Preservatives and FOOD

Marilyn Erickson
Preservatives
(food-grade antimicrobials)

FDA definition: “substances used to preserve food by preventing growth and metabolic activity of microorganisms and subsequent spoilage”

Maintains microorganisms in “stasis”.

Some preservatives may be microbiocidal at high concentrations but not essential to be classified as an antimicrobial preservative.
Antimicrobial Preservatives
(Potential to Affect Various Groups of Microbial Contaminants)

Rarely Effective
Viruses
Parasites

Minor Effect
Bacterial pathogens
(low infectious dose)

Major Effect
Spoilage-producing microbes
Toxin-producing microbes
Bacterial pathogens
(high infectious dose)
### Selected examples of food spoilage and their underlying causes

<table>
<thead>
<tr>
<th>Food</th>
<th>Spoilage description and major microbial contaminant(s) involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic stored meat and poultry</td>
<td>Off-odors, including sulfides, ammonia, and amines are produced primarily by <em>Pseudomonas</em> spp.</td>
</tr>
<tr>
<td>Vacuum-package high pH fresh meat</td>
<td>Organic acids, hydrogen sulfide, and greening of meats are produced by <em>Enterobacteriaceae</em> activity</td>
</tr>
<tr>
<td>Condiments and syrups</td>
<td>Medicinal taste resulting from alcohol production by yeasts</td>
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</tbody>
</table>
| Fruit juices                              | Surface pellicles or fibrous mats, cloudiness, and off-odors arising from yeast and mold activity  

|                                                                                   | Bloated, swollen packages resulting from the oxidation of acetic acid by *Gluconobacter* spp.                                                                                                       |
|                                                                                   | Phenolic-tasting compound, guaiacol, produced by *Alicyclobacillus*                                                                                                                              |
| Buttermilk                              | Excessive viscosity in product caused by encapsulated, slime-producing lactococci                                                                                                                  |
| Ripened cheeses                         | A pink to brown discoloration caused by the metabolism of tyrosine by certain lactobacilli                                                                                                         |
| Yogurts                                  | Yeasty and fermented off-flavors and gassy appearance when yeasts grow                                                                                                                            |
## Antimicrobial Preservatives

*Potential to Affect Various Groups of Microbial Contaminants*

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<tr>
<th>Effect</th>
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Antimicrobial’s Role in Enhancement of Food Safety

Bacteriostatic and fungistatic agents (growth inhibitors) of toxin-producing pathogens

Aspergillus and other fungi
Staphylococcus aureus
Clostridium botulinum
Aflatoxins and fumonisins (mycotoxins) are secondary metabolites produced by a wide variety of filamentous fungi.

Methods for controlling mycotoxin production are usually preventative (e.g., sufficient drying of crops).

Chronic health impacts include carcinogenicity, immunological suppression, nutritional interference, and impaired growth.

The presence of mycotoxins has been documented in commercial bread samples (Spain and Morocco) as well as in commodities that have traditionally not been associated with mycotoxin production (i.e., fresh tomatoes, onions, and soft red fruits). Should we begin considering using antifungal agents in these products?
## Antimicrobial Preservatives

*(Potential to Affect Various Groups of Microbial Contaminants)*

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Antimicrobial’s Role in Enhancement of Food Safety (cont.)

- Bacteriostatic agents (growth inhibitors) targeting *Listeria monocytogenes* having relatively high infectious dose (> 5 log)

- *Listeria monocytogenes* may grow at refrigerator temperatures

- Addition of bacteriostatic antimicrobials has been estimated to have reduced foodborne listeriosis by as much as 96%.
Antimicrobial Preservatives
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Antimicrobial’s Role in Enhancement of Food Safety (cont.)

