Food Safety Ingredients in Meat Products

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Brazilian Association of Animal Protein
Associação Brasileira de Proteína Animal
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About Iowa

Iowa in U.S. Agriculture
- #1 Pig and Hog Inventory and Value
- #1 Commercial Hog Slaughter
- #1 Live Animals and Meat Export Value
- #1 Soybean Production and Export Value
- #1 Corn for Grain Production
- #1 Feed Grains and Export Value
- #1 Egg Production
- #2 Red Meat Production
- #4 Cattle on Feed
http://www.ans.iastate.edu/section/meat/
Antimicrobials

• Substances that inactivate or inhibit the growth of microorganisms (bacteria, yeasts, molds, viruses)

• Used for two primary reasons:
  – Food Safety
    • Prevent the outgrowth of disease-causing microorganisms
  – Shelf-life Guarantee
    • Ensure microorganisms that cause food to spoil do not overcome the product before a desired period of time
Antimicrobials

General Considerations for Use

• Antimicrobial’s properties
  – pKa, concentration/use level, solubility, antimicrobial spectrum

• Environmental conditions
  – pH, $a_w$, temperature, food composition

• Application method
  – Rinse, spray, dip, internal application

• Synergism with other antimicrobials
  – Use of single antimicrobial may not be very effective
    – “Hurdle” effect

• Cost-in-use
  – Price x use level

• Safety
  – Environmental and employee
Antimicrobials

General Considerations for Use, cont.

• Effect on food product organoleptic attributes
  – Flavor, texture, color
• Labeling requirements
• Consumer/customer acceptance
Antimicrobials

- Salt
- Phosphates
- Nitrite
- Organic Acids and Salts
- Parabens
- Medium- and Long-Chain Fatty Acids and Esters
- Chlorine Compounds
- Quaternary Ammonium Compounds
- Ozone
- Peroxides and Peroxyacids
- Antagonistic Cultures
- Bacteriocins
- Lactoferrin
- Lysozyme
- Plant Extracts and Essential Oils
- Other
Antimicrobials

Salt (sodium chloride)

- Quite possibly the oldest known preservative
- Antimicrobial effect primarily involves cellular dehydration via osmosis
- Synergistic with other antimicrobial ingredients, such as benzoate, sorbate, nitrite, phosphates, spices, liquid smoke
- As salt is decreased or removed (as when reducing sodium), its antimicrobial properties must be carefully considered and compensated for.
- Potassium chloride has similar antimicrobial properties
Antimicrobials

Phosphates

• Primary use in meats is for water-holding, texture modification and yield improvement
• Polyvalent anions → bind cations
• Deprive microorganisms of divalent cations and free water
• More effective against G+ bacteria and molds
• Not as effective against G- bacteria
• Effectiveness affected by water hardness
• Trisodium phosphate (TSP) (pH 10–12) is approved in U.S. for decontamination of poultry carcasses and parts
Antimicrobials

Nitrite

• Available in sodium or potassium nitrite
• Effective against *Clostridium botulinum*, and other bacteria, including Listeria monocytogenes and Salmonella
• Antimicrobial activity enhanced by acidic pH, presence of salt, low temperature and anaerobiosis
• Acts in synergy with other antimicrobials, such as lactate and diacetate
• It has been estimated that at least 70-80 ppm is needed for adequate antilisterial activity (Glass et al., 2008)
Antimicrobials

Organic Acids and Salts

• Short-chain organic acids
• Weak acids
• Antimicrobial activity is pH-dependent
• Antimicrobial activity increases as environmental pH approaches pKₐ
  – When pH = pKₐ, half of the acid molecules are dissociated
  – At pH<pKₐ, more of the acid is undissociated (and thus more effective)
• In undissociated state, organic acids enter cell, dissociate and decrease cytoplasmic pH. In effort to maintain homeostasis, cellular ATP is depleted
• Organic acids are lipophilic and therefore difficult to solubilize in water phase; therefore they are more commonly added in their salt forms
Antimicrobials

