THE ALMOND CONFERENCE 2025

WELCOME!

25 YEARS OF FOOD SAFETY: WE'VE COME A LONG WAY!

MODERATOR:
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CULTIVATING A HEALTHIER FUTURE

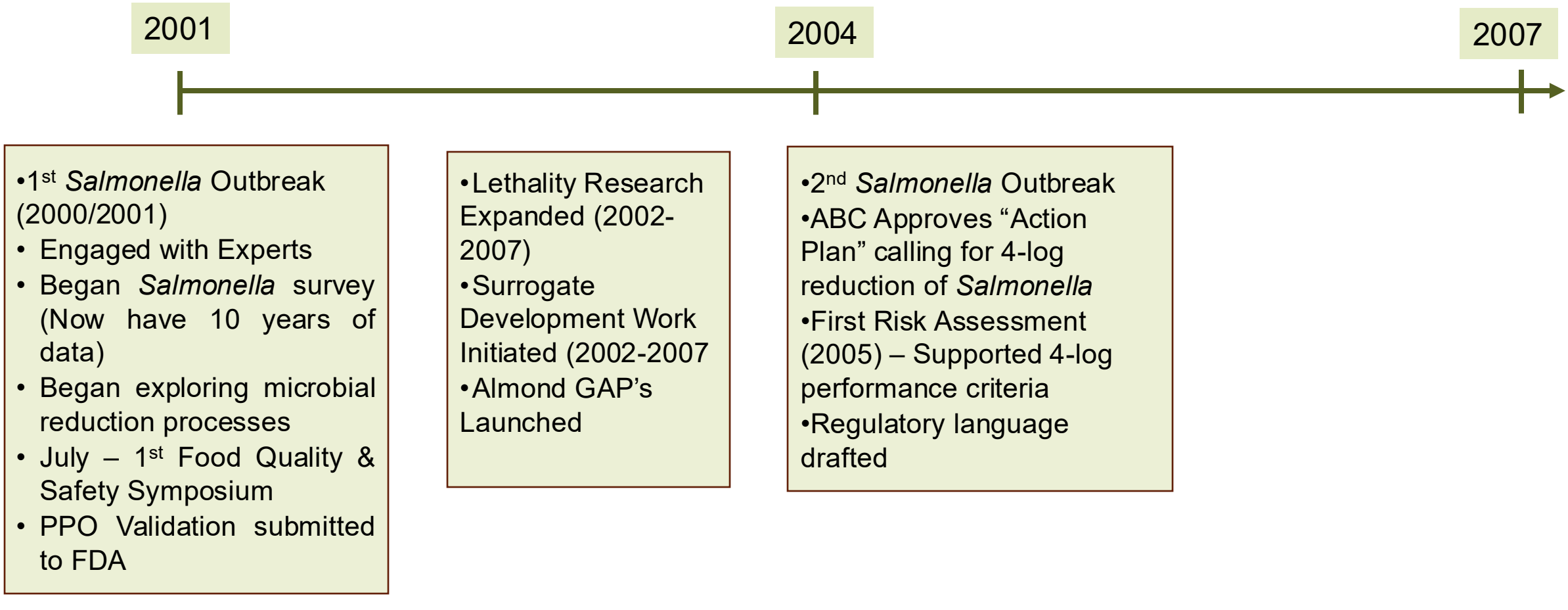
THE ALMOND CONFERENCE 2025

Todays Speakers

DR. HAN CHEN – PURDUE UNIVERSITY

DR. LINDA HARRIS – UC DAVIS

CULTIVATING A HEALTHIER FUTURE


2001
2004
2007
•1st *Salmonella* Outbreak (2000/2001)
• Engaged with Experts
• Began *Salmonella* survey (Now have 10 years of data)
• Began exploring microbial reduction processes
• July – 1st Food Quality & Safety Symposium
• PPO Validation submitted to FDA
•Lethality Research Expanded (2002-2007)
•Surrogate Development Work Initiated (2002-2007
•Almond GAP's Launched
•2nd *Salmonella* Outbreak
•ABC Approves "Action Plan" calling for 4-log reduction of *Salmonella*
•First Risk Assessment (2005) – Supported 4-log performance criteria
•Regulatory language drafted

“Unless we move quickly to process all raw almonds with approved pasteurization technologies, we run the very real risk of committing inexcusable injury to our product and our consumers, and will inevitably invite the forced regulation of our industry, precisely what the Action Plan strives to avoid.”

