PD4 1.40%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>Pro P24 1.00%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>Powder Ace S61 0.60%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>85s 13.7%</td>
</tr>
<tr>
<td>Beef</td>
<td>50s 46.9%</td>
</tr>
<tr>
<td>Water</td>
<td>26.3%</td>
</tr>
<tr>
<td>Corn syrup</td>
<td>7.38%</td>
</tr>
<tr>
<td>Modified food starch</td>
<td>2.21%</td>
</tr>
<tr>
<td>Mustard</td>
<td>2.02%</td>
</tr>
<tr>
<td>Salt</td>
<td>1.67%</td>
</tr>
<tr>
<td>Sodium phosphate</td>
<td>0.42%</td>
</tr>
<tr>
<td>Flavors</td>
<td>(spice)</td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>0.01%</td>
</tr>
<tr>
<td>Sodium erythorbate</td>
<td>0.03%</td>
</tr>
<tr>
<td>Antimicrobial</td>
<td>*Varies</td>
</tr>
</tbody>
</table>

*Water is removed to compensate for the addition of the antimicrobial.

Opti.Form Pro P24

Inhibits Listeria growth as effectively as Opti.Form PD4

Yield Data: Coarse Ground Pork Sausage

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Antimicrobial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>None</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>PD4 3.50%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>Ace P13 1.70%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>Ace P37 1.50%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>Ace P40 1.70%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>Pro P24 1.20%</td>
</tr>
<tr>
<td>Opti.Form</td>
<td>Powder Ace S61 0.60%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pork</td>
<td>Shoulder 96.30%</td>
</tr>
<tr>
<td>Pork</td>
<td>Neck 9.75%</td>
</tr>
<tr>
<td>Salt</td>
<td>2.75%</td>
</tr>
<tr>
<td>Organic spice (Kirkland no salt)</td>
<td>1.25%</td>
</tr>
<tr>
<td>Antimicrobial</td>
<td>*Varies</td>
</tr>
</tbody>
</table>

*Water is removed to compensate for the addition of the antimicrobial.

Listeria monocytogenes results in Deli Turkey: Ace P37

Inhibits Listeria growth as effectively as Opti.Form PD4

**Micro: Beef Hot Dogs, High Fat (37%)**

Cost effective concentrations calculated on equivalent Opti.Form PD4 concentrations.

Conclusion: all products can provide 120 day Listeria monocytogenes growth inhibition.
Propionate, Benzoate and Sorbate

Propionate: 7120.1. Na, K or Propionic Acid. Approved for RTE meat and poultry where antimicrobials are permitted. Up to 0.5% of formulation: Effective on spoilage bacteria, yeast and molds.

Benzoate: 7120.1. Na benzoate. Approved for RTE meat and poultry where antimicrobials are permitted. Up to 0.1% of formulation.

Potassium sorbate: 9CFR. To retard mold growth. Dry sausage: 10 percent in water solution may be applied to casings after stuffing or casings may be dipped in solution prior to stuffing. Inhibits mold growth on dry sausages.

Additional comments on Solids levels

Current formulation (100%)

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>20</td>
</tr>
<tr>
<td>Meat block</td>
<td>60</td>
</tr>
</tbody>
</table>

When taking out solids level

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>20</td>
</tr>
<tr>
<td>Meat block</td>
<td>60</td>
</tr>
</tbody>
</table>

How will you compensate?

Water is your best option!

Possibilities:

- Meat block $$$
- Binders $$
- Starch $$
- Corn syrup $$
- Water

Definition of Natural:

Standards and Labeling Policy Memo 055, Nov 22, 1982

- Guide regarding voluntary claim “Natural”.

Natural Label for Meat & Poultry, provided that:

1. Product contains no artificial flavor, coloring, or chemical preservative (defined in 21 CFR 101.22) or artificial or synthetic ingredient.

2. Product and ingredients are not more than “minimally processed” — traditional processes used to make food edible or to preserve it or to make safe for human consumption.
   - Smoking, roasting, freezing, drying, fermenting

3. Physical processes that do not alter raw product or only separate a whole, intact food into component parts
   - Grinding meat, separating egg yolk and albumen, pressing fruit into juice.

Natural Flavors: with antimicrobial dual effect

- Lemon juice
- Lime juice
- Vinegar (liquid or powder): extremely effective against Lm.
- Vinegar/lemon blend: (acetic, citric)
- Natural Smoke: product exterior
- Various Extracts: rosemary, green tea, grape seed.
**Vinegar**

- **Vinegar:**
  - Functional ingredient: Acetic Acid (4%)
  - Lowers pH
  - Typical use 1.5-2.5% liquid or .8% powder
  - Potent
  - Pungent odor
  - Hydroscopic when dried
  - Fast growing antimicrobial category
  - Approved "Natural" label — as flavor.

**VINEGAR: Food Standards and Labeling Policy Book**

Product must contain at least 4 grams of acetic acid per 100 cubic centimeters (approximately 4 percent acetic acid). This strength is referred to as 40 grain vinegar.

