

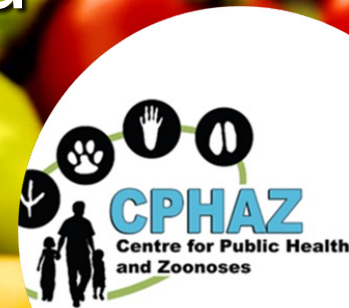
# Food Safety of Fresh Produce: An Old Food Safety Problem But With New Solutions

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Department of Food Science  
University of Guelph

Hosted by Martin Kiernan



[www.webbertraining.com](http://www.webbertraining.com)



Ministry of Agriculture,  
Food and Rural Affairs

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February 13, 2025

# Outline

- Be aware of historic food safety issues associated with fresh produce
- Identify the main pathogens of concern and sources.
- Be aware of food safety initiatives and limitations
- Be aware of alternatives to post-harvest washing to decontaminate fresh produce

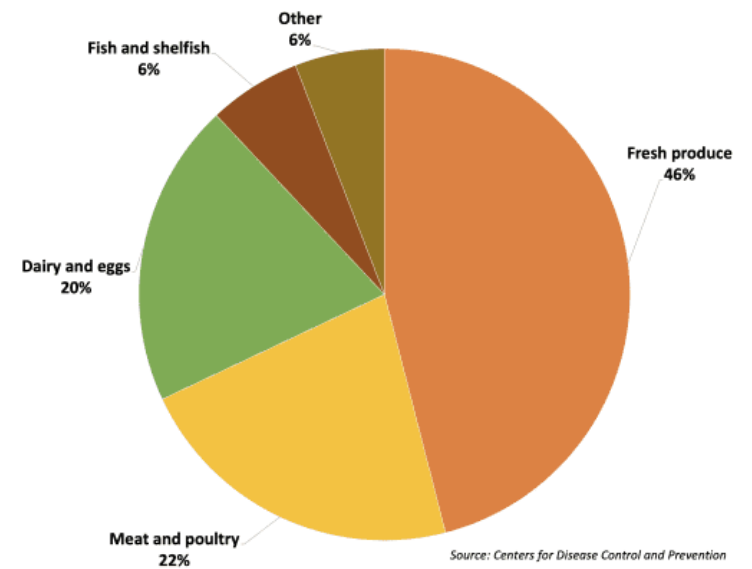
# Fresh Produce

- Prior to 1990s
  - Seasonal
  - Local distribution
  - Narrow selection
  - Considered low food safety risk
- Post-1990's
  - Ready-to-Eat packed salad
  - All year around selection
  - Centralized production
  - Global sourcing





- Leading cause of foodborne illness outbreaks
- Consumed raw
- Open to multiple contamination sources
- Lack of evolution in interventions





# Dole under U.S. probe after deadly Listeria outbreak, berry recall and hepatitis A: What you need to know

Plant in Ohio linked to outbreak in Canada and U.S. resumed production last week

Thomson Reuters | Posted: Apr 30, 2016 10:08 AM ET | Last Updated: Apr 30, 2016 10:08 AM ET

'vaccination can prevent the onset of symptoms if given within 2 weeks of exposure,' health officials say

News | Posted: Apr 26, 2016 11:42 AM ET | Last Updated: Apr 26, 2016 12:02 PM ET



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aeroplan members redeemed for 1.9 million flights last year

Four U.S. outbreaks traced to papayas from Mexico have sickened 235; more cases expected

BY NEWS DESK | SEPTEMBER 1, 2015

The popularity of fresh papaya in some ethnic cuisine is resulting in a disproportionate number of Hispanics being infected in four ongoing Salmonella outbreaks.

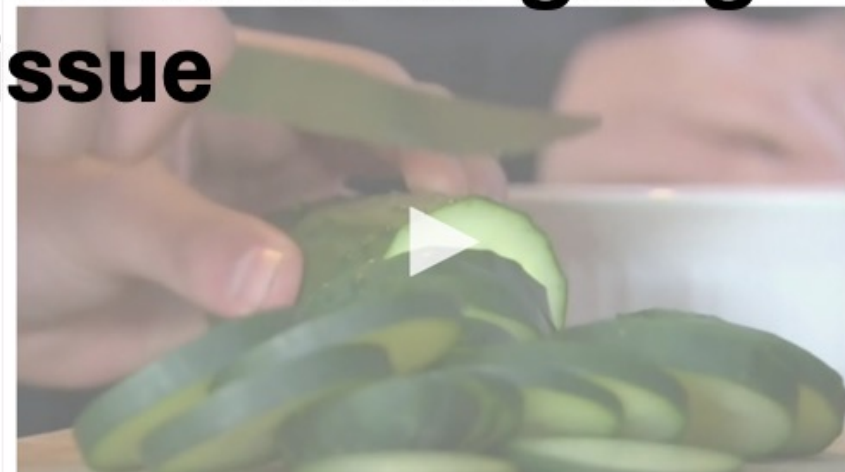
With 235 laboratory confirmed infections as of this week, the Centers for Disease Control and Prevention reports the number of Hispanic victims in the individual outbreaks ranges from 50 percent to 91 percent. Two people have died, but their ethnicity has not been made public.

The CDC and Food and Drug Administration are tracking eight different varieties of Salmonella, all found in maradol papayas from Mexico and matched by laboratory testing to samples from the victims. As of Thursday the CDC split the victims into four outbreaks, based on four farms in Mexico that produced contaminated fruit.



## Fresh Produce and Fruit: An on-going safety issue

Salmonella outbreak in 5 provinces may be linked to cucumbers



Possible widespread



## There's a break in leafy green outbreaks, but work to eliminate them forever continues

By Dan Flynn on November 29, 2023

Eight times since 2017, growers of leafy greens, especially those producing Romaine lettuce, have been rocked by outbreaks of *E. coli* O157:H7. The pathogen associated with the intestines of cows rode in on the greens, causing sicknesses,

## Cyclospora outbreak in Canada possibly linked to imported produce

51 cases reported between May and July in Quebec, Ontario, Alberta and B.C.

## Nearly 150 sick in Salmonella outbreak affecting 11 countries

By Joe Whitworth on November 21, 2023

Eleven countries, including the United States, have recorded almost 150 Salmonella infections that could be linked to tomatoes.

Why cantaloupe is a fruit you should avoid — recall or not — food safety expert says

## Owners of Colorado family cantaloupe farm charged in fatal listeria outbreak

Brothers Eric and Ryan Jensen were arrested Thursday on charges of introducing adulterated food into interstate commerce

NEWS

FDA working to make berries safer after history of Hepatitis A, norovirus outbreaks

## FDA, CDC now investigating cucumbers as source of nationwide Salmonella outbreak that's sent 54 to the hospital

The FDA believes a total of 162 illnesses may be connected to the outbreak.



## One person dead from E coli and 120 hospitalised, says UK Health Security Agency

Death in England linked to outbreak by officials, who say lettuce is the likely source of the illness



Photo illustration

## Pre-washed salad behind Swedish Salmonella outbreak

By News Desk on March 19, 2024

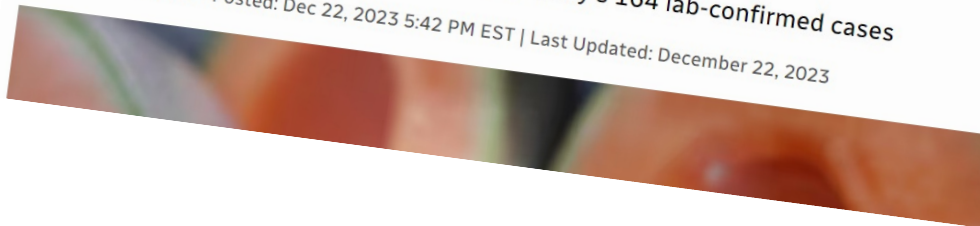
Researchers have shared details on one of the largest national Salmonella outbreaks in Sweden that was likely caused by produce.

Health

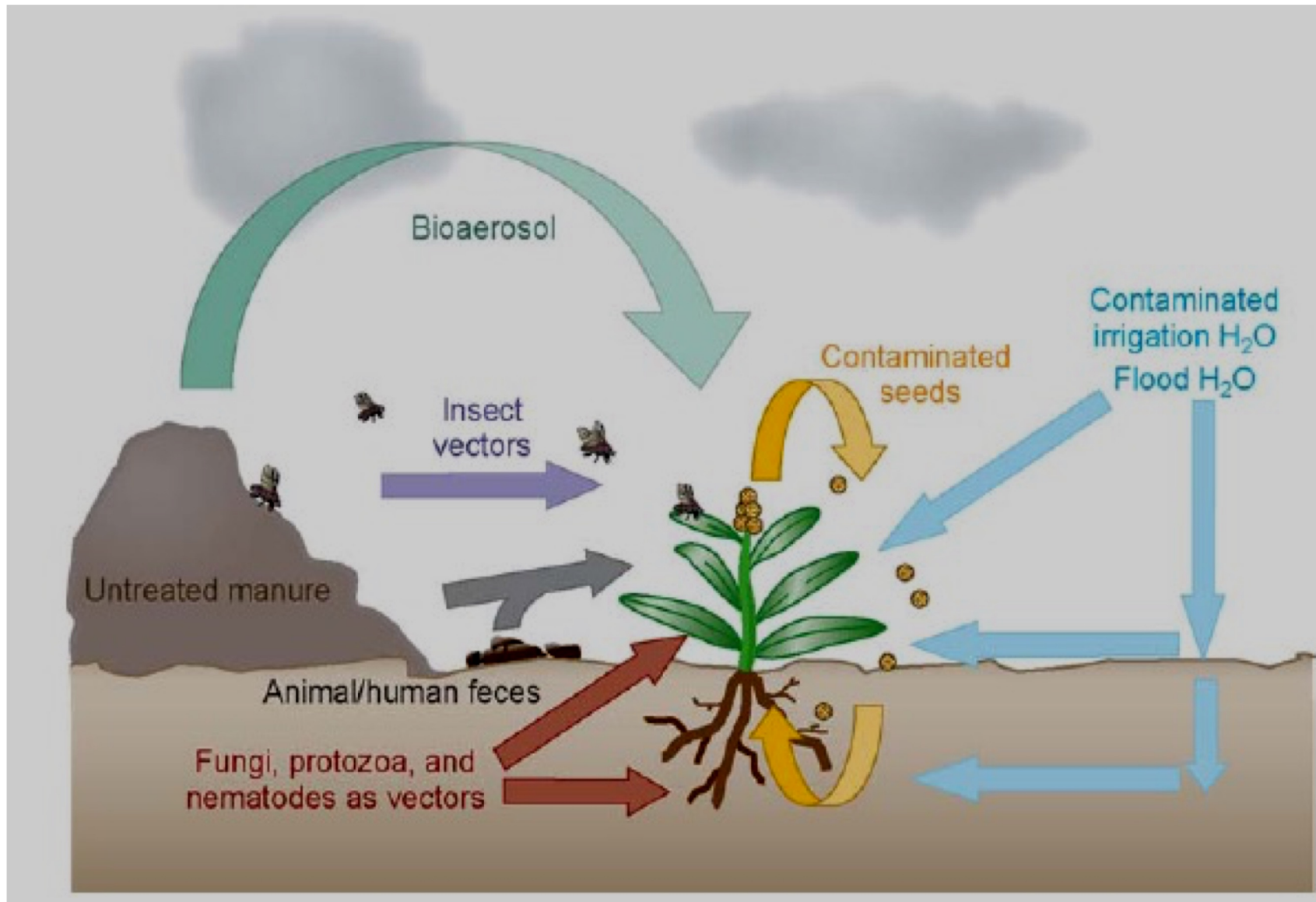
## Death toll rises to 7 from cantaloupe salmonella outbreak in Canada

Quebec has been hardest hit, with 111 of country's 164 lab-confirmed cases

The Canadian Press - Posted: Dec 22, 2023 5:42 PM EST | Last Updated: December 22, 2023





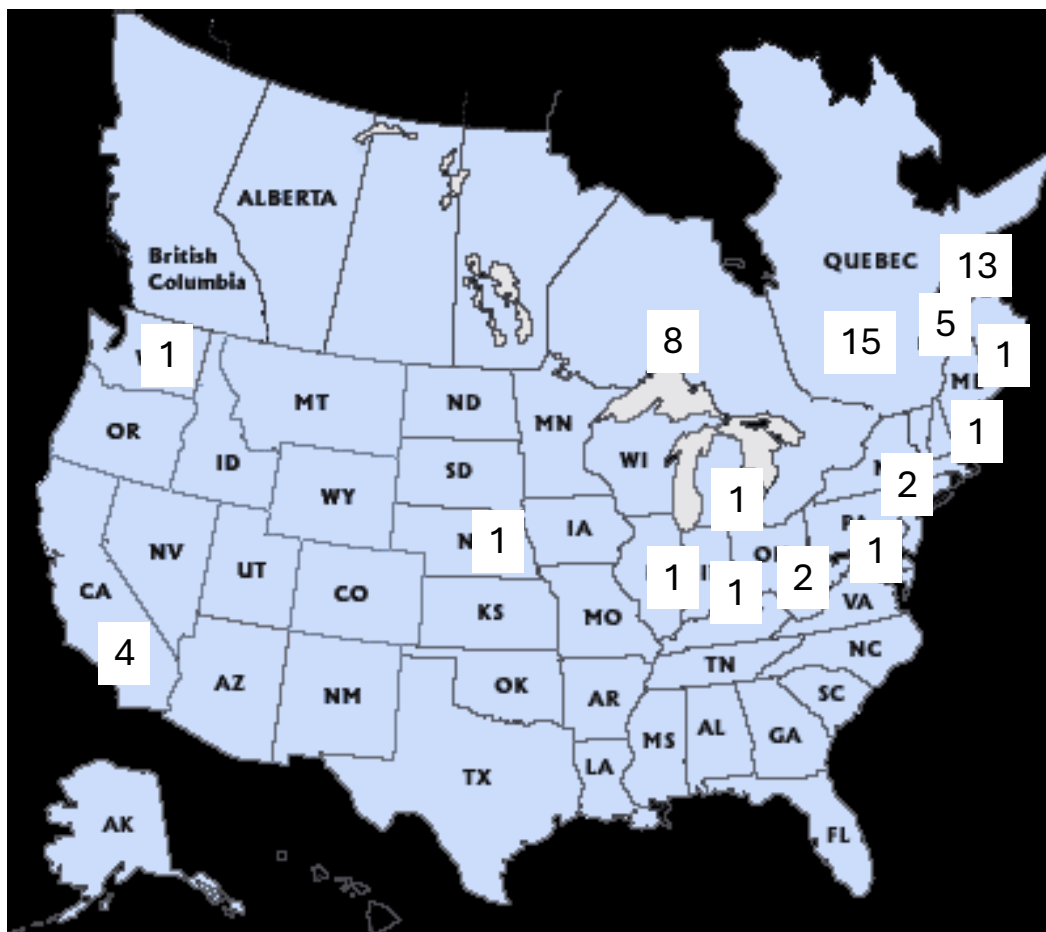


# Fresh Produce Market

- Ready-to-eat Salads Market Growing at 10% per Year
- Current Market Value >US\$70bn
- Greater Diversity of Produce Available (All Year Round)
- Global market and supply chains
- Centralized Production
- Low margins



