Managing Microbial Food Safety
Presentation Flow

- About Micro Organisms
- Microbial Food Safety Strategy
- Microbe Management Processes
- General Process Flow and controls
  - Chilled Juice
  - Hot Fill
  - Aseptic etc.
About Micro-Organisms
Microbes Are Everywhere

- Foods and Beverages
- Water storage and delivery systems
- Sweetener systems
- Filling processes
- Empty packages
- Plant environment – including insects
- Air (environmental and filtered)
- Process equipment, tanks, conveyors, etc.
- Tools
- People / Foot traffic

We cannot eliminate them, but we must manage them!
Juices, Dairy, Canned foods, sport drinks, teas, energy drinks, carbonated soft drinks and other beverages often provide an environment for microorganism growth.
Micro-organisms of Concern

Yeast
Mold
Aciduric Bacteria
Coliforms
Total Plate Count

Microbes Omnipresent In Foods
Micro-Organisms of Concern

- Yeast
- Mold
- Non-Spore forming bacteria (Lactic acid and Acetic acid bacteria)
- Spore-forming bacteria
Yeast

- Grow in Foods n Beverage, water, and environment
- Cause off-odors, off-tastes, visible particles
- White to tan, pink, brown or black creamy
- Generally round or oval (1-20 µm in size)
- Increase package pressure (fermentation)
- Common types:
  - Saccharomyces
  - Zygosaccharomyces
  - Rhodotorula
  - Candida
  - Brettanomyces
Yeast

**Preservative Resistant**
- Zygosaccharomyces bailii
- Saccharomyces cerevisiae

**Non-fermenting Yeast**
- Candida spp.

**Osmophilic Yeast**
- Zygosaccharomyces rouxii

**Psychrophilic Yeast**
- Candida spp., Torulopsis spp.
- Hanseniaspora spp., Saccharomyces spp.

**Significant resistance to preservatives** (benzoic/sorbic acids).
- Produce gas (CO2)
- Low to moderate resistance to preservative
- No CO2 produced

**Can grow in very low water activity/high brix environments**

**Can grow at chilled temperatures (as low as 32-35F)**
Mold

- Need oxygen for growth
- Normally do not grow in a carbonated beverage
- Spores and mycelium can survive
- CO$_2$ loss can result in growth
- Cause off-odor, off-taste, fuzzy gray-green or white, usually long filaments (1-3 µm in width)
- Common types:
  - Aspergillus
  - Penicillium
  - Rhizopus
"Common" Mold Asexual spores - CONIDIA

Penicillium, Alternaria, Aspergillus, Cladosporium, Fusarium, Geotrichum, Phoma, Penicillium, spp. and more...

Heat-resistant Mold - ASCOSPORES
Formation of sexual spores with an ascus: Ascospores
Eight (8) recognized

Eg. Byssochlamys, Talaromyces, Xeromyces
Bacteria

- Cause off-odor, off-taste, package pressure, sediment, rings, turbidity and “slimy” texture
- almost colorless, turquoise green, yellow (0.5-1 µm in size)
- High counts reflect unsanitary conditions, difficult to remove (for example, Pseudomonas)
- Common spoilage types:
  - Lactobacillus
  - Gluconobacter
Coliform Bacteria

• Found in human and animal intestines, their presence in water is therefore thought to indicate faecal contamination

• Gram negative rods, ferment lactose with the production of acid and gas and possess the β-galactosidase enzyme
Coliform Bacteria

- **Coliform and *E. coli***
  - Indicate unsanitary conditions and potentially serious problems
  - Should not be anywhere in the process
  - **Typical sources:**
    - Contaminated water supply (fecal contamination)
    - Inadequately maintained cooling tower or closed chiller system
    - Poor equipment sanitation
    - Poor hygienic equipment design
    - People
Aciduric Bacteria

- Aciduric bacteria are associated with environments of an acidic nature
- These are the predominant bacteria associated with carbonated and non carbonated beverages
- These organisms are primarily associated with spoilage
- Aciduric bacteria often cause common faults such as off odours, slimy texture, ringing
## Non-spore forming bacteria