**Verdad Powder N6: Listeria Control in Clean Label Ham**

- Boneless pork ham formula:
  - 30% enhanced | 1.0% Salt (NaCl) | 1.5% Dehyster | 0.6% Phosphate | 0.5% celery juice powder
  - Verdad N6: three concentrations | Storage Temp: 4°C
- Listeria inhibition for 120 days by addition of 0.9% Verdad Powder N6

**Verdad Vinegars**

- Verdad Vinegars are made with natural ingredients and minimally processed
- Applicable in both cooked and fresh meat items
  - Listeria control in cooked meat
  - Shelf life extension in fresh and cooked meat

**Verdad® Vinegars: Natural cured ham**

- Effect on Listeria, taste and yield
- Formulation of all natural ham: 25 % extension

**Verdad® Vinegars**

- Inoculated with 5 strain Lm cocktail

---

**TPC: N6 Powder - Fresh Beef Sausage**

Total Plate Count of Fresh Pork and Beef Sausages at 4°C

---

**Verdad® Vinegars**

Listeria challenge test: Natural Cured Ham

- Equal performance between Verdad® vinegars.
- Verdad® N9 lowest use level for liquid vinegars.
Natural/Clean Label Antimicrobials in Model Systems

2% Turkey Meat Story, 2.2% NaCl, pH 6.5-7.1
No growth for cured or uncured through 4 weeks

Buffered Vinegar 2.0%
Cultured sugar and vinegar blend 3.0%
Lemon/Cherry vinegar blend 1.5%
Tea Tree oil 0.5%
Vinegar/lemon juice blend 2.5%
Grapefruit juice/vinegar blend 2.5%
No growth with cured treatments for 4 weeks

Cherry powder 0.5%
Grape Seed Extract powder 0.3%
Smoked flavor 1.0%

What are Cultured Sugars and Ferments?

- A family of label friendly antimicrobials: labeled cultured corn sugar or dextrose— or cultured sugar
  - Naturally fermented sugars using specific food cultures that produce a range fermentation products
  - Ferments contain: natural organic acid salts, peptides, sugars
  - Composition of ferments is consistent due to fixed metabolic routes of cultures
- Light brown solutions
- Blended with vinegar to aid in Listeria control
- Enhance meat flavors- meaty, brothy, savory
- Good for sodium reduced products

Why use Ferments versus Vinegar?

Both are effective against Listeria.

Pros: Vinegar
- Vinegar: has USDA Natural labeling.

Pros: Ferments
- Ferments: more effective against spoilage organisms.
- Ferments: more effective against pathogenic Clostridium.
- Ferment and vinegar blends: provide the best antimicrobial combination with consumer-friendly labels.
- Ferments enhance savory meat flavors, improve product texture and do not hinder cook yields.

Clean Label Antimicrobials

<table>
<thead>
<tr>
<th>Product</th>
<th>Label</th>
<th>Use Range, %</th>
<th>Positioning (Lm control, shelf life extension)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral N3</td>
<td>Cultured corn sugar</td>
<td>2.0-3.0</td>
<td>Fresh means + shelf life extension (Limited Lm control) + Fresh meat color stability</td>
</tr>
<tr>
<td>Neutral N6</td>
<td>Cultured corn sugar, vinegar</td>
<td>1.5-3.5</td>
<td>Cured RTE means + Low use level + Low flavor impact + Sodium reduction (no sodium contribution, salt flavor enhancement)</td>
</tr>
<tr>
<td>Neutral N64</td>
<td>Cultured sugar, vinegar</td>
<td>Uncured: 2.0-3.5 Cured: 2.0-3.5</td>
<td>Cured RTE means + Low use level + Low flavor impact + SANS free</td>
</tr>
</tbody>
</table>

Natural/Clean Label Lm control: Roast Beef

Growth inhibition from natural sources, L. monocytogenes
Uncured Beef, 40°F, 0.5% NaCl, 65-67% moisture, pH 5.7-5.9 (no nitrite or PO4)

- Beef Control No Antimicrobials
- Beef - 3% cultured sugar/vinegar blend
- Beef - 2% Buffered vinegar
- Beef - 3% vinegar/tea/cherry/vinegar blend

Glass & Sindelar, 2010, AMI Foundation
APC counts: N16 – Fresh Pork

Total Plate Count of Fresh Pork at 4C

Verdad N64 in Uncured Turkey

Formulation: Turkey, salt, water, phosphate, maltodextrin, carrageenan, starch, 43% pump

Composition: 70.0% Moisture, pH 6.4, 1.68% Salt

Purac Listeria Control Model 2012

Online

2 versions available
- Full version through registration
- Basic trial to try the model

www.purac.com/lcm

User support
- Downloadable guidance documents
- FAQ
- Purac contact
lcsm@purac.com

Purac Listeria Control Model 2012

Growth prediction

In Listeria Control Model 2012
- Best fit (highest probability of outcome), i.e. 50% of data on each side of the line
- Grey area represents 90% of data, i.e. 95% of data lay right of left boundary

How does this relate to user specific situation?
- Model’s variance is likely larger than user specific situation
- The model includes more failsafe and more fail dangerous studies than user specific challenge studies

Enter Product Parameters

Model Lm Growth Results