# *E. coli* O157:H7 Romaine Lettuce November 2017



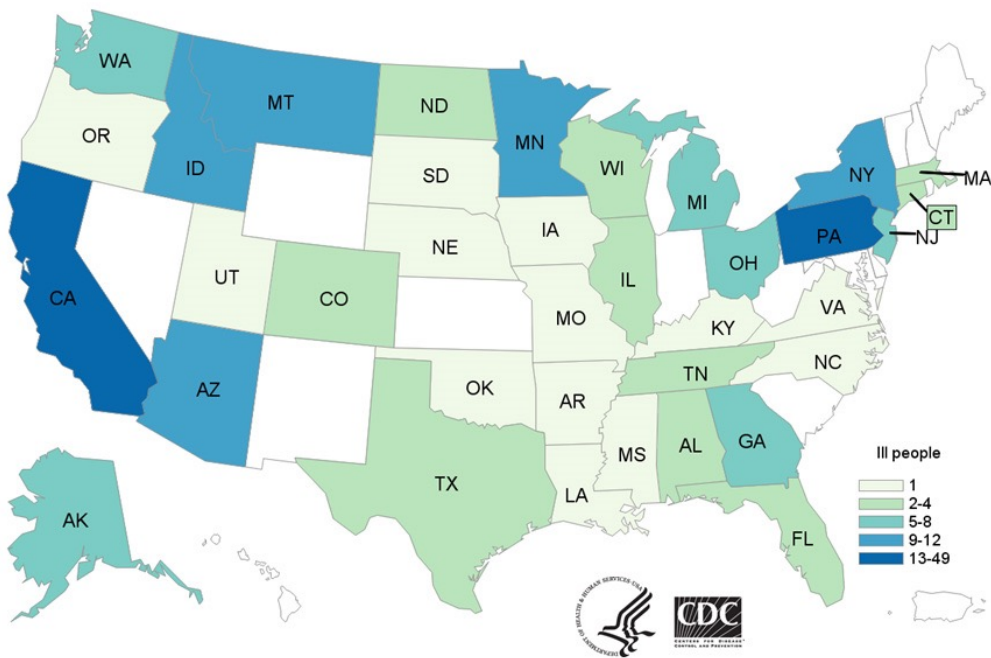
Canada: 45 cases  
US: 25 cases

Vague warning continues  
Will there be new news in the New Year?





# *E. coli* O157:H7 Romaine Lettuce March 2018



Canada 8 cases  
US 210 cases

## E. Coli Cases In Alaskan Prison May Lead To Source Of Contaminated Lettuce

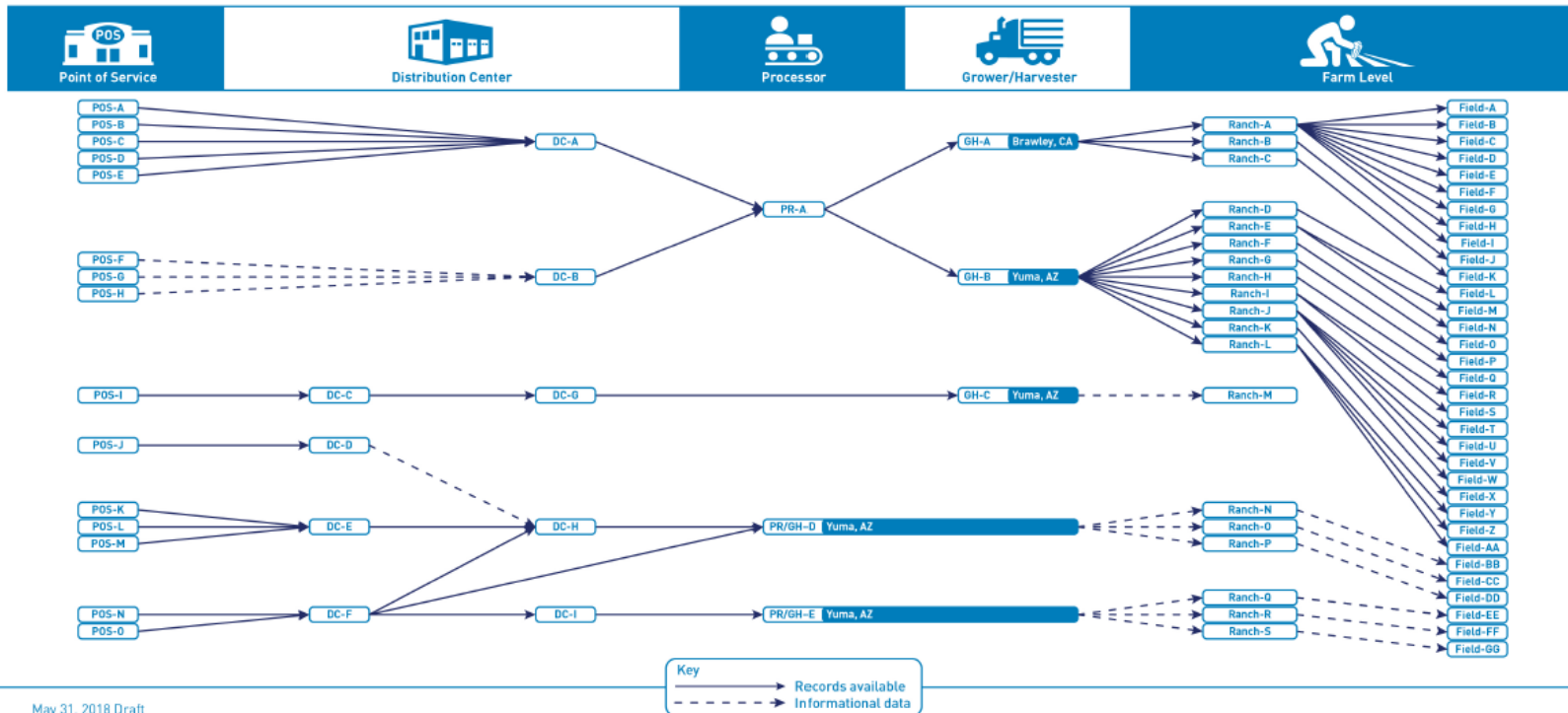
Julia Mitric

Monday, April 23, 2018 | Sacramento, CA | [Permalink](#)



# Fresh Produce Distribution and Processing is Complex Network

E. coli O157:H7 – Romaine – Multi-state Outbreak  
Master Traceback Diagram





**Legend**

- Main Outbreak Strain
- Second Outbreak Strain
- Other O157 Strains
- Negative Site

## FDA-CDC Environmental Assessment June, July and August, 2018

0 3.75 7.5 15 22.5 30 Miles

Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere  
 Projection: Mercator Auxiliary Sphere  
 Datum: WGS 1984





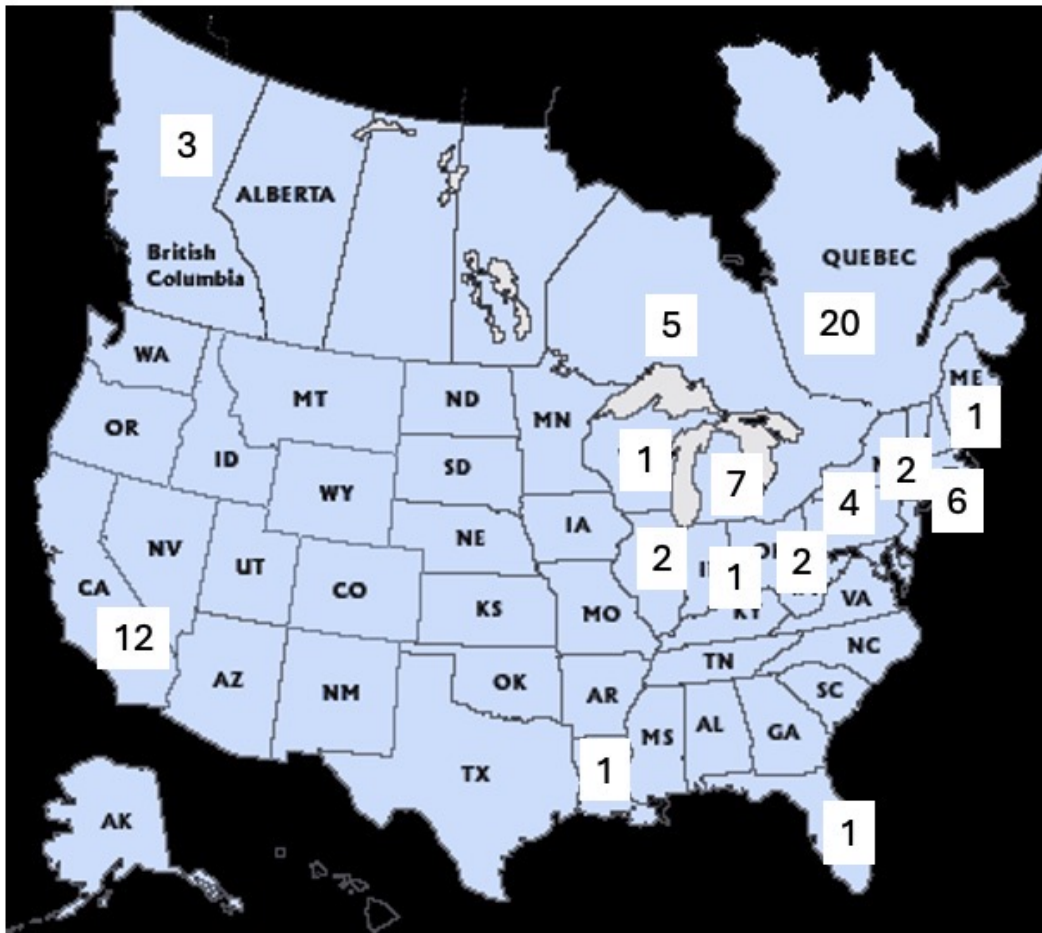


## **IS SALAD SAFE TO EAT AGAIN?**

**THE LETTUCE INDUSTRY SPEAKS OUT**



# *E. coli* O157:H7 Romaine Lettuce October 2018



Canada 20 cases  
US 59 cases

Same *E. coli* O157:H7 strain as 2017





# **It's not easy being green: Romaine lettuce E. coli outbreak rattles food, grocery industries**

The FDA's decision to request that the popular green gets pulled from shelves sent "a strong message" to the produce sector while costing supermarkets millions of dollars.



- Heavy irrigation of crop
- Irrigation water tested positive for fecal indicators
- Chlorination treatment inoperative

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## *Lettuce Try Not to Panic*

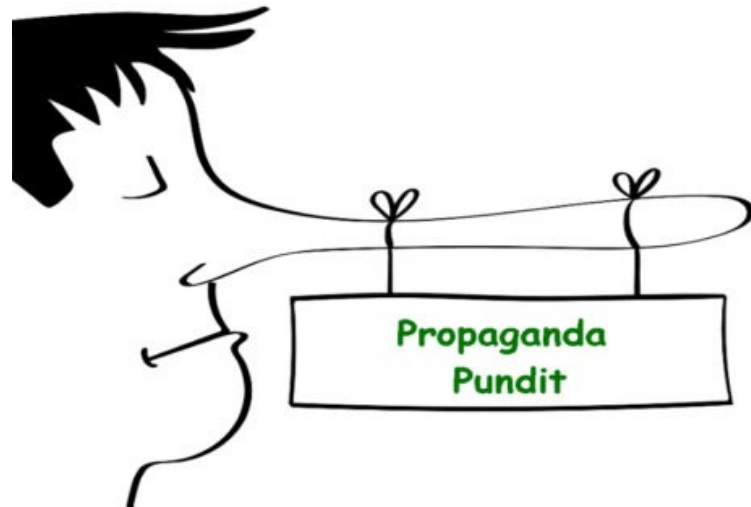
Will a tragic overreaction topple Caesar and lead to the decline of the romaine empire?

By Jim Prevor  
Nov. 29, 2018 6:37 p.m. ET



ILLUSTRATION: PHIL FOSTER

The Centers for Disease Control and Prevention urged before Thanksgiving that “U.S. consumers not eat any romaine lettuce, and retailers and restaurants not serve or sell current E. coli outbreak is resolved. This effectively closed down the

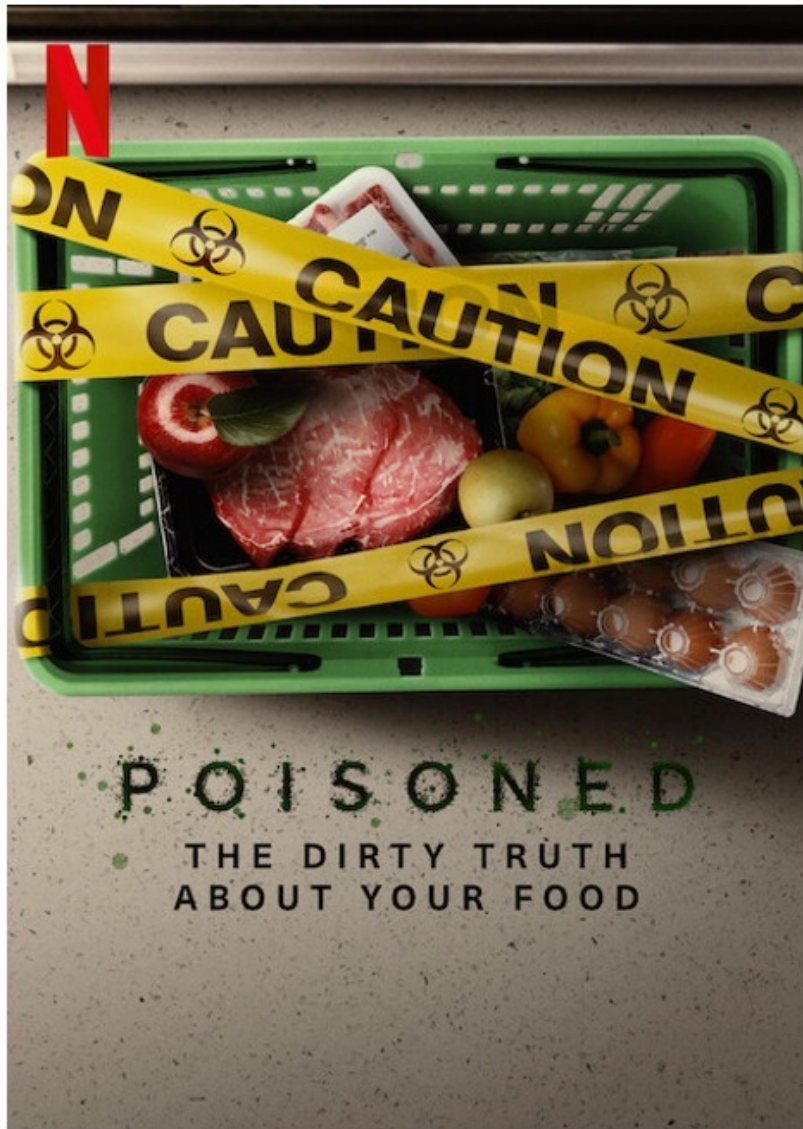




“The LGMA welcomes the information provided by FDA today through their investigation as it will be extremely valuable in helping the leafy greens industry identify the source of this outbreak so that future illnesses can be prevented.