<table>
<thead>
<tr>
<th>Lactic acid bacteria (Gram positive)</th>
<th>Growth as low as pH 3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Lactobacillus</em> spp.</td>
<td>Moderate preservative resistance</td>
</tr>
<tr>
<td></td>
<td>Tolerant of CO2</td>
</tr>
<tr>
<td></td>
<td>Produce CO2, lactic/other acids</td>
</tr>
<tr>
<td></td>
<td>Heat sensitive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acetic acid bacteria (gram negative)</th>
<th>Extremely resistant to preservatives</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Gluconobacter</em> spp., <em>Acetobacter</em> spp.</td>
<td>Aerobic (requires O2), NCB only</td>
</tr>
<tr>
<td></td>
<td>Produce acetic acid</td>
</tr>
<tr>
<td></td>
<td>Heat sensitive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other bacteria (gram negative)</th>
<th>Sanitation indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Enterobacteria</em> (coliforms)</td>
<td>Coliforms &lt; pH 4.4</td>
</tr>
<tr>
<td></td>
<td>Heat sensitive</td>
</tr>
</tbody>
</table>
How Bacteria Grow

Bacteria reproduce by *splitting in two*

Under ideal conditions bacteria *can divide in two* every

10 minutes

One bacteria can become 1,000,000 in 3 hours & 20 minutes
# Growth of Bacteria

<table>
<thead>
<tr>
<th>HOURS</th>
<th>MINUTES</th>
<th>No. BACTERIA</th>
<th>HOURS</th>
<th>MINUTES</th>
<th>No. BACTERIA</th>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>120</td>
<td>4,096</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>2</td>
<td>130</td>
<td></td>
<td>8,192</td>
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<td>20</td>
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<td>4</td>
<td>140</td>
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<td>16,384</td>
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<td>30</td>
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<td>8</td>
<td>150</td>
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<td>32,768</td>
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<td>40</td>
<td></td>
<td>16</td>
<td>160</td>
<td></td>
<td>65,536</td>
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<tr>
<td>50</td>
<td></td>
<td>32</td>
<td>170</td>
<td></td>
<td>131,072</td>
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<tr>
<td>1</td>
<td>60</td>
<td>64</td>
<td>3</td>
<td>180</td>
<td>262,144</td>
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<tr>
<td>70</td>
<td></td>
<td>128</td>
<td>190</td>
<td></td>
<td>524,288</td>
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<tr>
<td>80</td>
<td></td>
<td>256</td>
<td>200</td>
<td></td>
<td>1,048,576</td>
</tr>
<tr>
<td>90</td>
<td></td>
<td>512</td>
<td></td>
<td>TOTAL</td>
<td>1,048,576</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td>1,024</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td></td>
<td>2,048</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Growth of Bacteria

This is called exponential growth.
Conditions for Microbial Growth

- FOOD
- WARMTH
- TIME
- WATER
- pH
Growth of Microorganisms: pH range

HIGH ACID (LOW pH ≤ pH 4.6)

Salmonella
Clostridium botulinum
Listeria
Shigella
Alicyclobacillus (acid tolerant spore former)
Bacillus species (non-acid tolerant)
Staphylococcus
E.coli and other enterics
Shigella
Sporolactobacillus
Acetobacter & Acetobacter
Lactics
Mold & Yeast Fungi

LOW ACID (HIGH pH > pH 4.6)

pH of product
2.5 3.0 3.5 4.0 4.5 4.6 5.0 5.5 6.0 6.5 7.0
Spore forming Microorganisms

Heat Resistant

**pH > 3.9**
- *Bacillus coagulans*
- *Clostridium thermosaccharolyticum*
- *Clostridium butyricum*
- *Clostridium pasteurianum*

**pH < 3.9**
- *Alicyclobacillus*
- *Heat Resistant Molds*
Microbial Food safety Strategy
Consumer Protection and Hence Business Continuity Is Assured With High Level Of Food Safety Management Process

**Prevention**
- Good Manufacturing Practices
- Food Safety Programs
- Hygiene
- MOCs

**Reduction to Safety**
- Processing Technology
- CIP and Sanitations
- Technology Upgrades

**Protection**
- Standards
- Regulations
- Reporting

**Managing Microbial Food Safety**
Managing Microbial Food safety

Prevention

- Good Manufacturing Practices
- Food Safety Programs
- MOCs

- AIBI Standards
- CCP controls
- Hygiene Audits and compliances

- GFSI – FSSC 22000, SQF Etc.

