Pathogen Transfer in Fresh-Cut Operations

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PROJECT GOAL

• To enhance the microbial safety and quality of ready-to-eat, fresh-cut fruit and vegetable products via integrated research and outreach/training targeted at the processing, packaging, and distribution phases of the produce chain.

5 PROJECT MODULES

• PROCESSING
  — Quantify pathogen transfer and cross-contamination
• PACKAGING
  — Develop optimal packaging systems to enhance microbial safety and quality
• DISTRIBUTION
  — Evaluate and model potential for pathogen survival/growth during distribution
• RISK MODELING/ECONOMICS
  — Quantify risk of pathogen survival, and appropriate intervention strategies
• EDUCATION/TRAINING
  — Reduce risk of foodborne illness via high quality training programs

How Safe is Our Produce?

The Good Old Days
Welcome to the 21st Century

Pre-Harvest Contamination
- Cattle Feedlots
- Irrigation Water
- Wild Animals
- Composting Practices

Harvesting is Highly Variable

Processing is Also Highly Variable
- Commercial Processors
  - Mechanical
  - Semi-mechanical
  - Manual
- Foodservice/Supermarkets
  - Semi-mechanical
  - Manual

Contamination During Processing
- Crates, bins, tarps
- Food contact surfaces during processing
  - Equipment, knives, conveyors, brushes, flume tanks, shredders, shakers, dryers
- Non-food contact surfaces
  - Floors, drains
- Coolers, storage areas
- Personnel
  - Gloves, hygienic practices

Leafy Green Processing
- Shredder
- Conveyor
- Flume tank
- Centrifugal drier
- Shaker table
Product $\rightarrow$ Equipment and Water

50 lb of *E. coli* O157:H7-inoculated lettuce or spinach


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Distribution of *E. coli* O157:H7 after Centrifugal Drying of Lettuce

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Equipment (and Water) $\rightarrow$ Product

22.5 kg (50 lbs) uninoculated + 22.5 kg (50 lbs) inoculated

90 kg (200 lbs) uninoculated

Empty and refill water recirculation tank


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Spread of *E. coli* O157:H7 to Product during Processing of Leafy Greens Containing ~4 log CFU/g

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Spread of Contaminated Radicchio

45 kg (100 lbs) uninoculated Iceberg

9 kg (20 lbs) inoculated Radicchio

900 kg (2,000 lbs) uninoculated Iceberg

Empty and refill water recirculation tank

Buchholz et al. 2014. *J. Food Prot.* 77:1487-1494

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Radicchio Remaining on Equipment Surfaces after Processing 900 kg of Uninoculated Lettuce

Conveyer Belt and Flume Tank

Blade and Interior Surface of the Lettuce Shredder

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Spread of Contaminated Radicchio to Iceberg Lettuce during Processing

Percentage of Radicchio Recovered from Equipment Surfaces After Processing

How well do sanitizers work?

D-values for L. monocytogenes on fresh produce exposed to various sanitizers

Not well if the organic load in the water is high?
**Wash Water Preparation**

- Organic load (blended iceberg lettuce)
  - 0%, 2.5%, 5%, or 10% (w/v)
- 890 L (235 gal) recirculation tank

Davidson et al. 2014. J Food Prot. 77:1669-1681

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**Chlorine-Based Sanitizer**

- XY-12, at 50 ppm available chlorine
  - Unadjusted, pH 8.10
  - Adjusted to pH 6.5 with Citric Acid (CA)
  - Adjusted to pH 6.5 with SmartWash™ (SW)
- Sanitizer concentration confirmation
  - XY-12: Chlorine Test Kit 321, Ecolab

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**Processing (5.4 kg Batches)**

- Uninoculated (90 s) → 10 min → Inoculated (90 s) → 10 min → Uninoculated (90 s)
- Activities during 10 min intervals:
  - Adjust sanitizer to 50 ppm
  - Adjust pH to 6.5
  - Collect water samples

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**Populations of E. coli O157:H7 in Recirculating Wash Water**

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**Populations of E. coli O157:H7 on Iceberg Lettuce after Centrifugation**

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**Populations of E. coli O157:H7 in Centrifugation Water**
Salmonella Transfer during Tomato Slicing

- Assess the impact of multiple processing variables on Salmonella transfer during slicing of tomatoes.