• As part of today’s statement, the FDA is providing some results from environmental findings being conducted in counties identified as potential sources of romaine lettuce involved in this outbreak.







# 'Something has to change': Parents speak out after 2-year-old's E. coli-linked death



## CTV National News: Casualty of contamination



An Ontario couple speaks out about losing their two-year-old boy to an E. coli infection linked to lettuce. Avis Favaro reports.

 11K    11K



**Avis Favaro**, Medical Correspondent, CTV National News  
[@ctv\\_avisfavaro](#)

Published Saturday, May 4, 2019 10:14PM EDT

Last Updated Saturday, May 4, 2019 10:32PM EDT

It all started with a romaine salad.

Kristen and Brad Bell felt a little sick after eating the salad last October.





# E. Coli Outbreak In Romaine Lettuce Underscores Need For Change And Technology

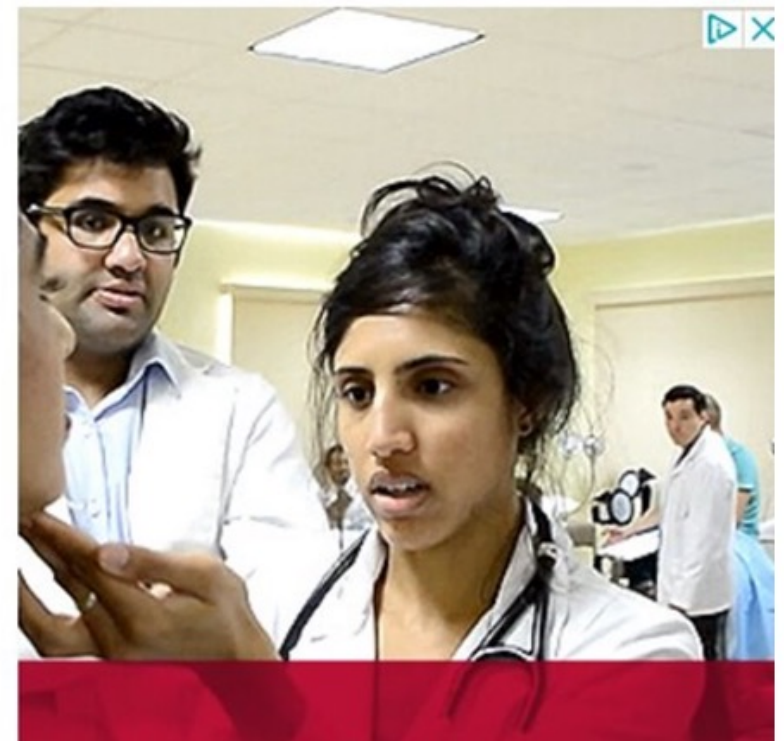


**Phil Lempert**, CONTRIBUTOR

*I cover issues and trends in the food and agriculture sectors.*

[FULL BIO](#) ▾

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# Options to enhance food safety of fresh produce

- Regulations and guidelines
  - Policy to guide industry
  - Requires inspectors to enforce
  - Which regulations would cause a change
- Indoor Farming/Controlled Environmental Agriculture
  - Growing sector
  - Protection from Environmental sources
- Intervention Technologies
  - Alternative to washing
  - Transition from research to commercial practice

# Regulations

- Legal frameworks
- Establish boundaries of Business
- Protect consumers
- Protect environment
- Rulebook to judge compliance vs non-compliance





# Codex Alimentarius : Unifying factor

## Post-WWII

- Increase in trade
- Reduce foodborne illness and food insecurity
- Standards and regulations- regional, weak science based
- Food and Agriculture Organization (FAO) – Food Security
- World Health Organization (WHO) – Public Health
- World Trade Organization (WTO) – Global Trade



# FSMA Final Fresh Produce Rule

- Management of biological/organic amendments
  - Domestic and wild animal exclusion
  - Worker health and hygiene
  - Equipment, tools and buildings
  - Agriculture water rule
- 
- Sprouted seeds
  - Growers take reasonable steps to prevent contamination of crops
  - Exemption if a validation kill step is included in the process

# Pre-harvest Agriculture Water Rule

## Agriculture risk assessment

- Location
- Water distribution system
- Nearby sources of contamination
- Type of irrigation
- Irrigation withdrawal times
- Environmental events (storms, drought, temperature, rains events, weather fluctuations)
- No microbiological criteria



# Pre-harvest Agriculture Water Rule

- Risk Management Strategies
- Effective (validated) mitigation and control methods
- Treating water (PAA, chlorine)
- Re-evaluation of water sources
- Validation (water testing)

# Annual Agricultural Water Assessments and Risk-Based Outcomes

Pre-harvest agricultural water for non-sprout covered produce.



# Indoor Farming/Controlled Environmental Agriculture



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Food and Agriculture Organization  
of the United Nations

Food Safety Guideline for Indoor Farming

Publication: March 2025

# History of Indoor Farming

Niche



Commercially Viable



**TIBERIUS**



© romanemperors.com



Venlo Greenhouse



LED Technology

# Benefits

## **The Vision**

- Increasing productivity
- Reducing food insecurity
- Independence of location and climate
- Environmental sustainability

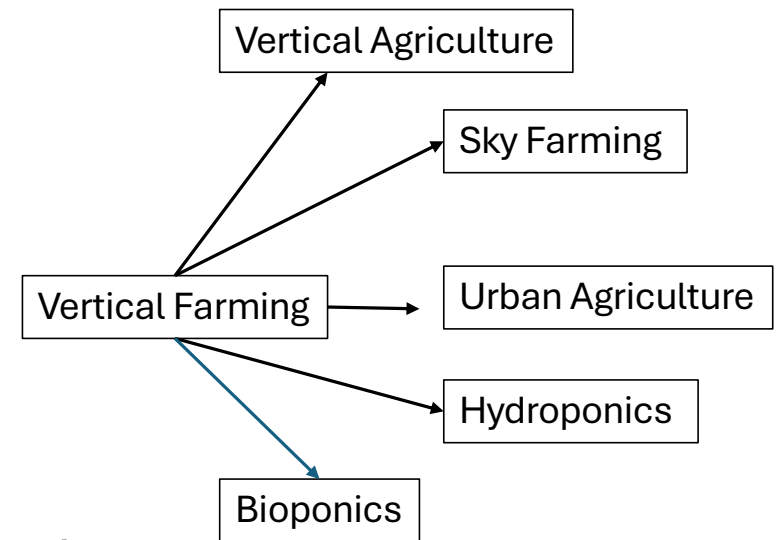
## **The Reality**

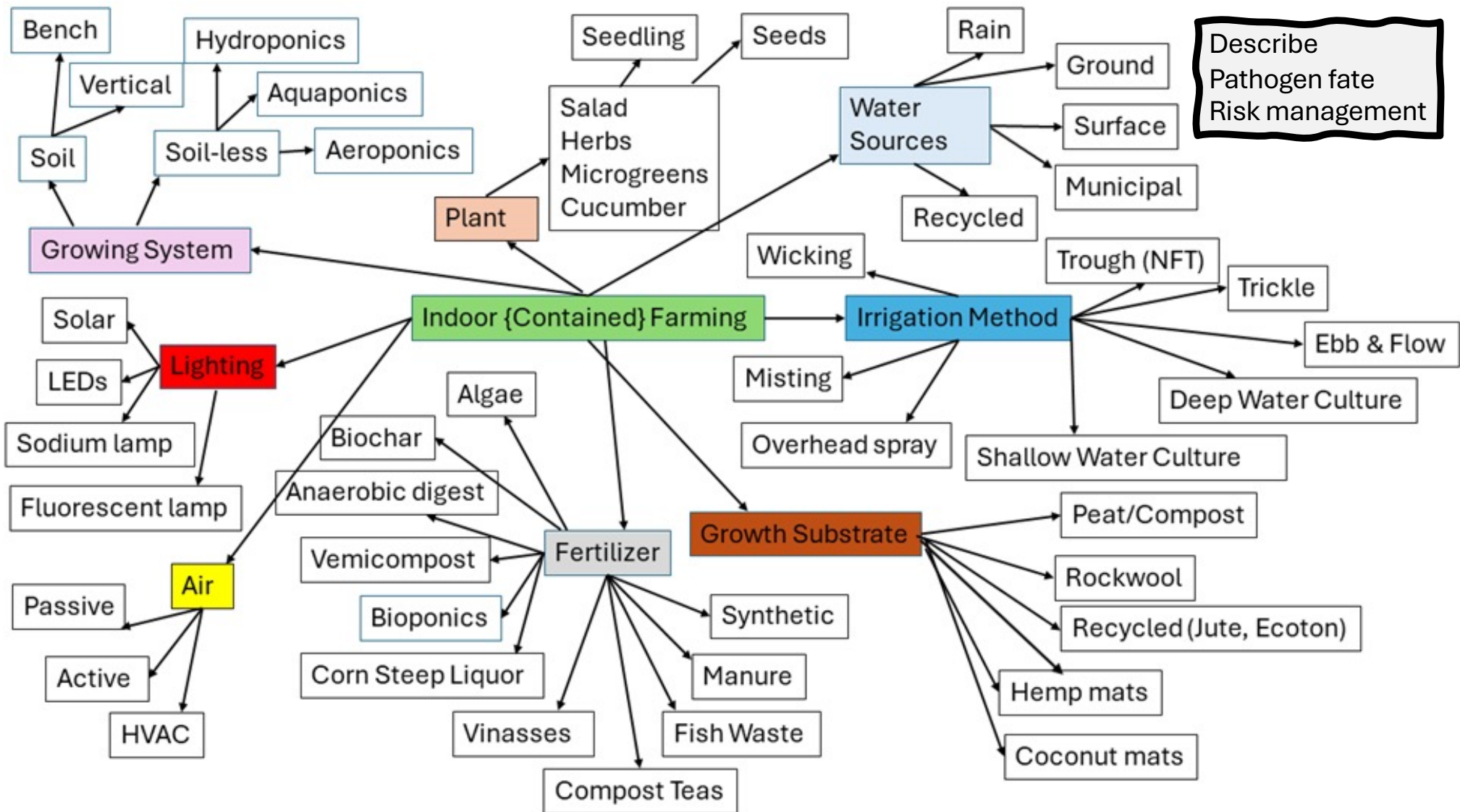
- Economics: Subsidies
- Energy costs
- Consumer preference (sustainability and local doesn't sell)
- Lack of organic certification outside US



# Nomenclature of Indoor Farming

- Rapid diversification of growing methods
- Interchangeable use of terms
- Require descriptive terms
- Who will be responsible for agreed terminology





Describe  
Pathogen fate  
Risk management

Seeds



Growth  
Substrate



Nutrient  
Solution



*Listeria*  
*monocytogenes*  
*Salmonella*  
Toxicogenic *Escherichia*  
*coli*

# Intervention/Decontamination Approaches



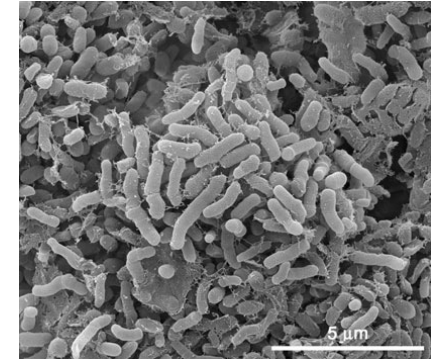
# Washing was not cutting it.