Organic Acids and Salts

Organic acids commonly used in meat products

<table>
<thead>
<tr>
<th>Organic acid</th>
<th>MW</th>
<th>pK&lt;sub&gt;a&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic</td>
<td>60.50</td>
<td>4.75</td>
</tr>
<tr>
<td>Propionic</td>
<td>74.08</td>
<td>4.88</td>
</tr>
<tr>
<td>Lactic</td>
<td>90.08</td>
<td>3.08</td>
</tr>
<tr>
<td>Phosphoric</td>
<td>98.00</td>
<td>2.21</td>
</tr>
<tr>
<td>Sorbic</td>
<td>112.13</td>
<td>4.80</td>
</tr>
<tr>
<td>Fumaric</td>
<td>116.70</td>
<td>3.03</td>
</tr>
<tr>
<td>Benzoic</td>
<td>122.12</td>
<td>4.19</td>
</tr>
<tr>
<td>Malic</td>
<td>134.09</td>
<td>3.40</td>
</tr>
<tr>
<td>Caprylic (octanoic)</td>
<td>144.21</td>
<td>4.89</td>
</tr>
<tr>
<td>Citric</td>
<td>192.12</td>
<td>3.14</td>
</tr>
</tbody>
</table>

Combinations of organic acids (or with other antimicrobials) can sometimes be more effective than a single one.

Commercial applications:
  - Decontamination of fresh meat or carcasses
  - Processed meats

Lactate (usage ≈ 2–3%), sometimes in combination with diacetate, has been used effectively in processed meats for many years.

Recently benzoate and propionate have gained popularity due to their lower cost-in-use (usage ≈ 0.2–0.3%)
Antimicrobials

Parabens

• Inactivate membrane functions by disrupting membrane lipids

• Susceptibility
  – Fungi > G+ bacteria > G- bacteria

• Effectiveness increases as chain length increases
  – Heptyl > butyl > propyl > ethyl > methyl

• Activity is dependent on pH, time, temperature, substrate

• Most effective at near neutral pH

• Potassium salts are more soluble

• Not permitted in meat products in the U.S., but are used in other countries
**Antimicrobials**

**Medium- and Long-Chain Fatty Acids and Esters**

- Work by disrupting cell membrane
- More commonly used in sanitation programs
- Medium-chain fatty acids → 8–14 carbons
  - Caprylic (8:0), capric (10:0), lauric (12:0)
- Long-chain fatty acids → ≥ 16 carbons
  - Palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2),
    linolenic (18:3)
- Esterified by replacing H atom of acid group with an alcohol or sugar group
- As a family, their antimicrobial spectrum varies, and they respond differently to environmental conditions
- In general more effective at pH ≤ 4.6
Antimicrobials

Medium- and Long-Chain Fatty Acids and Esters

• Applications
  – Octanoic (caprylic) acid approved in U.S. for beef carcass decontamination and as antimicrobial in RTE meat & poultry products
  – Lauramide arginine ethyl ester (LAE) as surface treatment for fresh meat and poultry cuts as well as RTE products
  – Monolaurin has demonstrated activity against *L. monocytogenes*, especially at low temperature and pH
Antimicrobials

Chlorine Compounds

- Effective against G+ and G- bacteria, fungi and viruses
- Biofilm-forming bacteria are less susceptible
- Effectiveness reduced by alkaline pH, low temperatures, organic matter and water hardness
- Several chlorine compounds approved in U.S. for decontamination of poultry and meat carcasses and parts, including carcass chiller water
  - Chlorine gas (Cl₂), chlorine dioxide (ClO₂), acidified sodium chlorite (NaClO₂), sodium hypochlorite (NaClO), calcium hypochlorite (Ca(ClO)₂), hypochlorous acid (HClO)
Antimicrobials

Quaternary Ammonium Compounds

- Also known as QACs or “quats”
- Commonly added to pharmaceutical, personal hygiene and environmental sanitation products
- Amphiphilic molecules that disrupt and damage cell membranes
- Effective against fungi, viruses and bacteria (mostly G+s)
- More effective at higher temperatures
- Effectiveness reduced by organic matter and hard water
- Cetylpyridinium chloride (CPC), a cationic QC, approved in U.S. “to treat the surface of raw poultry carcasses or giblets, or raw poultry parts (skin-on or skinless)”
Ozone