1 inoculated tomato (~ 5 log CFU/g)
Slicer design
Temperature
Time
Wetness
Thickness
Variety
Tomato slice samples
Microbial analysis
20 uninoculated tomato

Impact of Slicer Design on Salmonella Transfer

Salmonella Transfer to Different Parts of a Manual Slicer

Salmonella Transfer to Different Parts of an Electric Slicer

Salmonella Transfer Rate to 20 Uninoculated Tomatoes

<table>
<thead>
<tr>
<th>Variables</th>
<th>Transfer rate (%)</th>
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<tbody>
<tr>
<td>Slicer design</td>
<td>Manual</td>
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<tr>
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<td>1.11 ± 0.48 A</td>
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<tr>
<td>Time</td>
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<tr>
<td>Wetness</td>
<td>Dry</td>
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<tr>
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<tr>
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<td>0.63 ± 0.35 A</td>
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<tr>
<td>Slice thickness</td>
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<td>Variety</td>
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<td>Bigdena</td>
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</table>

Salmonella Transfer during Tomato Dicing

2 lb Uninoculated Roma tomatoes
2 lb Inoculated tomatoes (~ 5 log CFU/g)
10 batches of 2 lb Uninoculated tomatoes
50 g / sample
Microbial analysis
Salmonella Populations Transferred to Uninoculated Tomatoes

Salmonella Populations on Diced Tomatoes during 2 min of Washing

Salmonella Populations in Wash Water during 2 min of Washing

Salmonella Populations on Equipment Surfaces after 2 min of Washing

Salmonella Transfer during Conveying of Diced Tomatoes
**Salmonella Reduction after Spray Treatment on Conveyor Belts**

![Graph showing Salmonella reduction after spray treatment on conveyor belts.]

**Listeria Transfer during Celery Dicing**

![Image showing Listeria transfer during celery dicing.]

Kaminski et al. 2014. *J. Food Prot.* 77:756-761

**Experimental Design**

- Uninoculated celery (250 g)
- Inoculated celery or Swiss chard (250 g)
- 15 batches uninoculated celery (250 g each)

**Percentage of Swiss Chard Transferred**

![Graph showing percentage of Swiss chard transferred.]

**Growth of *L. monocytogenes* in Diced Celery at 4°C**

![Graph showing growth of *L. monocytogenes* in diced celery at 4°C.]

**Growth of *L. monocytogenes* in Diced Celery at 7°C**

![Graph showing growth of *L. monocytogenes* in diced celery at 7°C.]

Day 0 = Day 3 = Day 7
Generation time = 3.54 d

Generation time = 2.35 d
Growth of *L. monocytogenes* in Diced Celery at 10°C

- Day 0
- Day 3
- Day 7

Generation time = 0.87 d

Spread of *Listeria* during Slicing of Onions

- Dry in fume hood for 90 min
- Slice inoculated Onion
- Collect top, middle and bottom slice
- Slice 20 un inoculated Onions

Listeria Transfer during Mechanical Dicing of Onions

- 2.3 kg of onions dip-inoculated with *Listeria* at 4 or 2 Log CFU/g
- Prime Dicer with 2.3 kg of un inoculated onions
- Dice 1 (2.3 kg) batch of inoculated onions
- Collect 50 g sample from each batch.
- Dice 10 (2.3 kg) batches of un inoculated onions

Listeria Transfer from 1 (2.3 kg) Batch of Inoculated Onions (4.2 Log CFU/g)

- Listeria transfer from 1 inoculated onion (8.5 Log CFU/onion)
- Listeria transfer from 1 inoculated onion (6.4 Log CFU/onion)
- Listeria transfer from 1 inoculated onion (5.5 Log CFU/onion)

Transfer of *L. monocytogenes* during Coring of Cantaloupe and Honeydew Melon

- Experimental Design
- Inoculation of Cantaloupe and Honeydew
- Sterile Cork Borer to obtain core samples
- Core Samples from Different Red Regions
- Enumeration of *Listeria* on TSA-IR
- Aseptically Cutting one three sections

Figure 1: Simulated Cutting Process.
**L. monocytogenes on the Rind of Cantaloupe and Honeydew Melon**

**Transfer of L. monocytogenes from the Rind to Cantaloupe Flesh**

- Dip-inoculated for 10 min in a 3-strain avirulent cocktail of L. monocytogenes (strains M3, J22F, and J29H) containing 10^9 CFU/ml, air-dried for 1 h and then stored at 4°C for 24 h
- Two inoculated melon halves were mechanically sliced using a 0.75 inch manual slicer (Vollrath Redco 401N) followed by eight uninoculated melon halves
- Enumeration of L. mono on modified TSA-YE and Enrichment with UVM media

**Transfer of L. monocytogenes from the Rind to Honeydew Melon Flesh**

**Slicing Experiments**

- Listeria Transfer from Inoculated to Uninoculated Cantaloupe Melon Halves during Mechanical Slicing
- Listeria Transfer from Inoculated to Uninoculated Honeydew Melon Halves during Mechanical Slicing
Take Home Message

• A small contamination event in the field can lead to the contamination of large quantities of product after processing.
• New microbial intervention strategies are needed to minimize contamination of fresh-cut produce during washing.
• Changes in processing equipment design can lead to decreased levels of contamination
• The order in which fresh produce is processed may play a role in minimizing contamination

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TEAM MEMBERS