Microbiology of primary food commodities

IV
Fruits and Vegetables

Microbiology of Fruit and Vegetables

- Widely varied products
  - Raw
  - Frozen
  - Canned
  - Dehydrated
  - Fermented
- Create numerous selective environments for development of diverse microflora

Sources of microorganisms in fresh fruits and vegetables

- Soil
- Water
- Fertilizers
- Dust
Sources of pathogens in fresh produce

**Pre harvest**
- Feces
- Soil
- Water
  - Irrigation
  - Solvent
- Non-fermented manure
- Air (dust)
- Animals
  - Wild
  - Domestic
- Insects
- Humans

Beuchat, 1997

Sources of pathogens in fresh produce

**Post harvest**
- Feces
- Humans
- Harvesting equipment and utensils
- Transporting vehicles
- Animals
  - Wild
  - Domestic
  - Insects
- Air (dust)
- Water (washing)
- Packing equipment
- Ice
- Transporting vehicles
- Inadequate storages
- Cross contamination
- Handling previous to consumption

Beuchat, 1997

Factors that influence initial microbial population

- Harvesting and Transportation
  - Sanitary condition of equipment
  - Time-temperature profile
- Processing
  - Blanching, slicing, chopping, cutting, washing, packaging, freezing
Factors that influence initial microbial population

- Microorganisms present on the surface of vegetables and fruit include many species of different genera from a variety of sources
- Numbers and types vary greatly depending on the influence of these sources

Microbiota of fruits and vegetables

- Soil
  - Bacillus, Clostridium, fungi
- Wide distribution in nature
  - Lactobacillus, Leuconostoc, Streptococcus
- Common gram-negative rods.
  - Pseudomonas, Moraxella-Acinetobacter, Alcaligenes, Flavobacterium

Frozen products

- Blanching (1928)
  - Enzyme inactivation by heat
    - Steam or hot water
  - Has marked effect on microbial load
    - Numbers and types
Large bacterial numbers in fruits and vegetables result from:

• Poor equipment design
• Lack of effective cleaning and sanitizing
• Faulty processing methods

Processing of various vegetables

• Slicing and chopping increases total counts
• Chopped broccoli has highest counts; peas, cut green beans and spinach, the lowest
• Equipment that chops and slices is often not cleaned and sanitized properly

Canned Products

• Low-acid foods
  – 12-D concept
• High-acid foods
  – Pasteurization
Fermented products

• Sauerkraut
  – Product obtained from a lactic fermentation (*Leuconostoc, Lactobacillus*) of shredded cabbage
    • 2-3% salt
    • Upon completed fermentation not less than 1.5% lactic acid

Fermented Products

• Pickles
  – Immature cucumber, prepared by taking up NaCl and preserved in vinegar, with or without spices and sugar
  • Cucumbers have a flesh pH of 5.1-5.8 and a sugar content of 1.2-2.2%

Spoilage

• Handling
  – Damage releases nutrients and allows entry
• Containers
  – May supply spoilage organisms
• Washing
  – 90% reduction, but rapid growth in water
• Processing
  – Faster and greater growth in cut vegetables
Types of spoilage
• Bacterial soft rot
  – Soft, mushy product, sometimes with off-odors
• Souring by lactic acid bacteria
• Gray mold rot (*Botrytis* sp.), *Rhizopus* soft rot (*Rhizopus* sp.), and many other rots caused by species of molds
• Bacteria are of less importance in the spoilage of fruits because of the lower pH

Food safety aspects
• Sewage contamination
  – Fertilization
  – Harvest and processing workers - hygiene ([Salmonella in "Texas" melons, 1991](#))
  – Sprouts
  – *Shigella*, *Salmonella*, *E. coli*, parasites, cholera
• Hospital foodservice should be concerned about opportunistic pathogens (*Pseudomonas*, *Klebsiella*)

Produce outbreaks in the U.S.

<table>
<thead>
<tr>
<th>Vehicles</th>
<th>Agents</th>
<th>Outbreaks</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td><em>Salmonella</em></td>
<td>4</td>
<td>133</td>
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<tr>
<td>Raspberries</td>
<td><em>Cyclospora</em></td>
<td>101</td>
<td>2614</td>
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<tr>
<td>Lettuce</td>
<td><em>E. coli</em> O157:H7</td>
<td>3</td>
<td>105</td>
</tr>
<tr>
<td>Basil</td>
<td><em>Cyclospora</em></td>
<td>2</td>
<td>400</td>
</tr>
<tr>
<td>Tomato</td>
<td><em>Salmonella</em></td>
<td>3</td>
<td>&gt;129</td>
</tr>
<tr>
<td>Parsley</td>
<td><em>Shigella</em></td>
<td>1</td>
<td>&gt;400</td>
</tr>
</tbody>
</table>