Limited effectiveness on bacterial pathogens having low infectious dose even in cases where antimicrobial has bactericidal capacity

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<th>Pathogen</th>
<th>Infectious dose</th>
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<tr>
<td><em>Salmonella</em></td>
<td>&lt; 100 to &gt; 5 log</td>
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<tr>
<td><em>Shigella</em></td>
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<td><em>Escherichia coli O157:H7</em></td>
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Types of Antimicrobials that could have potential health impacts

Nitrites
Benozoates
Sorbates
Parabens
Role of Nitrites

- Inhibits *Clostridium botulinum* outgrowth and toxin production

- Imparts flavor and color characteristics
Health Impacts of Nitrites

- Ingestion of excess levels (2-9 g or 33-250 mg/kg body wt.)
  (Methemoglobinemia (oxyhemoglobin \(\rightarrow\) ferrihemoglobin)

- Formation of carcinogenic nitrosamines in presence of high heat
  - bacon identified as only cured meat subjected to such conditions
  - presence of ascorbate or isoascorbate blocks nitrosamine
    formation and magnifies antibotulinal effect of nitrites

- USDA regulations for bacon
  - either ascorbate or isoascorbate be added at 550 µg/g
  - sodium nitrite levels must not exceed 120 µg/g

- American Cancer Society and the European Food Safety Authority
  on Food Additives and Nutrient Sources Panel (EFS Panel) has
  deemed that nitrites in foods are not a significant cause of cancer
Role of Benzoic Acid and Benzoates

- Controls yeasts and molds
  - Beverages
  - Fruit and vegetable products (pickles, condiments jams/jellies, fruit juice)
  - Non-heat treated dairy-based desserts

- Bacteriostatic and bactericidal activity
  - *Bacillus* spp. (*cereus* and *subtilis*); *Listeria monocytogenes*; *Staphylococcus aureus*
Health Impacts of Benzoic Acid and Benzoates

- Benzoic acid occurs naturally in a number of foods (fruits, spices, fermented products)
- Low risk of acute toxicity as no accumulation in the body - benzoate detoxified through a two-step metabolic reaction
- Assigned GRAS status in U.S.
- No adverse effect of benzoic acid in a four-generation reproductive toxicity study when incorporated into the diet of rats at a level of 500 mg/kg body weight leading the EFS Panel to conclude in 2016 that the compound has no carcinogenic potential
- Maximum acceptable daily intake (ADI) of 5 mg/kg body weight established by European Union in 2016
Decarboxylation of benzoic acid in the presence of ascorbic acid and transition metal ions generates cancer-causing benzene
- estimated that consumption of benzene from food is only 2% of that which occurs from inhalation of benzene via environmental exposure

Increase in hyperactivity ascribed to ingestion of benzoic acids
- 2014 study described a high intake of benzoate-rich beverages by college students exhibiting attention deficit/hyperactivity disorder

Sodium benzoate exhibits an inhibition effect on chymotrypsin at concentrations 14 times lower than their ADI that would impact negatively on protein digestion & be dangerous for pancreatitis patients
Role of Sorbic Acid and its Salts

- Controls growth of yeasts, molds, and a variety of bacteria (e.g., *Campylobacter*, *Clostridium*, *Escherichia coli O157:H7*, *Salmonella*, *Staphylococcus aureus*)
- Originally isolated from unripened rowanberries that grow on mountain tree ash
- Concentrations used in foods (0.1-0.3%)
- Microbiocidal activity at higher levels
Health Impacts of Sorbic Acid and its Salts

- Conjugated system of double bonds in their structure makes them susceptible to nucleophilic attack, forming products that potentially may be mutagenic.

- Interaction of sorbic acid with different amines form products that are not mutagenic in Ames assay or with HeLa cells and plasmid DNA.

- Interaction of sorbic acid with nitrites or with ascorbic acid in the presence of iron salts can produce mutagenic reaction products in vitro.
  - EFS Panel concluded that conditions under which reactions products were formed from sorbic acid and ascorbic acid in presence of iron were not likely to occur in food systems.
Role of Parabens

- Paraben is a generic term used to describe a group of compounds that are esters of \( p \)-hydroxybenzoic acid

- Most common forms are methylparaben, ethylparaben, and propylparaben with antimicrobial effectiveness increasing as alkyl chain length increases

- Broad spectrum of activity against yeasts, molds, and bacteria
Properties of Parabens that Make Them Excellent Preservatives

- Chemical stability over a wide temperature and pH range
- Sufficient solubility in water
- No perceptible odor or taste
- An ability to be combined with other preservatives, maximizing their overall effect at smaller doses
- Low production cost
Health Impacts of Parabens

- Metabolic research conducted in the 50’s demonstrated that the majority of the parabens were metabolized and excreted within 24 h after being orally administered to humans.