## Laboratory

4-5 log count reduction



Cut Edges

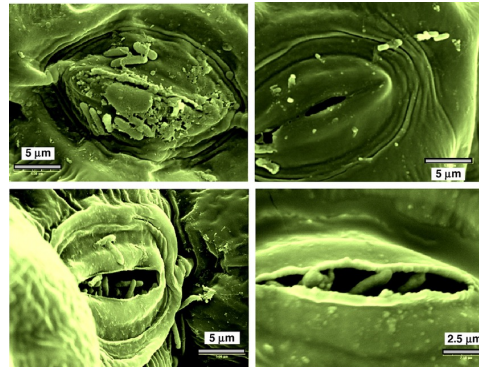


Biofilms

## Commercial scale

0-2 log count reduction

Independent of sanitizer type



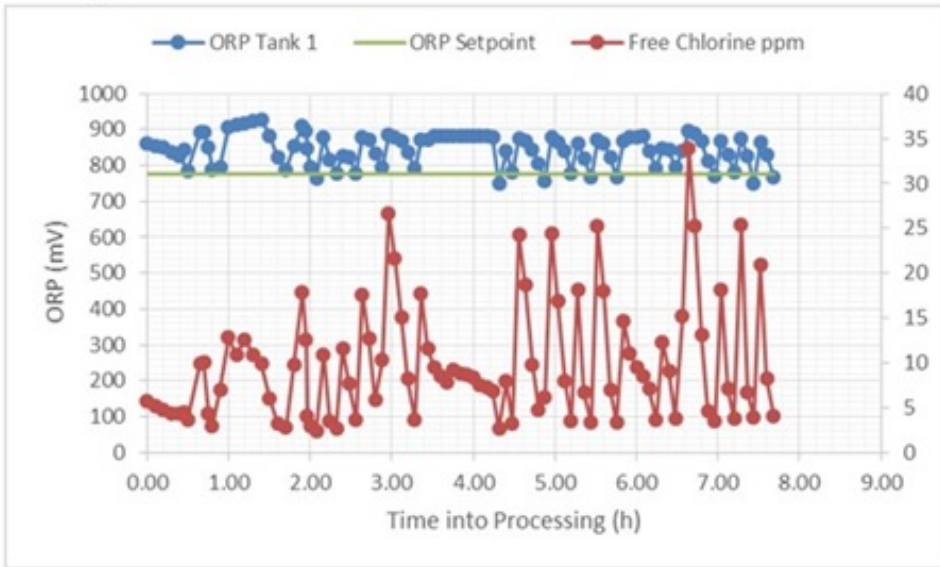
Natural Openings



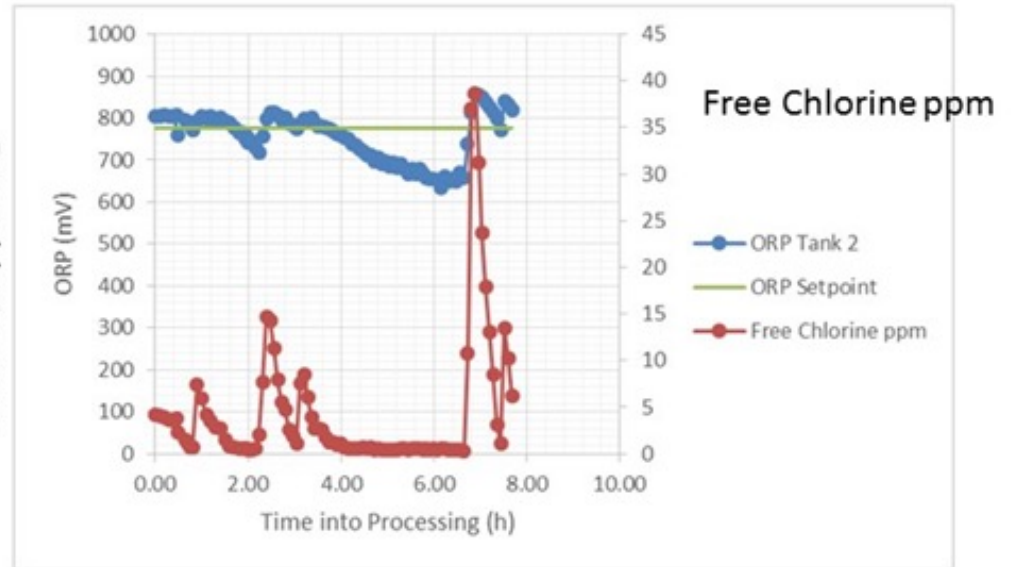
Vacuum Cooling



A



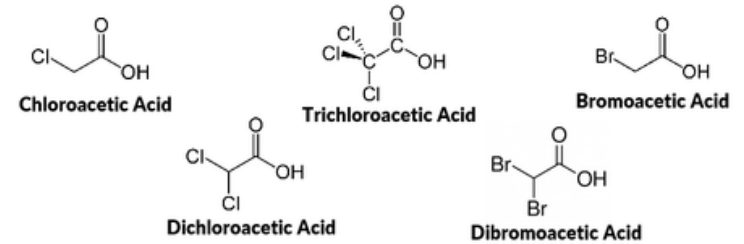
B



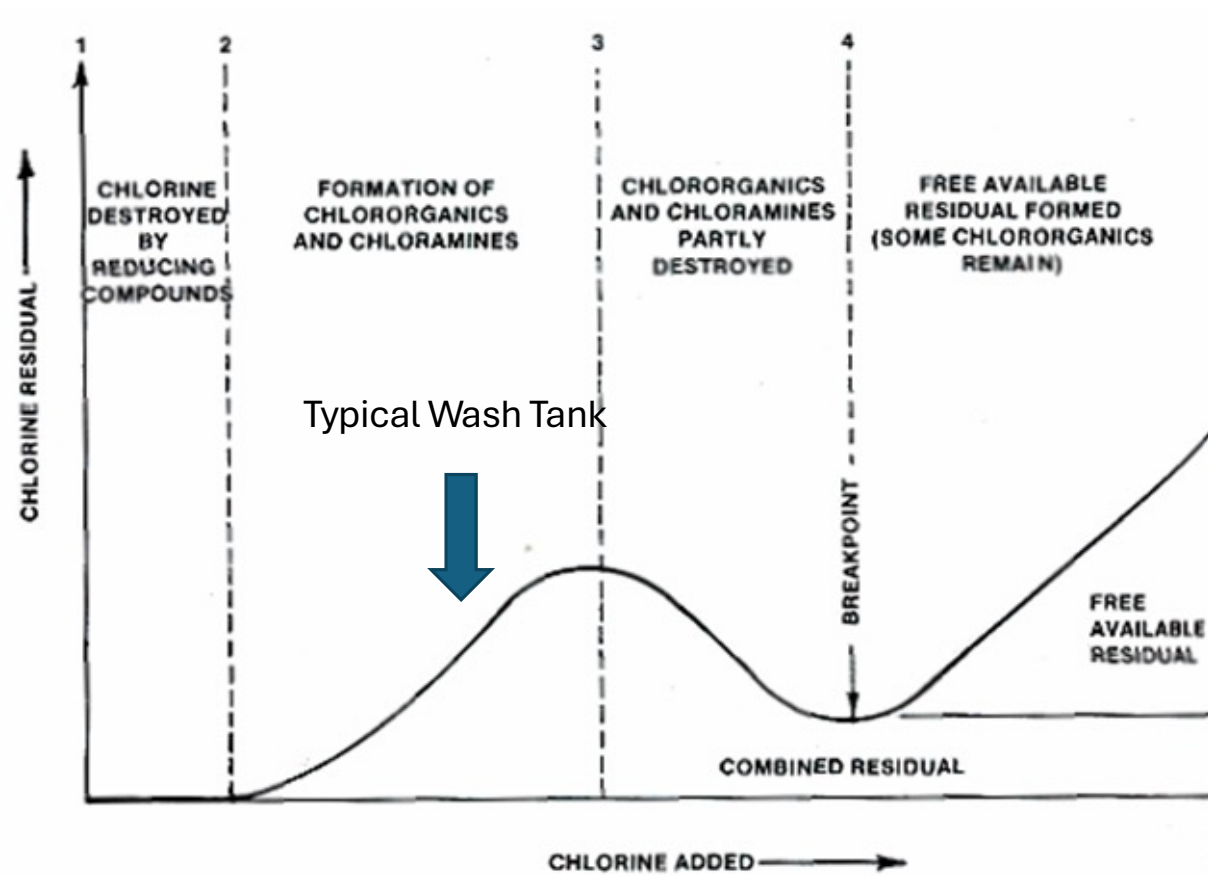
# Disinfection Byproducts

Reaction of hypochlorite with organics pH 6-7

- Trihalomethanes
- Halogenic acetic acids
- Chlorophenols
- N-chloroamines
- Carcinogenic. Pollutants, Sensory impact
- Contributes to ORP but not antimicrobial activity
- ORP narrow analytical range
- ORP sensors- slow response time

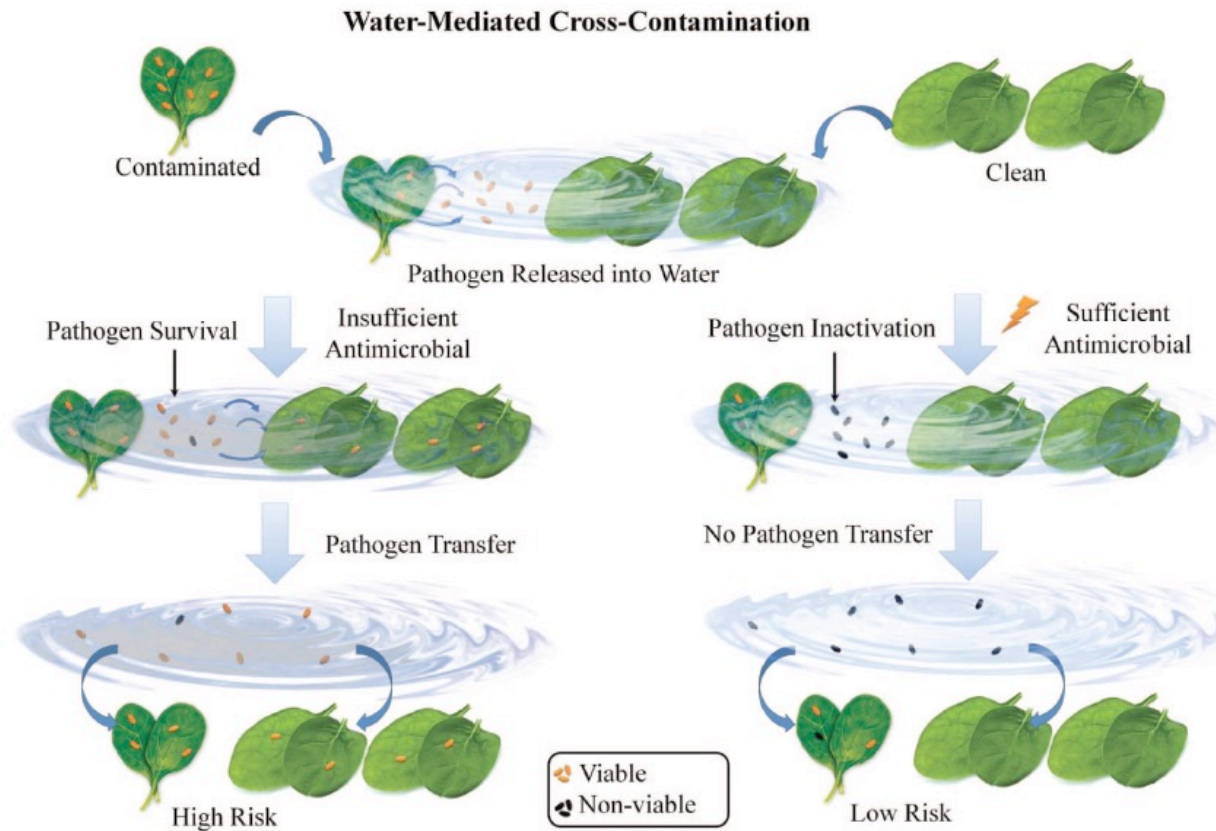


# Feedback Loop to Maintain Hypochlorite and pH





# If we cant decontaminate then prevent cross-contamination



What level of pathogen inactivation and at what rate?

# Alternative Approaches

- Protective cultures (Effective Microbes)
- Electrolyzed water
- Gas plasma
- Ultraviolet light
- Hydroxy-Radical Process



Hydroxyl-radical process

# Hydroxyl Radicals

| <u>Oxidant</u>  | <u>Oxidation Potential (V)</u> |
|---|--------------------------------|
| Fluorine [F <sub>2</sub> ]                                | 3.0                            |
| Hydroxyl radical [HO·]                                    | 2.8                            |
| Sulfate radical [SO <sub>4</sub> · <sup>-</sup> ]         | 2.5–3.1                        |
| Ozone [O <sub>3</sub> ]                                   | 2.1                            |
| Persulfate [S <sub>2</sub> O <sub>8</sub> <sup>2-</sup> ] | 2.1                            |
| Peroxymonosulfate [HSO <sub>5</sub> <sup>-</sup> ]        | 1.8                            |
| Hydrogen peroxide [H <sub>2</sub> O <sub>2</sub> ]        | 1.8                            |
| Permanganate [MnO <sub>4</sub> <sup>-</sup> ]             | 1.7                            |
| Chlorine dioxide [ClO <sub>2</sub> ]                      | 1.5                            |

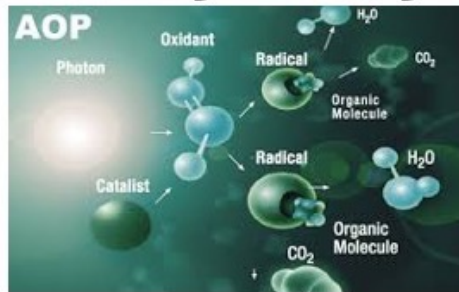




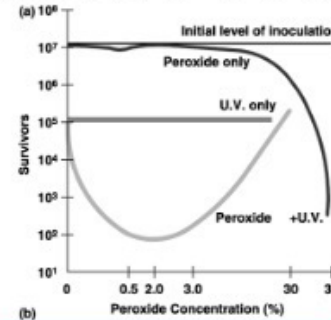
# History of the Hydroxyl-radical Process



Henry Fenton  
 $H_2O_2 + F(II)$   
 Fenton Reagent



Advanced Oxidation Process  
 Wastewater Treatment  
 $UV + H_2O_2$



Elopak  
 Carton Sterilization  
 $UV + H_2O_2$  vapor



Hydroxyl Radical Process  
 Fresh Produce  
 Decontamination  
 $UV + H_2O_2 + O_3$