- Food Grade Compatibility
- Migration tests
- Vendor Guarantees
Managing Microbial Food safety

Log Reduction to Safety

- Processing Technology
- CIP and Sanitations
- Technology Upgrades

- Evolving Process technology implementation
- Hybrid Process Technologies
- Execution Regimes
- Optimized Protocols
- R & D Innovation
- Breakthrough Technologies
- Cost effective
Microbe Management Processes/Factors

- Heating – Pasteurization, UHT, Hybrid Processes

- Chemical Means – Disinfectants, Sanitizers, Fumigations
  Low pH

- Physical Means – Ultra filtration, HEPA Filtration, RO technologies

- Irradiation – UV treatments

- New Technologies – HPS

- Preservation – Preservatives, Ingredients
General Process Flow Diagrams - Beverage Specific
Chilled Juice Process Overview

Raw Materials → Blending → Storage → Pasteurization → Bulk storage → Filling/Packaging → Distribution

Filler Ops/Technology: “The Weakest Link”
Step One: Pasteurize Product and Hold 30 sec.
185 – 205 °F

Step Two: Fill Hot Product into Bottles and Cap
Center Bottle Temp 175°F - 182°F

Step Three: Invert Bottle to Contact Hot Product to Closure
3 – 7 seconds > 175°F

Step Four: Cool the Hot Bottles Under Water Sprays
Into cooler within 3 minutes +30 min., Exits below 105°F

**Hot Fill Process Overview**

**Critical Factors:**
- Thermal process
- Package / seal integrity
- Closure/headsapce sterility
- Head-space volume
- Plant Environment
- Packaging
- Ingredients
- Bottle Washers (returnable)
Aseptic Processing and Packaging - Overview

- Pasteurization: Commercial Sterilization of Beverage (closed system) Cooled to Target Fill temp.
- Sterilization of Bottle and Closure
- Packaged in Sterile Environment (e.g., Procomac's Microbiological Isolator) “CRITICAL INTERFACE”
- 100% Juices - Extended Refrig. Shelf-life (120 days) or Shelf-stability (10% juice drinks, Gatorade)
Tunnel Pasteurization Process Overview

Tunnel Pasteurization:

• High acid beverages only

• Carbonated Beverages: thermal process target: yeast ascospores

• Non carbonated: thermal process target: mold spores (more heat tolerant than yeast)

Batching → Processing → Filling/Capping → Tunnel Pasteurizer → Pasteurization/Cooling

Carbonated: 150F-165F / 10 minutes
Non-Carbonated: 175F / 10 minutes
Retort Process

- Clostridium sporogenes in green beans
- D value = time in minutes to reduce 1 log
- $D_{250} = 2.5$ minutes to kill 10 spores
- 12.5 minutes to kill 100,000 spores
- Z value = rate of death
- 2.5 min at 250°F = 42 min at 230°F
Beverages pH Categories

• Acid, pH 4.0 - 4.5
  Some juices (Tomato), tea beverages

• High acid, pH <3.9
  Apple Juice, Sport Beverages

• Low acid, pH > 4.6 – Meat, Fish, Vegetable Juices
Thermal Processes for Non-sporeformers

- Yeast, mold, *Lactobacilli*

- One minute hold, pH dependent
  - pH 3.0 - 150°F (65 C)
  - pH 3.5 - 165°F (73 C)
  - pH 4.0 - 185°F (85 C)
  - pH 4.5 - 210°F (99 C)
Thermal Processes for Spore-formers

**Clostridium / Bacillus sp. (pH 3.8 – 4.6)**
- D250 - 0.1 min (D212 - 20 minutes)
- Fo - 0.5 min (retort/HTST process)

**Clostridium / Bacillus sp. (pH > 4.6)**
- Fo – 6 min. at 250°F

**Alicyclobacillus**
- 230°F, 60 sec.

**HRM’s**
- Heat resistance varies, 198 - 210°F, 1 minute
- Can exceed 60 minutes at 212 °F
Pasteurization - Juices

- The act or process of heating a beverage or other food to a specific temperature for a specific period of time in order to kill microorganisms that could cause disease, spoilage, or undesired fermentation.
Ozonation – Packaged Drinking Water

• Ozone (O₃) destroys algae, viruses, bacteria, and fungi on contact. It kills microorganisms by rupturing their cell walls.