CFSAN/FDA

<table>
<thead>
<tr>
<th>Vehicles</th>
<th>Agents</th>
<th>Outbreaks</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantaloupe</td>
<td>Salmonella</td>
<td>6</td>
<td>195</td>
</tr>
<tr>
<td>Cabbage</td>
<td>E. coli O157:H7</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>Green onions</td>
<td>HAV</td>
<td>1</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Almonds</td>
<td>Salmonella</td>
<td>1</td>
<td>~75</td>
</tr>
<tr>
<td>Tomato/onions</td>
<td>HAV</td>
<td>1</td>
<td>38</td>
</tr>
</tbody>
</table>

CFSAN/FDA

President Clinton’s Food Safety Initiative

• Resulting from the memorandum on the Food Safety Initiative
  – Subject: Initiative to Ensure the Safety of Imported and Domestic Fruits and Vegetables
  – October 2, 1997

First outcome

Good Agricultural Practices

Included in the document:
• Guidance for Industry: Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables
• Published by
  – Food and Drug Administration
  – U.S. Department of Agriculture
  – Centers for Disease Control and Prevention
• October 26, 1998
GAP
Include the following sections:
• Water
• Manure and municipal biosolids
• Worker health and hygiene
• Sanitary facilities
• Field sanitation
• Packing facility sanitation
• Transportation
• Traceback

For each section, identify:
• Associated microbial hazards
• Control measures

Patogen survey for imported produce
(FDA, 1999)
1003 samples

25% of all samples
• Mexico
• Canada
• Costa Rica
• Guatemala
• Holland
• Honduras
• Belgium
• Italy
• Israel
• Chile
• Peru

• Colombia
• Trinidad & Tobago
• New Zealand
• Nicaragua
• Dominican Republic
• France
• Argentina
• Ecuador
• Haiti
• Korea

Isolation of Salmonella and Shigella from imported produce (USA, 1999)

Adapted from CFSAN/FDA, 2000
Cantaloupe-associated outbreaks in the U.S.

<table>
<thead>
<tr>
<th>Year</th>
<th>Pathogen</th>
<th>Location</th>
<th>No. cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989-90</td>
<td>S. Chester</td>
<td>U.S.A.</td>
<td>&gt;245</td>
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<tr>
<td>1991</td>
<td>S. Poona</td>
<td>U.S.A., Canada</td>
<td>&gt;400</td>
</tr>
<tr>
<td>1997</td>
<td>S. Saphra</td>
<td>U.S.A.</td>
<td>25</td>
</tr>
<tr>
<td>1998</td>
<td>S. Oranienburg</td>
<td>Canada</td>
<td>22</td>
</tr>
<tr>
<td>2000</td>
<td>S. Poona</td>
<td>U.S.A., Canada</td>
<td>43</td>
</tr>
<tr>
<td>2001</td>
<td>S. Poona</td>
<td>U.S.A., Canada</td>
<td>51</td>
</tr>
<tr>
<td>2001</td>
<td>S. Anatum</td>
<td>U.S.A.</td>
<td>15</td>
</tr>
<tr>
<td>2002</td>
<td>S. Poona</td>
<td>U.S.A.</td>
<td>43</td>
</tr>
</tbody>
</table>

Control of hazards in produce

- GAP implementation
- Certification programs
  - HACCP based food safety programs

Generic flow chart for horticultural products

- Harvest → Transport to packing → Washing
- Cooling → Packing → Sorting
- Loading → Transporting

Significant hazards → No control measures
Production of fruits and vegetables

Harvest
Transport
Washing
Waxing
Sorting
Packing
Cooling
Loading and transporting

Decontamination
PCC

Detection (% positive samples) of *E. coli* and *Salmonella* in cantaloupes sampled in the U.S. and Mexico

<table>
<thead>
<tr>
<th>Country</th>
<th>Sample</th>
<th><em>E. coli</em></th>
<th><em>Salmonella</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>Field</td>
<td>3.0</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Before wash</td>
<td>6.7</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>After wash</td>
<td>7.3</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Cooler</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Mexico</td>
<td>Field</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Before wash</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>After wash</td>
<td>52.0</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Cooler</td>
<td>50.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Mercado, 2002

Decontamination methods commonly used or proposed for fruits and vegetables

- Chlorine
- Peroxyacetic acid
- Hot water
- Isothiocyanide
- Lactic acid
- Electron beam
Reduction (log/cm²) by treatment of *S. Typhimurium* and *E. coli O157:H7* inoculated onto the surface of fresh cantaloupes

Reduction (log/cm²) by treatment of *S. Typhimurium* and *E. coli O157:H7* inoculated onto the surface of fresh bell peppers
In-plant comparison of lactic acid and chlorine treatments for cantaloupe decontamination

Pathogen internalization after sanitizing rinses

Brilliant blue diffusion
Detection of internalized pathogens in tomatoes after rinsing with different sanitizers

Aerobic plate count of fresh-cut cantaloupe over 21 days of storage at 5°C after electron beam radiation