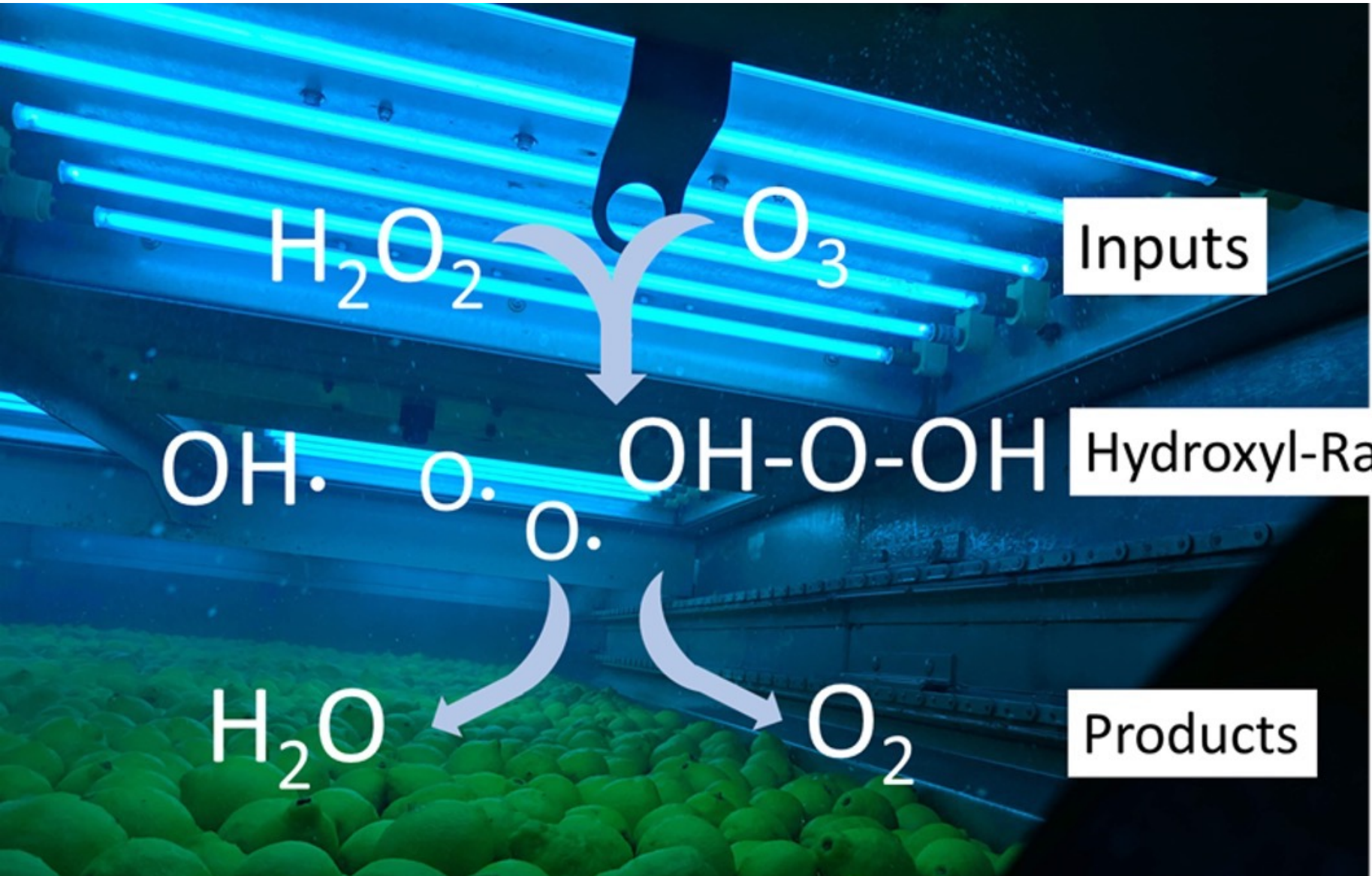
1892

1979

1983

2016



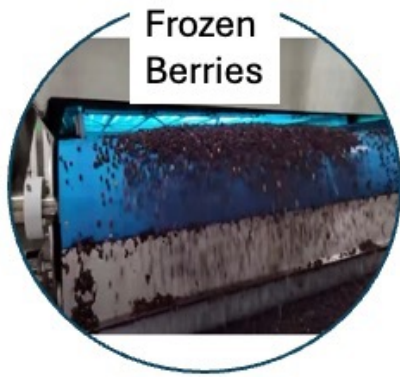
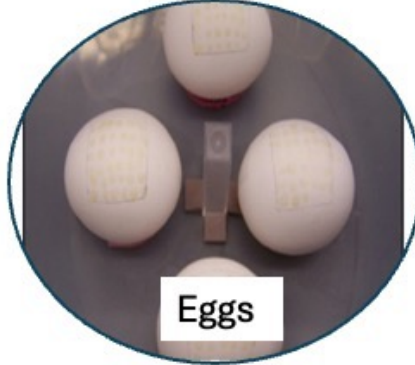
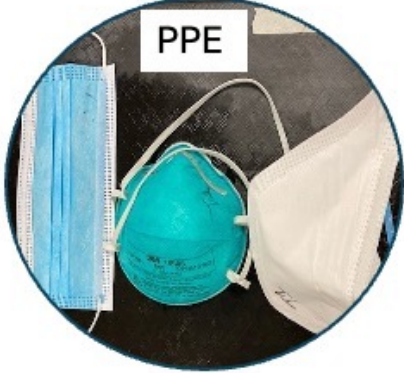
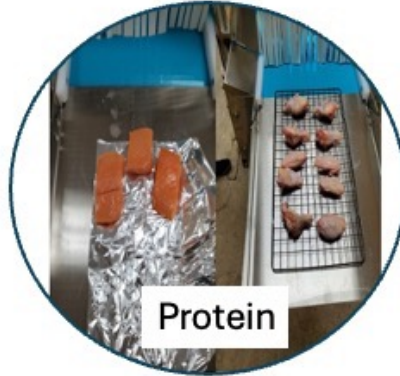
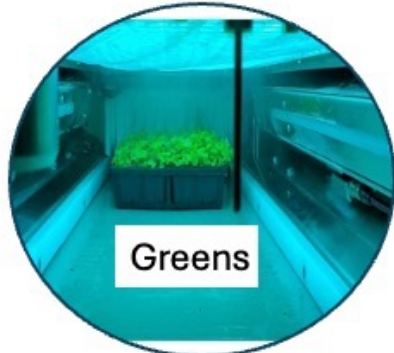
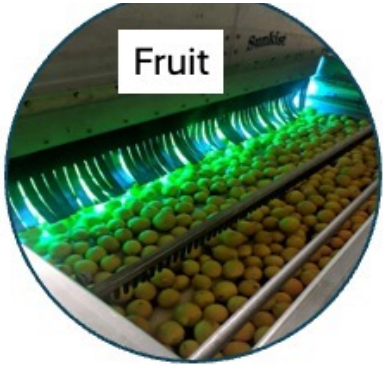


Inputs

Hydroxyl-Radicals

Products





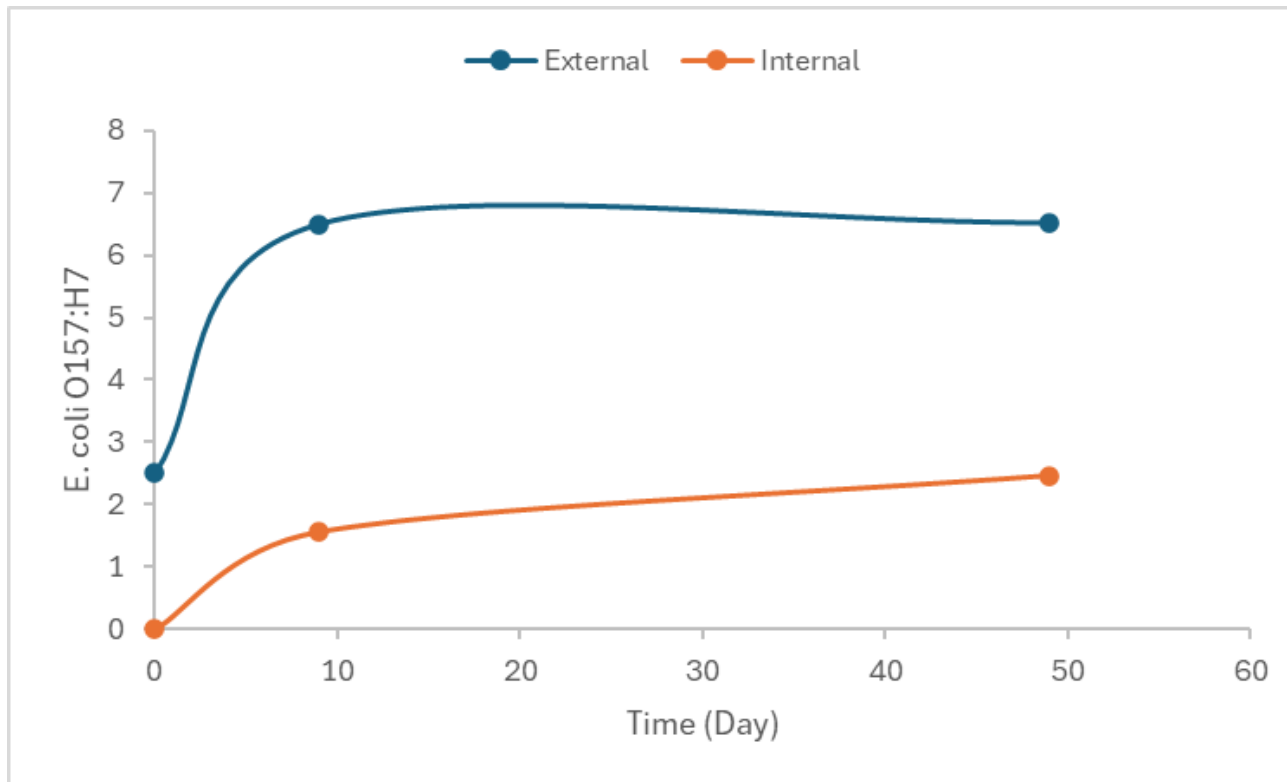
# Seeds and Seedlings

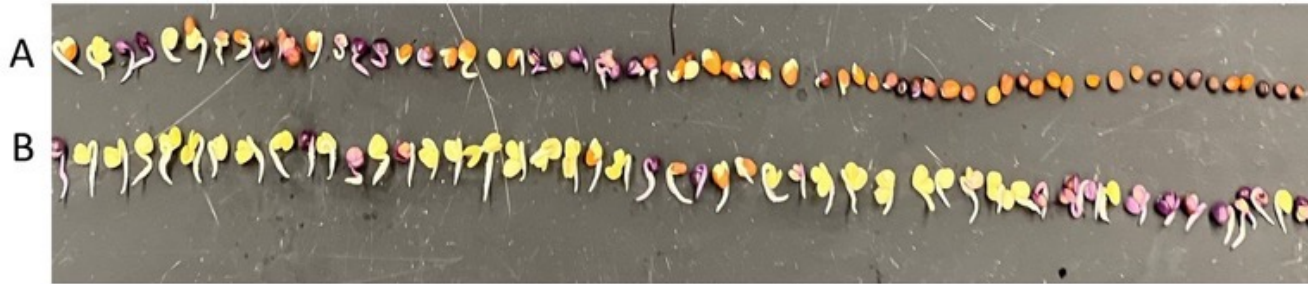
Raw agricultural product

- Seed production focus on plant pathogens
- Little control over human pathogen
- *Salmonella* and *E. coli* O157:H7 can survive >2 years on harvested seed.
- Human pathogen source
  - Sprouts
  - Microgreens
  - Baby leaf