- O₃ – unstable, colorless, gas that occurs naturally
- Created by exposing O₂ to electrical discharges or UV radiation
- Effective against bacteria, fungi, viruses and spores
- Effectiveness reduced by pH, temperature, organic matter and salt (≥ 2.5%)
- Many studies have looked at O₃ use for carcass decontamination
- Effectiveness is debatable; may work better in combination with other antimicrobials
- Strong oxidizer; exposure by humans can cause uncomfortable side effects (irritation of eyes and skin, headaches)
- Approved in U.S. for use in all meat and poultry products in accordance with good manufacturing practices
Antimicrobials

Peroxides and Peroxyacids

• Primarily hydrogen peroxide ($\text{H}_2\text{O}_2$) & peroxyacetic acid (PAA)
• Decomposition of $\text{H}_2\text{O}_2$ generates hydroxyl radicals ($\bullet\text{OH}$) that can damage cell membranes and DNA
• PAA acts in similar way
• Effective against bacteria, fungi, viruses and spores
• Effectiveness is enhanced by acidic pH, high temperatures and absence of organic matter
• $\text{H}_2\text{O}_2$ may cause bleaching of meat tissue, so PAA might be preferred
• Not as effective as other antimicrobials (e.g., lactate)
• In U.S. both approved for use together in combination with other antimicrobials for decontamination of carcasses and carcass parts, and chiller water
Antimicrobials

Antagonistic Cultures

• Lactic Acid Bacteria (LAB) typically produce antimicrobials such as:
  – Organic acids, hydrogen peroxide (H₂O₂), diacetyl, ethanol, free fatty acids
• Some produce bacteriocins
  – *Lactobacillus sakei, L. curvatus, L. plantarum, L. brevis, L. casei*
  – Bacteriocin-producing pediococci
• Bacteriocins
  – Positively-charged peptides that kill gram-positive bacteria by interacting with anionic phospholipids of their cell membranes
Antimicrobials

Bacteriocins

• Isolated and purified from LAB fermentation
• Advantages
  – Can be used when fermentation conditions are not desired
  – Permit more exact dosification
• Only nisin is approved in meats in the U.S.
• Pediocin and natamycin have also been used in food
**Antimicrobials**

**Lactoferrin**

- Iron-binding transferrin protein
- Commercially obtained from whey protein
- Effective against bacteria, fungi and viruses
- Approved in U.S. for decontamination of beef carcasses and parts
Antimicrobials

Lysozyme

- Muraminidase enzyme
- Commercially obtained from milk and egg white albumin
- Disrupts cell wall in gram-positive bacteria
- By itself, ineffective against gram-negative bacteria
- Activity can be enhanced by combining with other antimicrobials
- Approved in U.S. in casings and on cooked RTE meat and pultry products
Antimicrobials

Plant Extracts and Essential Oils

• Efficacy demonstrated in extracts and essential oils obtained from various plants, such as rosemary, oregano, sage, cinnamon, cloves, thyme, allspice, basil coriander, nutmeg

• General susceptibility
  – Fungi > gram + bacteria > gram – bacteria

• Efficacy can be affected by high protein and fat

• Efficacy favored by low $a_w$, high NaCl, organic acids

• Chemical types:
  – Phenols: eugenol, isoeugenol, carnosol, rosmanol, isorosmanol, rosmarinic acid, borneol
  – Aldehydes: cinnamaldehyde
  – Terpenes: thymol, carvacrol
  – Thiosulfinates: allicin
Antimicrobials

Others

• Smoke
• Bacteriophages
• Acidified calcium sulfate
  – Demonstrated effectiveness against *L. monocytogenes* in RTE products
• Epsilon-Polylysine
  – Fermentation by-product of *Streptomyces albulus*
• Chitosan
  – Derived from chitin via deacetylation
Muito obrigado

Perguntas?