Martin Pohl – Sept. 22, 2005

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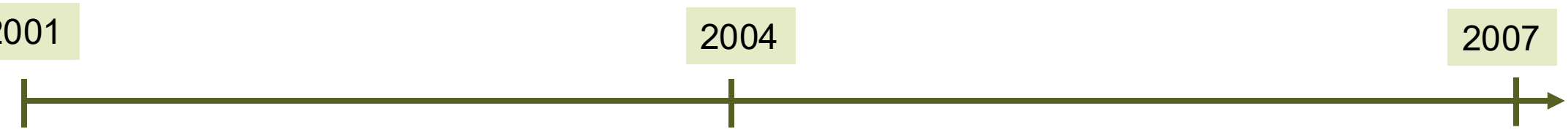

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- Regulatory language drafted

- Mandatory pasteurization rule submitted to USDA – referendum passed (2006)
- Continued lethality / surrogate research
- DV User Program Developed
- Stakeholder outreach / Program requirements developed
- **September 2007 – Effective date of Almond Mandatory Treatment Program for Salmonella Reduction**

Process Validations– 2007 to Present

Process	Active	Since Program Start (2007)
Blanching	20	49
Dry Roast	25	83
Oil Roast	62	139
PPO	13	25
Moist Heat	49	95
Other	1	9
Total	**170**	**400**

From Past to Present: The Evolution of Food Safety Management and Food Safety Culture in the California Almond Industry

Han Chen[1], Tim Birmingham[2], Guangwei Huang[2], Linda J. Harris[3], Yaohua Feng[1]*

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[2] The Almond Board of California, Modesto, CA 95354, USA

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The Almond Conference 2025

12/10/2025

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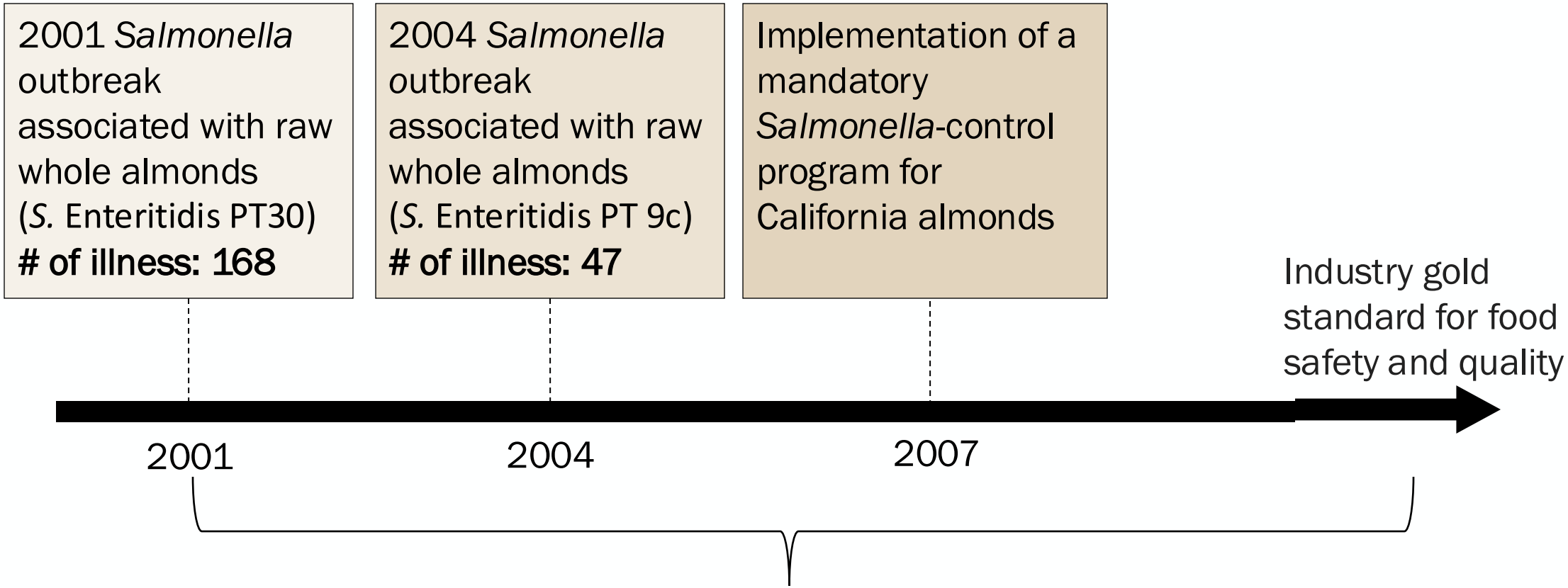
Background

Case study with California almond industry



Objectives

Showcase the evolution of food safety management and culture in the California almond industry and identify key factors contributing to these changes.