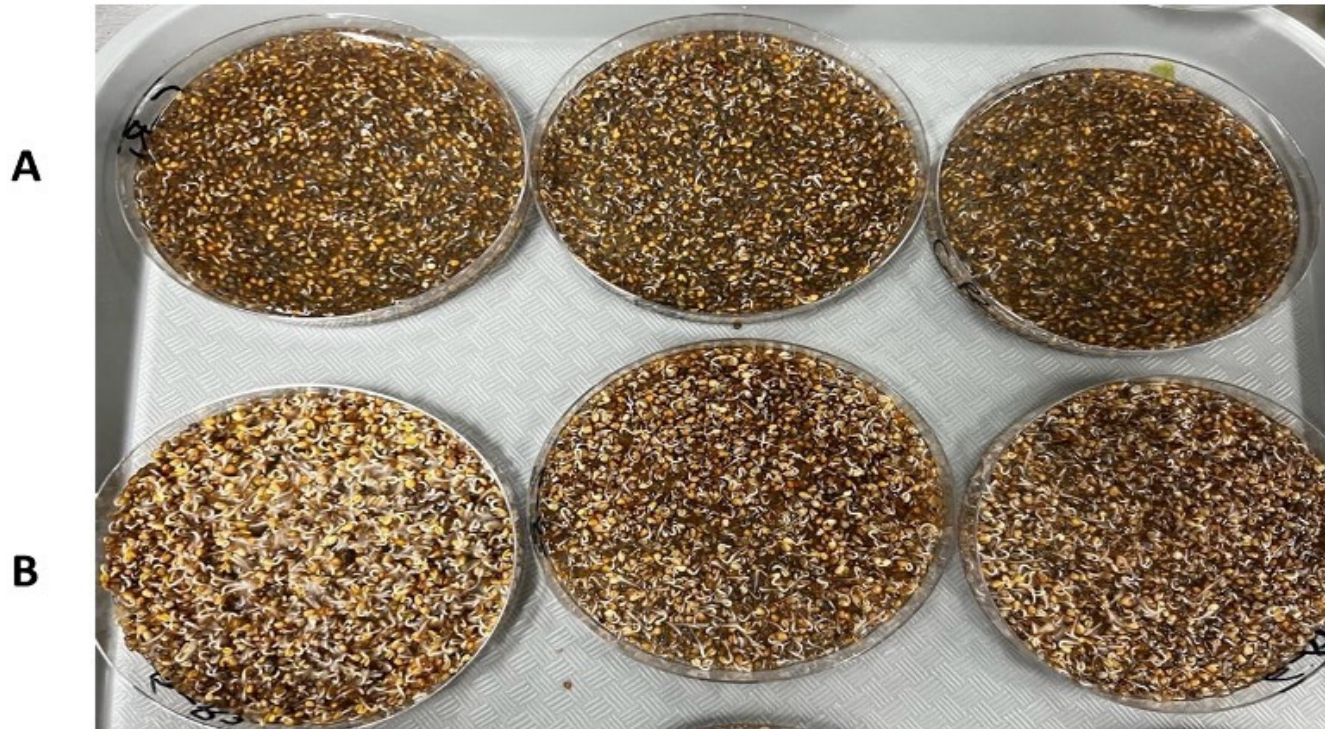


# *E. coli* O157:H7 Introduced onto Seed and Cultivated Hydroponically

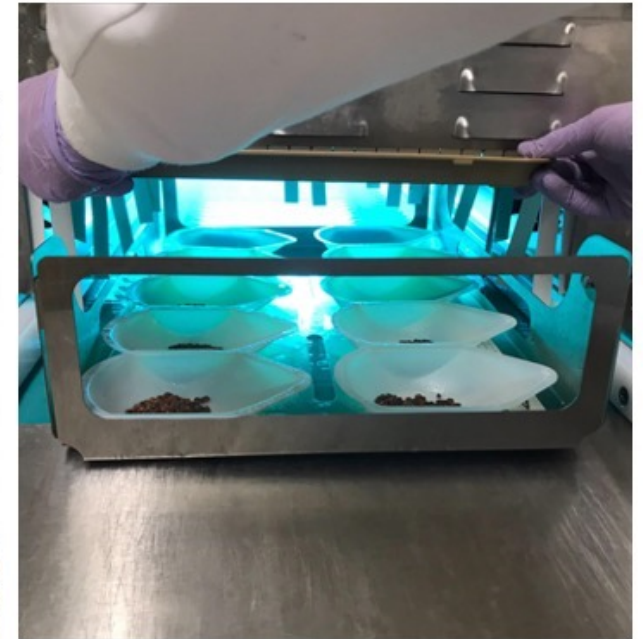




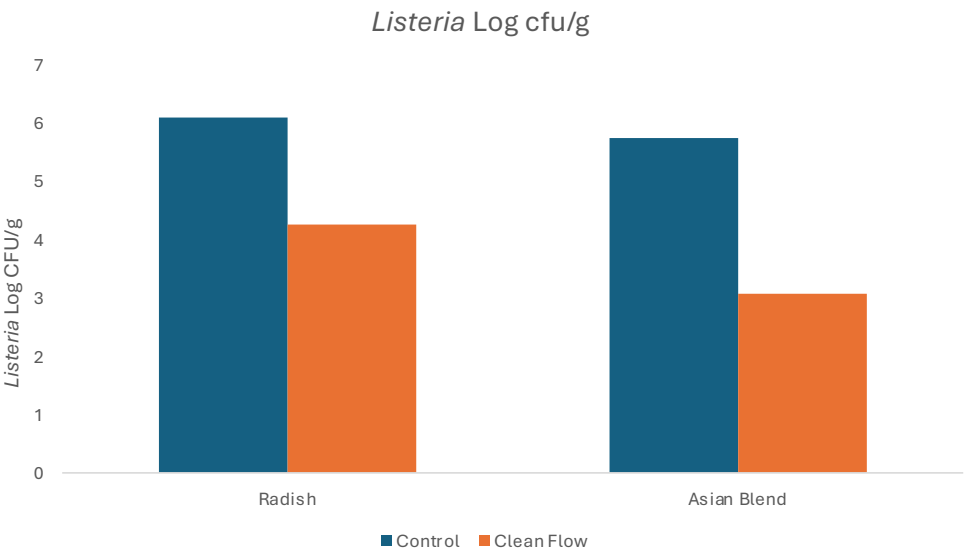
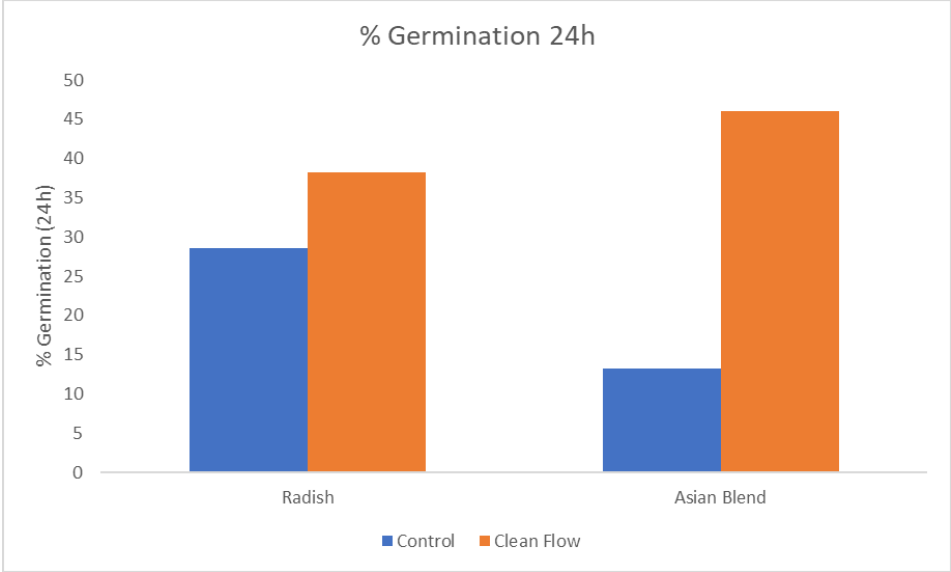
Control germinated seeds (A) and Activated Water 3 treated germinated seeds (B).



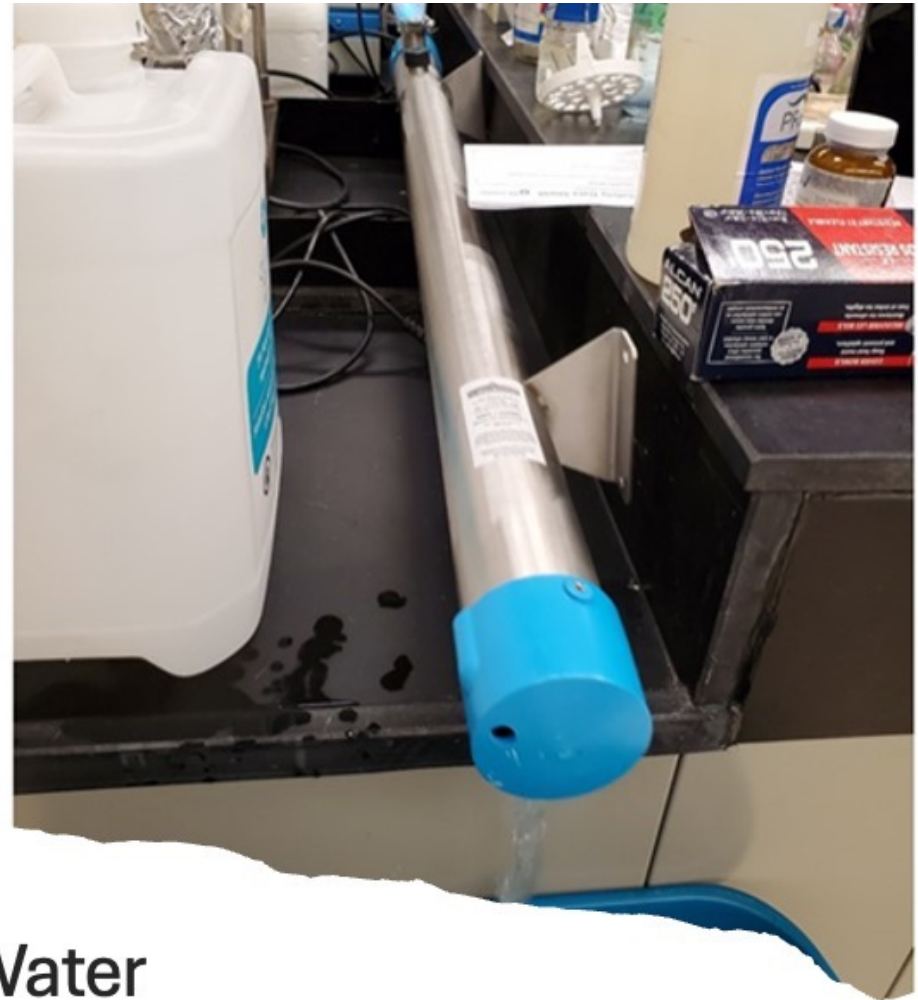
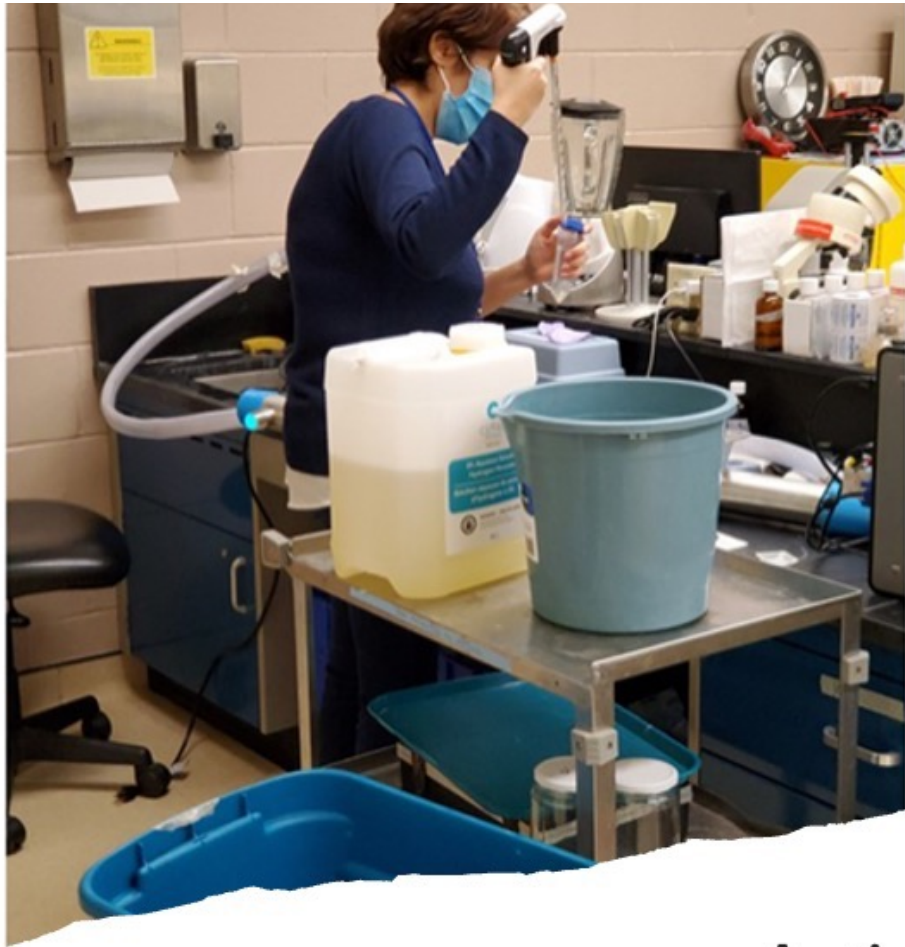
Germination of Arugula seeds after 48h, A: non-treated seeds, B: Clean Flow.