• Ozone has a half life of 20 minutes, thus used within the first 5-10 minutes to assure its strength.
Preservation usually involves preventing the growth of bacteria, fungi (such as yeasts), and other micro-organisms. This can be antioxidants such as oxygen absorbers which inhibit the oxidation of food / beverage constituents.
### Defect Rate:
- Yeast, Mold, acid-tolerant Bacteria

<table>
<thead>
<tr>
<th>Manufacturing Processes</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aseptic</strong></td>
<td>UHT Milk, juices</td>
</tr>
<tr>
<td><strong>Retort</strong></td>
<td>Coffee Dairy</td>
</tr>
<tr>
<td><strong>Tunnel</strong></td>
<td>Acidified Fruit Milk</td>
</tr>
<tr>
<td><strong>Hot Fill</strong></td>
<td>Ready to drink Tea</td>
</tr>
<tr>
<td></td>
<td>Still FC Juice &amp; Juice Drinks</td>
</tr>
<tr>
<td></td>
<td>Non Preserved Isotonics</td>
</tr>
<tr>
<td><strong>Clean Fill</strong></td>
<td>Carbonated/Nitrogenated Juice, coffee, tea</td>
</tr>
<tr>
<td></td>
<td>Flavored Water</td>
</tr>
<tr>
<td><strong>Cold Fill</strong></td>
<td>Carbonated Soft Drinks</td>
</tr>
<tr>
<td></td>
<td>Fruitworks/All Sport</td>
</tr>
<tr>
<td></td>
<td>Bottled Water/Aquafina*</td>
</tr>
<tr>
<td></td>
<td>Tea -Powder base/Brisk</td>
</tr>
</tbody>
</table>

*The manufacturing platform drives categorization. Bottled water is therefore bundled here intentionally despite higher pH.

Ref: Moise et al., 2001
High Pressure Processing
• First research in 1890s – milk pathogens

• Non-thermal processing technology (combination with heat possible)

• First commercialized in Japan

• High pressure treated foodstuffs have been marketed in Japan since 1990

• Rapid commercialization since 2000
High Pressure Process - HPP

- High pressure – how much pressure?
- Mariana Trench - deepest part of the world's oceans - 11.03 km deep
- Water column pressure at the bottom 15,750 psi - 1000 times atmospheric pressure
- HPP – 6000 times atmospheric pressure
HPP – Gaining Importance Widely

- Vegetable products (35%)
- Meat Products (31%)
- Sea Food / Fish (15%)
- Juices (12%)
- Others (7%)
HPP – Equipment

Product Out

Product In

Vertical

Horizontal (More Popular)
HPP – Equipment – Horizontal
HPP – Advantages

• Freshness and minimal processing

• Extended shelf life

• Uses less Energy

• Processing can be done in final packaging which avoids post-processing contamination and tempering

• Permits the inactivation of microorganisms and enzymes at low temperatures,

• Bioactives, vitamins, colours and flavourings, remain largely unaffected
HPS – High Pressure Sterilization

Principle of HPS

• Start HPP processing at an elevated temperature –70-90°C

• Use heat generated by applying pressure for uniform rapid increase of temperature, and vice versa cooling at pressure decrease

• Spores inactivated by combination of P and T

• Maximum temperature is 5 -10 °C lower than normal sterilisation temperature

• Lower heat input compared
HPP – Output Quality

Flavour of fresh basil

Firmness of green beans
Foods suitable for HPP Low-Medium moisture, semi-solid/solid foods, vacuum packaged

- Dry-cured or cooked meat products
- Cheeses
- Fish, seafood, marinated products
- Ready to eat meals, sauces High moisture, solid foods, vacuum packaged
- Fruits, marmalades/jams
- Vegetables High moisture, liquid foods in plastic bottle/flexible packaging
- Dairy products
- Fruit juices
Foods unsuitable for HPP: Solid foods with air included

- Bread and cakes
- Mousse Packaged foods in completely rigid packaging
- Glass packaging
- Canned foods: Foods with a very low water content
- Spices
- Dry fruits
- Powders
Summary - HPP

Consumers
• Quality, natural, additive-free, convenience, variety, health benefits, trust, safety & security

Distributors
• Long shelf life

Companies
• Technology, R&D Ideas, Innovation

Regulators
• Minimal processing
• Safety

High Pressure Processing

Share holders
• Return on investment, growth, benefits

Governments
• Safety
• Environmental friendly
We Cannot Eliminate Them, We Must Manage Them!
Thank You