- In U.S., GRAS status has been given to parabens when used in foods at permitted levels.

- Based on most in vivo studies using current levels of exposure, the impact of parabens on human reproduction, development, and homeostasis was considered to be of marginal importance.
Health Impacts of Parabens (cont.)

- Other studies have revealed the potential for paraben exposure to elicit endocrine modifying effects and estrogenic activity
  - using human populations, there was a weak but a significant relationship between urinary paraben concentrations and either sperm damage or serum thyroid hormones

- At concentrations detected in breast tissue, parabens, induced the proliferation of cells in vitro, suggesting a possible carcinogenic effect

- In comparison with exposure to parabens originating from personal care products, the estimated daily of intake from food was low (<1%)
Consumer’s Aversion to Chemical Additives

- A 2015 survey conducted by the Food Marketing Institute and the Grocery Store Manufacturer’s found that a large proportion of consumers (42%) were looking for foods with fewer ingredients and processing steps.

- Chemophobia - synthetic ingredients are “BAD” whereas naturally-produced ingredients are safer.

- Consumers view that minor doses are just as likely to cause harm as larger doses.

- “Clean labeled products” – One of the criteria to meet this classification is that the label contain recognizable ingredients (i.e., no chemical names).
Repercussions
Elimination of Antimicrobials

• shorter shelf-lives
• increased risk for aflatoxin production
• increased risk for growth of high infectious dose-pathogens
• more recalls despite changes in expiration dates (short-term)
• higher prices (changes in formulation/distribution practices)
Repercussions
Elimination of Antimicrobials

Selected examples of preservative-free foods that were recalled or were the subject of consumer complaints posted on the internet (2013-2016).

<table>
<thead>
<tr>
<th>Product</th>
<th>Problem</th>
<th>Date</th>
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<tbody>
<tr>
<td>Fruit drinks</td>
<td>Mold spoilage complaints posted on internet</td>
<td>February 2013</td>
</tr>
<tr>
<td>Organic yogurt baby food</td>
<td>Recall due to swelling and spoilage due to manufacturing defects</td>
<td>November 2013</td>
</tr>
<tr>
<td>Uncured turkey bacon</td>
<td>Recall following spoilage-related consumer complaints</td>
<td>August 2015</td>
</tr>
<tr>
<td>Organic baby food pouches</td>
<td>Recall due to bloating and spoilage off-odors/tastes resulting from packaging defect</td>
<td>March 2016</td>
</tr>
</tbody>
</table>
Repercussions
Substitution with Natural Plant Extracts

• Rationale for their use is that they have been generated through metabolic pathways that a higher power (i.e., “God”), not man, created; and man has been eating these plants for centuries without harm

• Plant extracts, consisting of hundreds of chemicals, are no longer in their natural state and compounds that may have been physically separated in the plant may interact with each other when extracted and generate compounds that may not be safe if consumed over a long period of time. Moreover, the complexity of these extracts likely leads to inconsistent antimicrobial responses

• Large concentrations of plant extracts may be needed to overcome interaction with other food matrix components

• Undesirable sensory properties may be introduced
Going Forward

Educating the Consumer
- A survey published in 2014 found that Korean parents judged food additives to be the greatest food safety hazard of all food safety concerns, whereas their children, due to their exposure to this issue in the educational system, regarded microbial contaminants as being the most hazardous.
- A Polish survey published in 2014 also found that university students acknowledged paying attention to the presence of additives in foods, but that they deemed them necessary.

Delivery System
- Encapsulation of antimicrobials into packaging materials and a slow release to food.
- Utilization of nanoparticle antimicrobials improves the delivery and biological activity of encapsulated active compounds.

Identification and incorporation of compounds that act synergistically with the antimicrobial and reduces the antimicrobial levels needed.

Continued research on health impacts of antimicrobials and incorporation of information into risk-benefit computational models.