# Clean Flow Treated Seeds



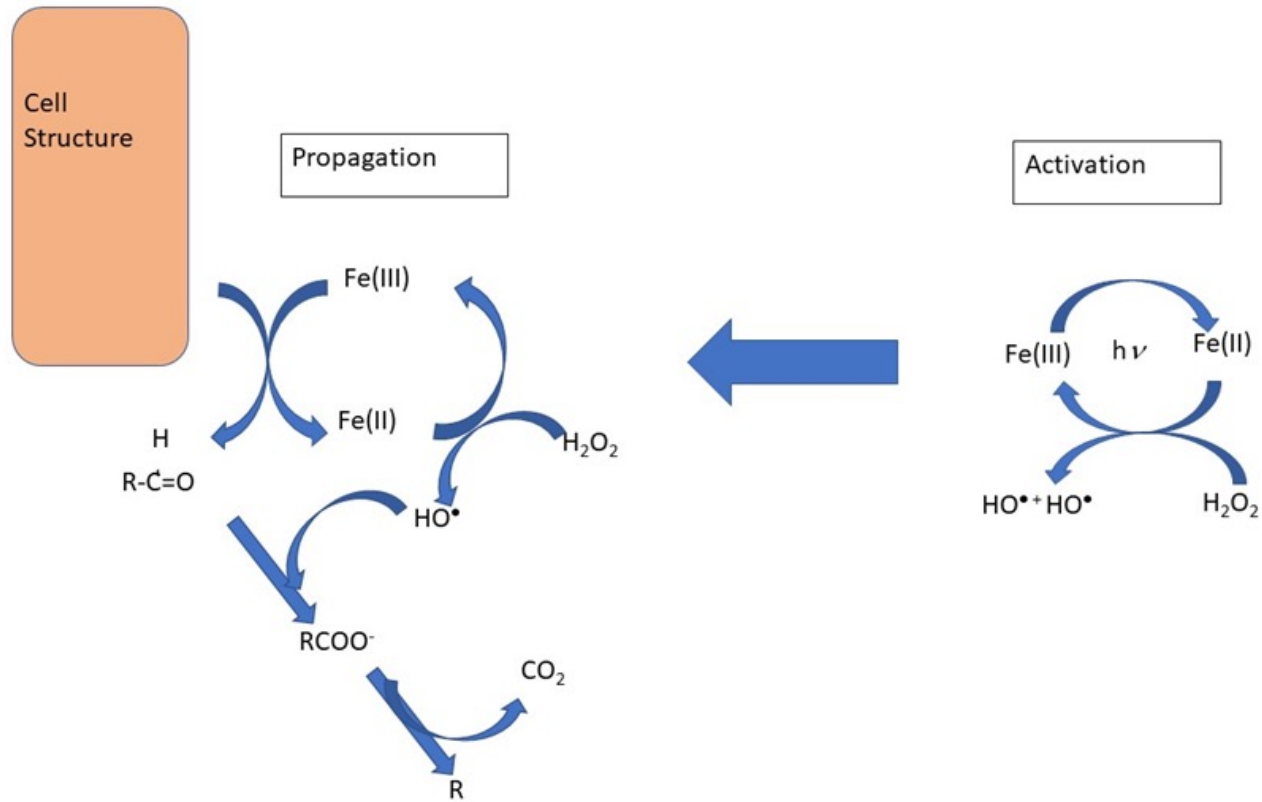




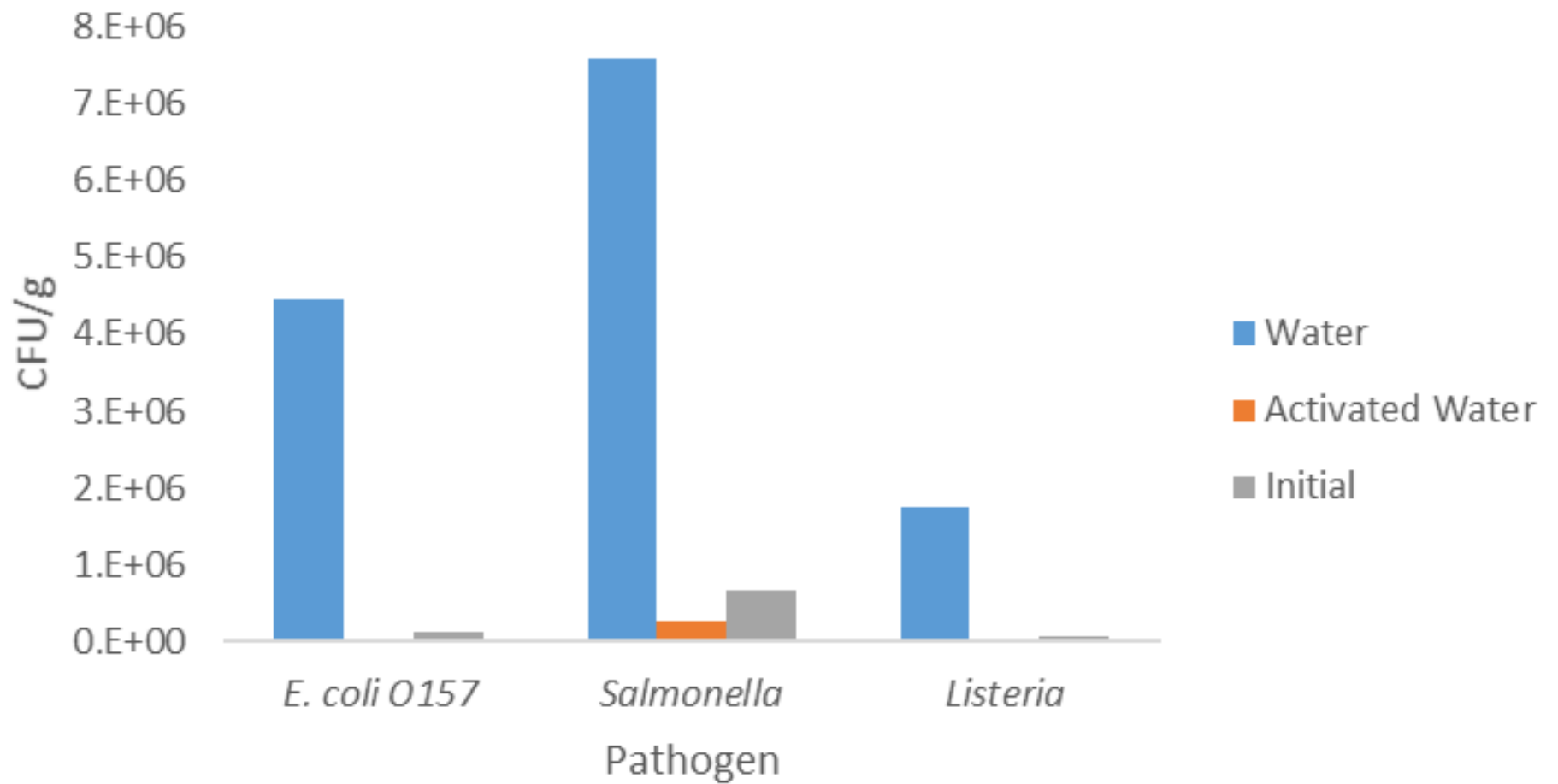
Activated Water



# Mode of Inactivation

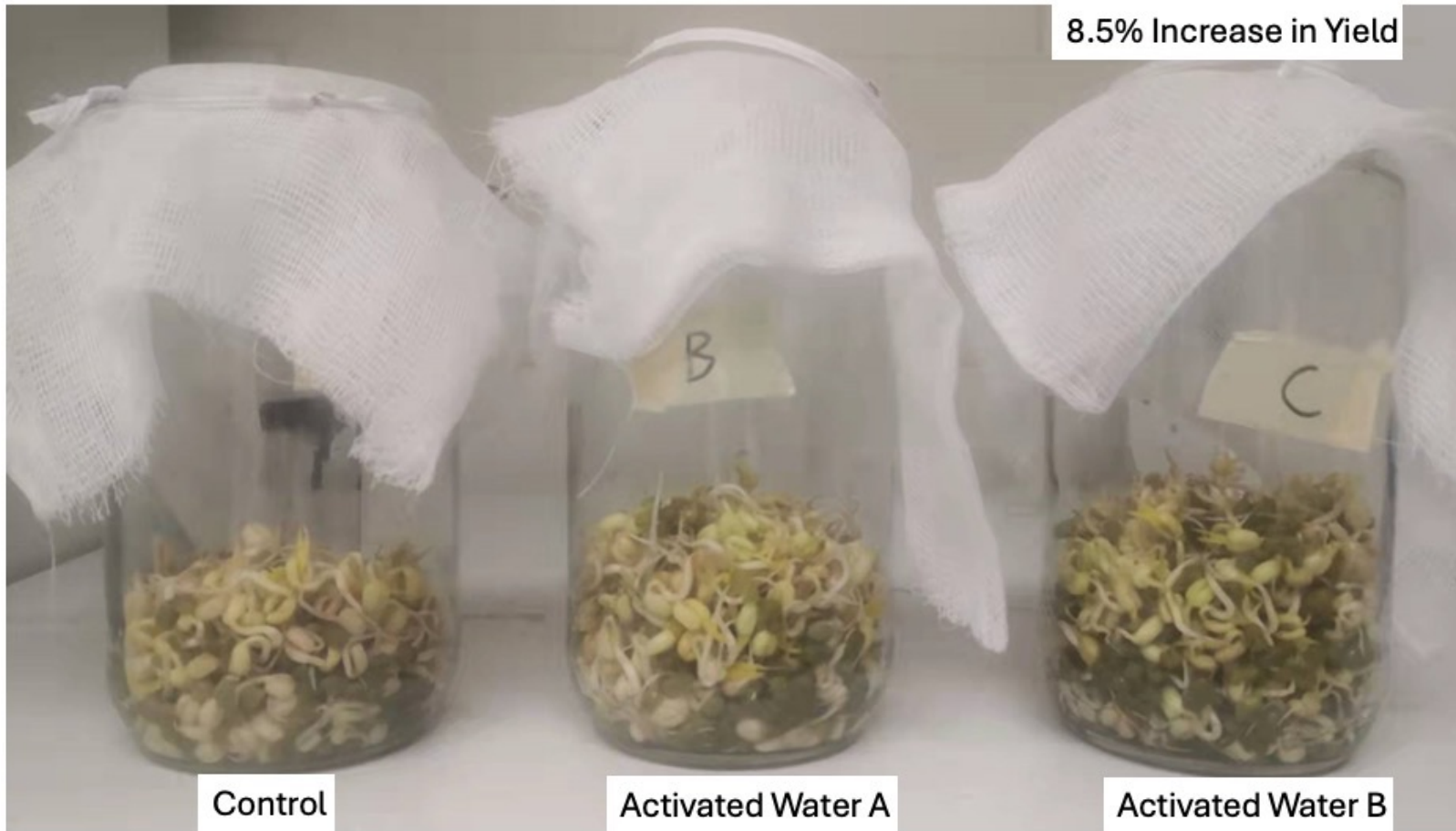


## Mung Beans 24h Steep

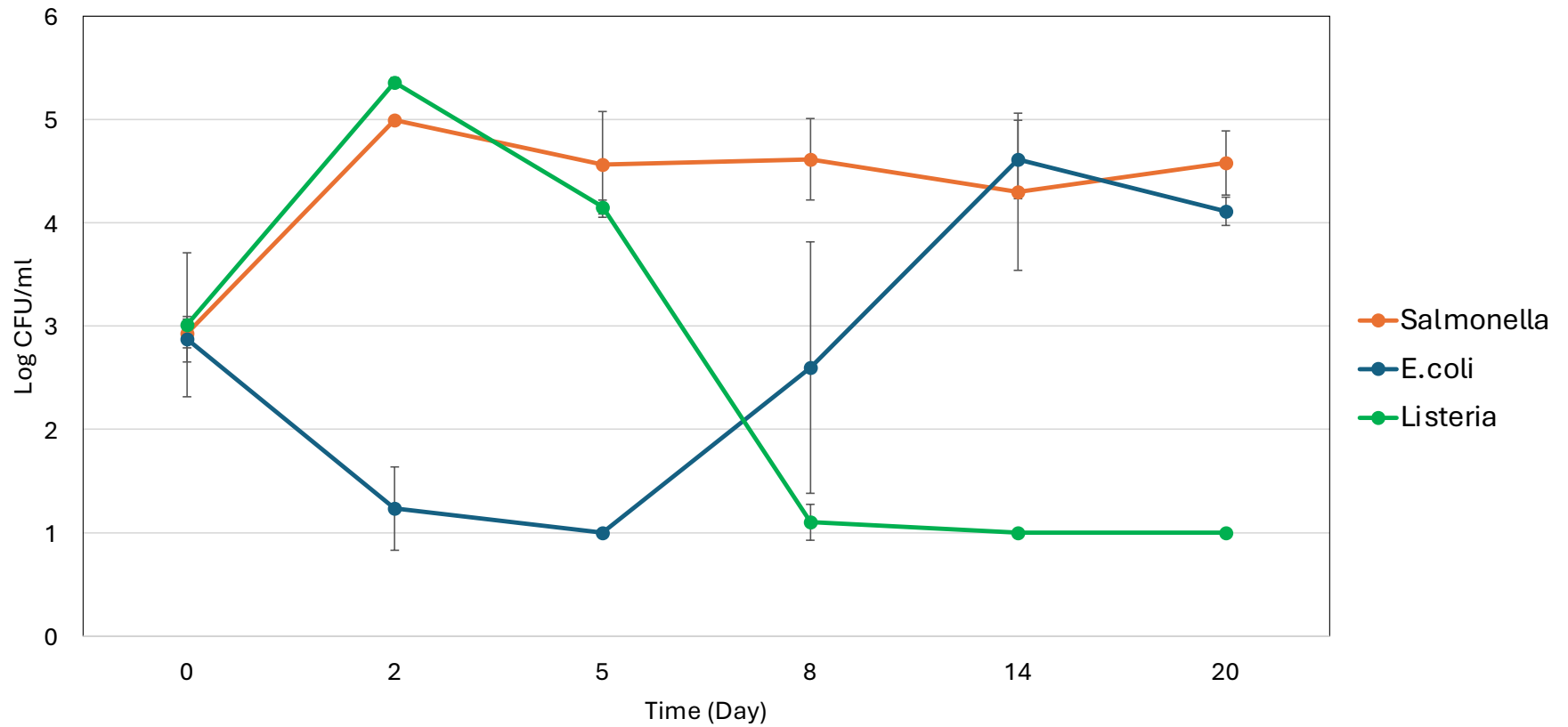


# Sprout Yield

8.5% Increase in Yield

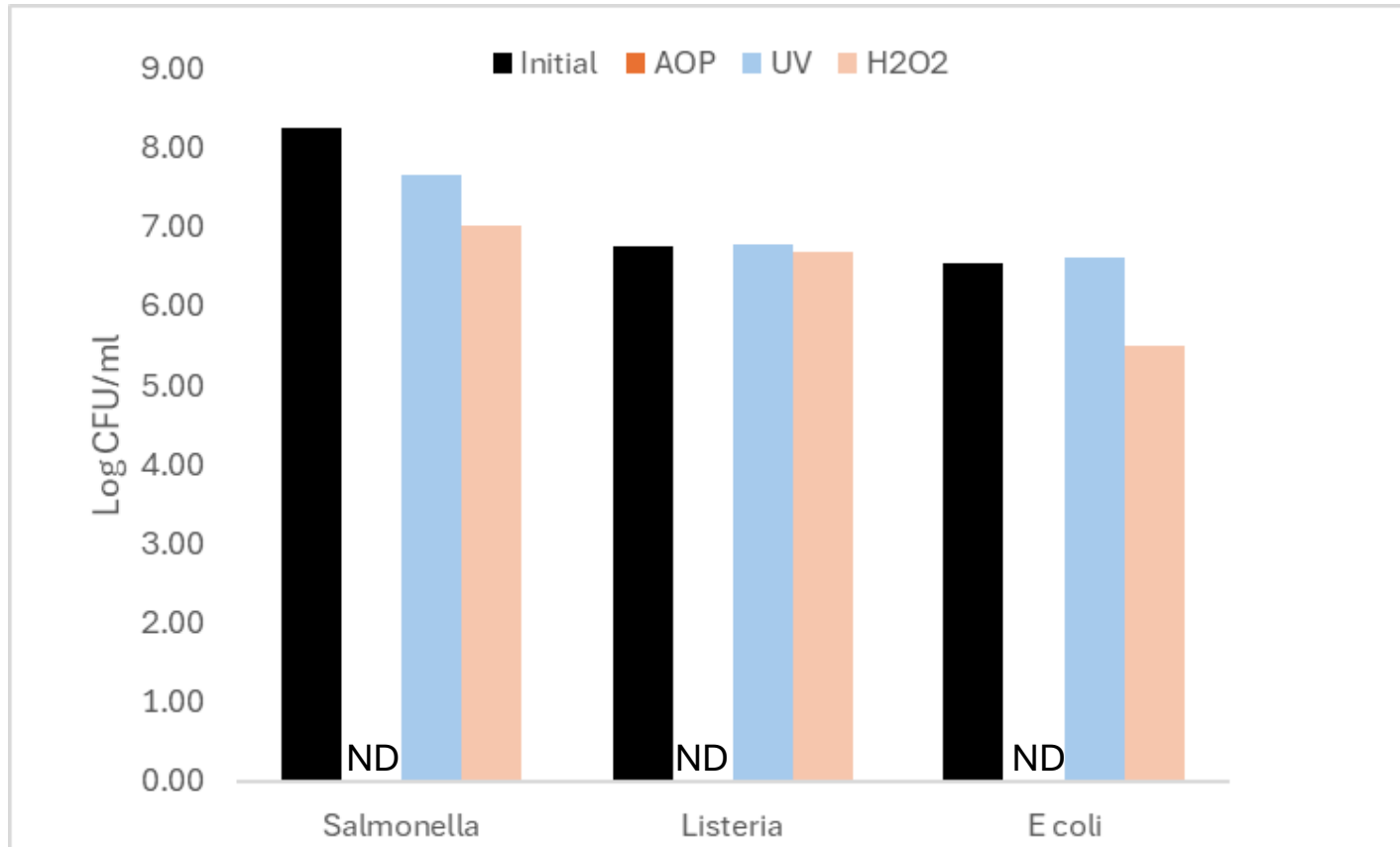


# Survival of Pathogens in Hydroponic Solution





# Inactivation of pathogens in hydroponic solution



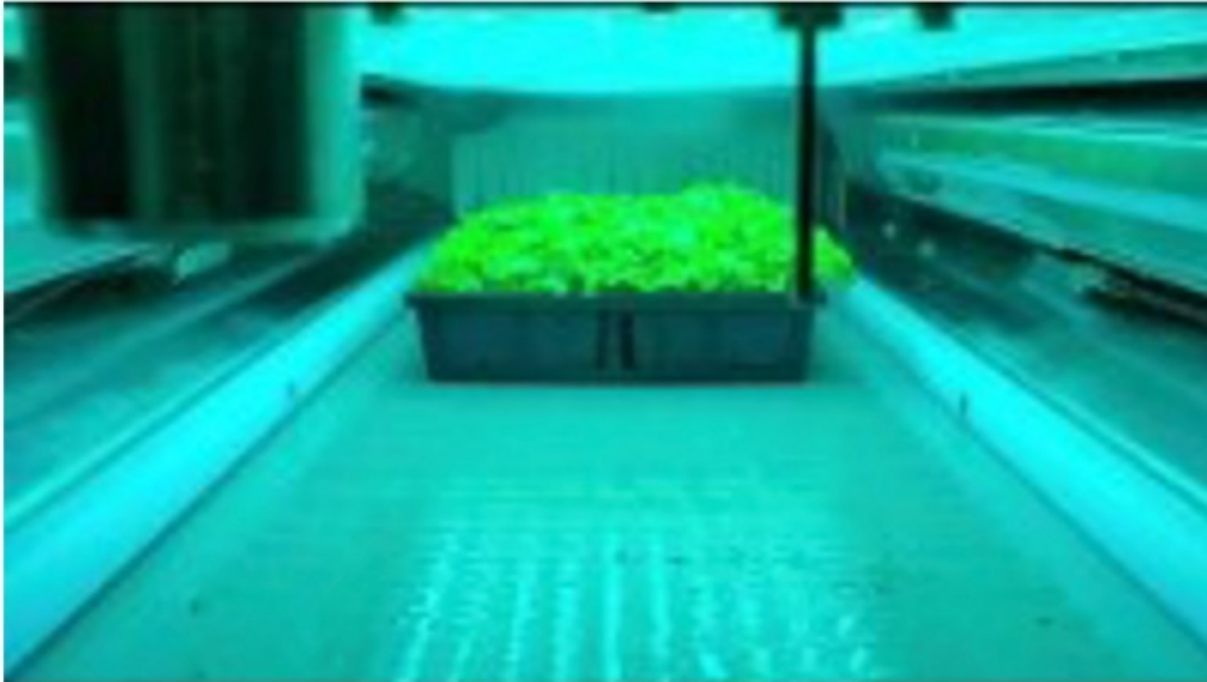
ND: Not Detected

## Growth Substrate & Trays

- 2% Hydrogen peroxide
  - 114 mJ/cm<sup>2</sup> UV-C
  - 2 ppm Ozone
- 
- >5 log CFU *Salmonella* Reduction

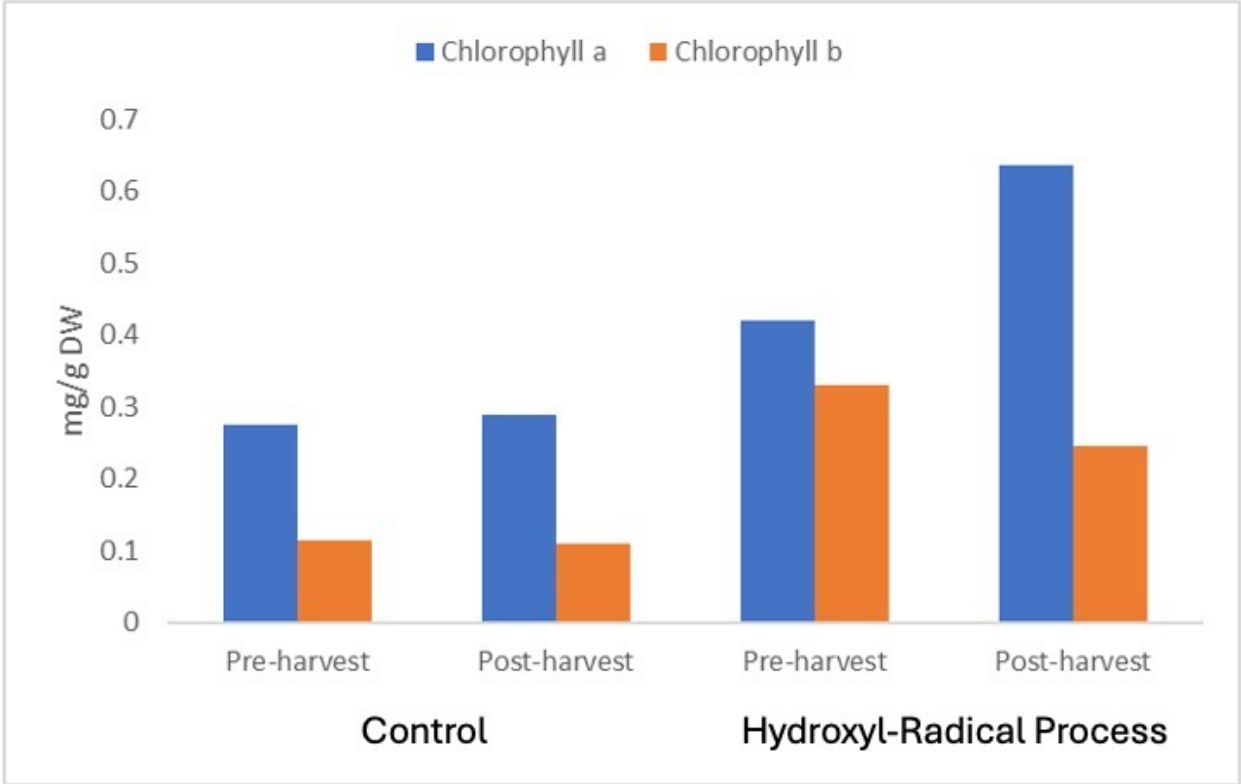


# Microgreens



- Pre-harvest treatment
- Reduction *Listeria monocytogenes*: 1.0 – 1.5 log CFU

# Chlorophyll Concentration





# Kale Microgreens: Clean Flow Shelf-life

Control

Clean Flow

Day 0



Day 15



# Salad Greens



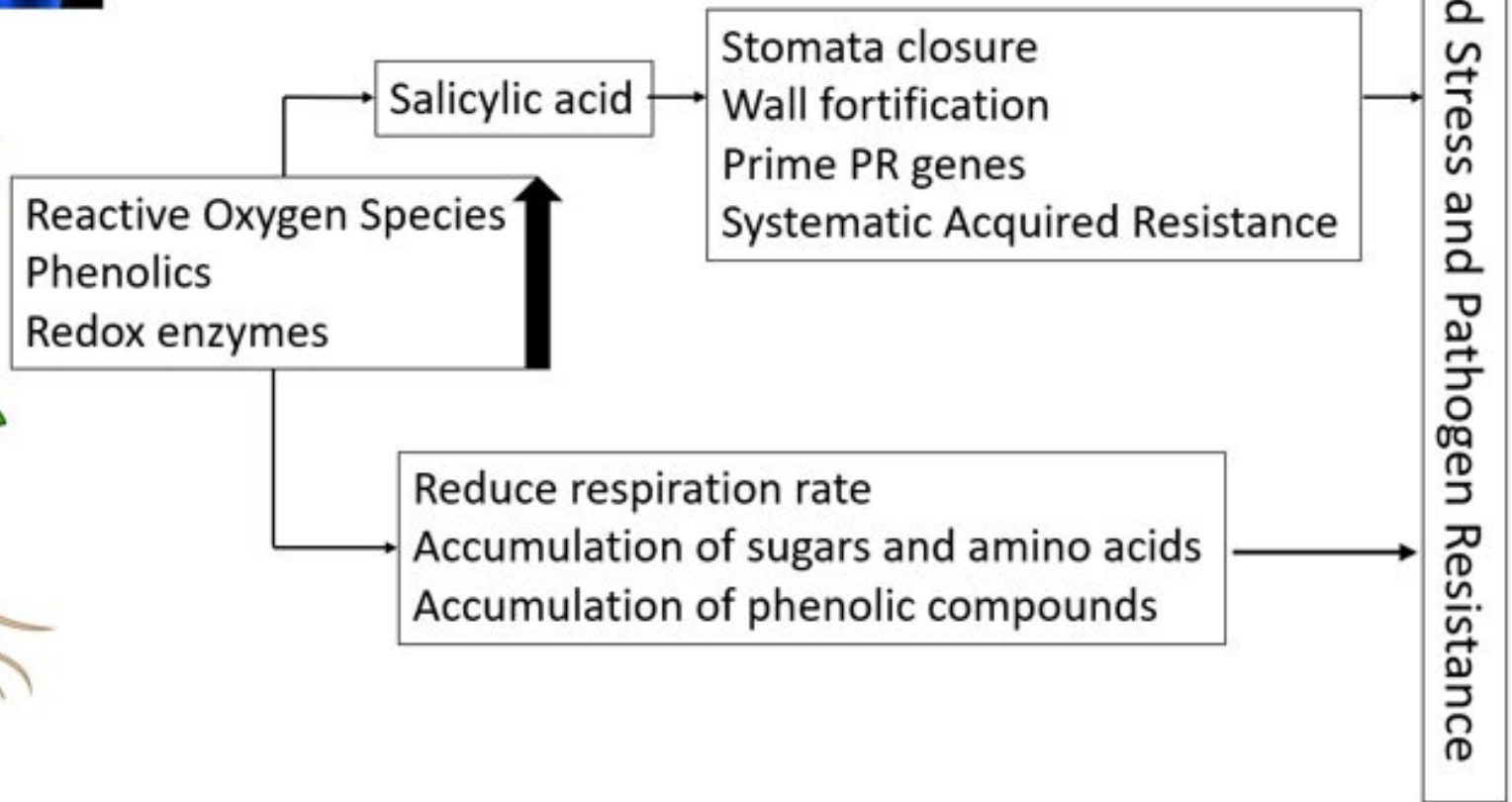


Fig 1



## Enhancing Food Safety of Leafy Greens

- UV-C, hydrogen peroxide and ozone
- Mature and baby spinach
- Reduction in surrogate
- Shelf-life extension





# Clean Flow Treatment of Vines



# Ontario innovator wins Food Waste Challenge

By Lilian Schaer

Published: 3 days ago  
News

Reading Time: 3 minutes



The Clean Works system installed on a grapevine harvester at Vineland Estates Winery. | Clean Works photo



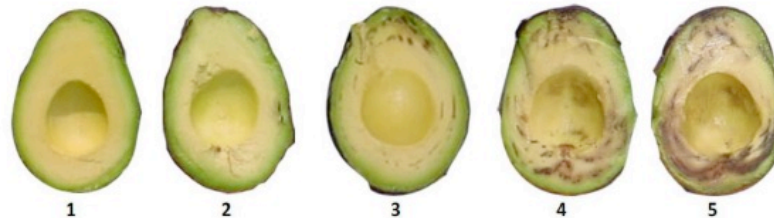
# Avocado



- Exterior Color



- Internal Defect Level





# Avocado: Non-treated Control



Day 0



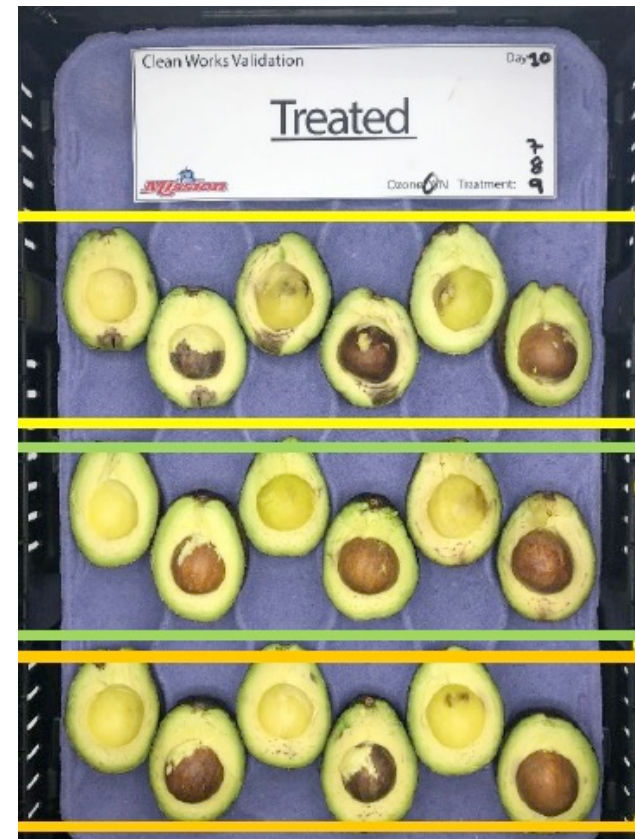
Day 10



# Hydroxyl Radical Treatment



Day 0



Day 10

Day 15

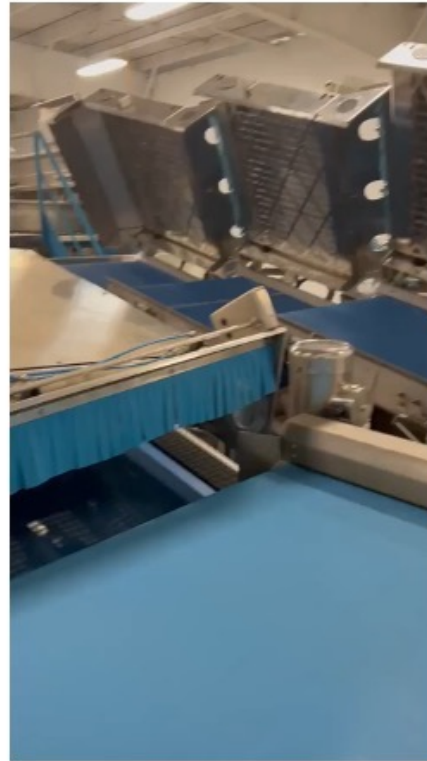
Hydroxyl-radical Treatment



Non-treated Control



# Commercial Units

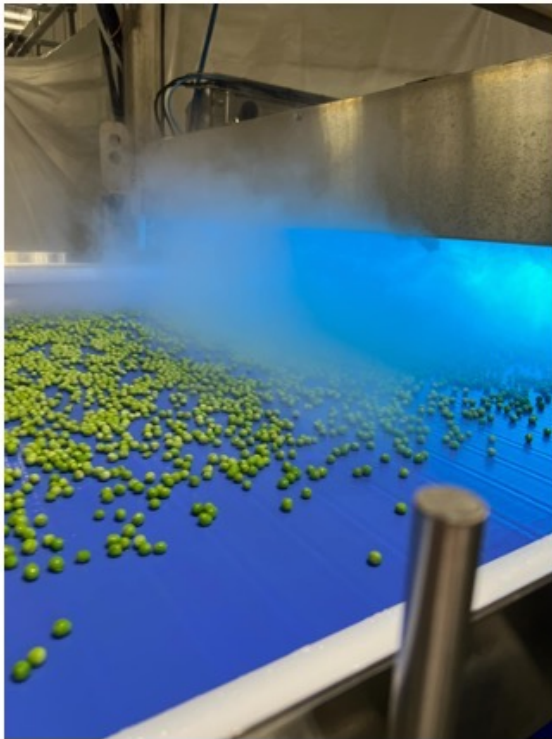








# Frozen Vegetables



# Final Thoughts

- Fresh produce remains the main cause of outbreaks
- Pathogens have become endemic in produce-growing areas
  - Climate change
  - Population growth
  - Extended distribution chains
- Indoor farming protected from the environment but not safer
- Intervention methods are key to enhancing food safety and extending shelf-life.

# Researchers

- Dr Mahdiyeh Hasani
- Kayla Hu
- Brenda Zai
- Eva Thapa
- Lara Warriner
- Ben La Devehat



## Financial Support

Food Safety Division United Nations Food & Agriculture Organization

OMAFRA Alliance:UoG Program

NSERC Alliance

## 2025 Teleclass Education Topics

*(most of them at least)*

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- 13 ... Food Safety of Fresh Produce: An Old Food Safety Problem Not With New Solutions  
With Prof. Keith Warriner, Canada
- 20 ... To aeruginosa or Not to aeruginosa: How Significant are Pseudomonads in Waterborne Healthcare Infections  
With Prof. Helen Rickard and Prof. Elaine Cloutman-Green, UK
- Afro-European Teleclass** 26 ... WHO Teleclass ... The Global Situation of Infection Prevention and Control and the Case for Action and Investment in Improving It  
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