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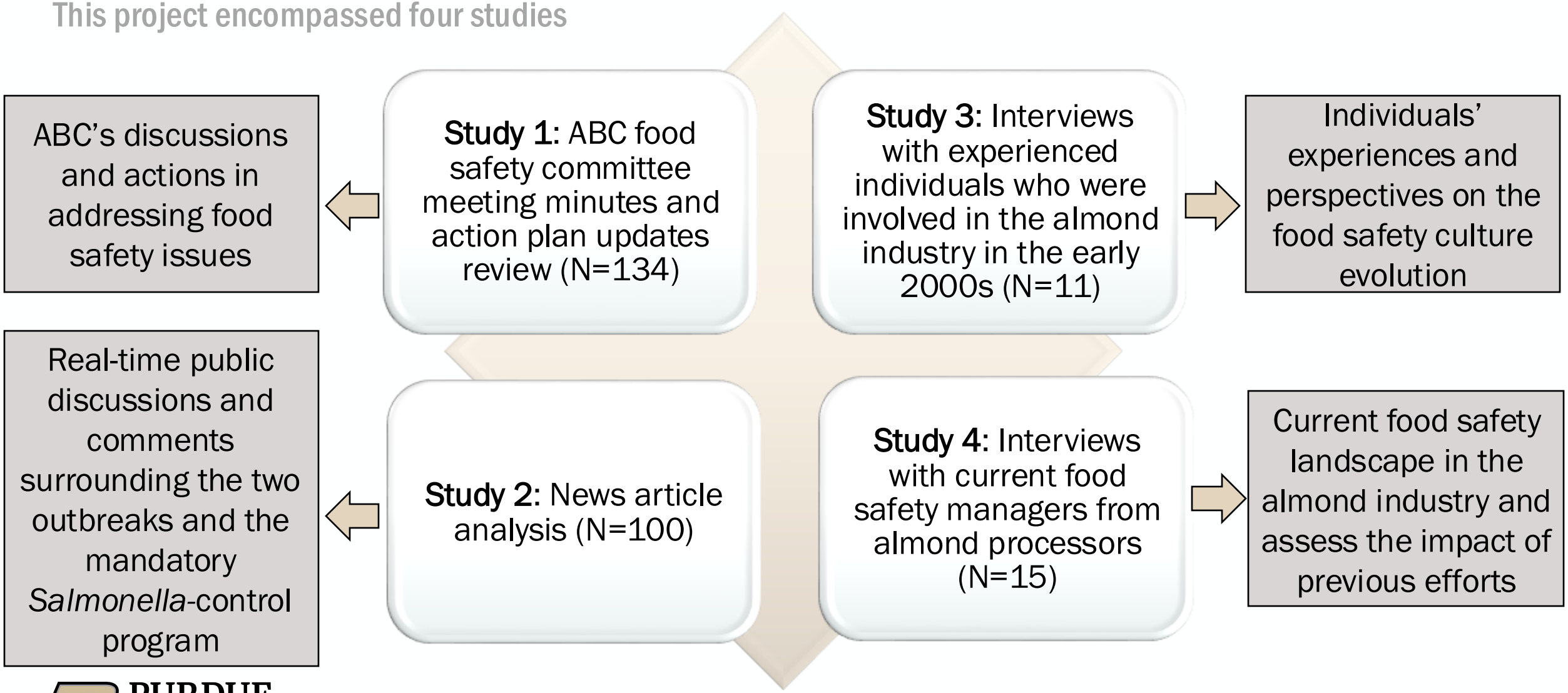
Multifaceted methods

This project encompassed four studies



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Prior to 2001: The uncharted land

The microbial food safety landscape for almonds remained largely unexplored.

- Basic level of food safety awareness, not specific to almonds
- Basic food safety practices implemented to meet federal regulations

> *"At that point in time, it was a **quality mentality**, not a food safety mentality. Generally, there wasn't the mindset that you could eat almonds and get sick."*
>
> (Study 3, Process Authority)

The first outbreak in 2001: The first sign of microbial risk

2001 *Salmonella* outbreak associated with raw whole almonds (*S.* Enteritidis PT30)
# of illness: 168

Outbreak traced back to one almond processor, one huller and sheller, and three growers [1]

2001 2004 2007

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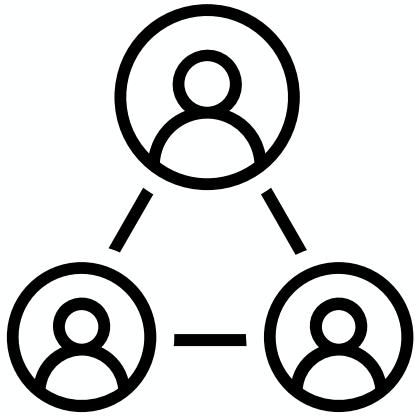
Varied reactions to the 2001 outbreak expressed

by most Study 3 participants

Scared



Shocked

Concerned

> *"It **scared** the bejesus out of me, you know, Salmonella, I need to get educated on that."*
>
> (Study 3, Industry Member)

- Risks and sources of *Salmonella*
- Industry reputational damage

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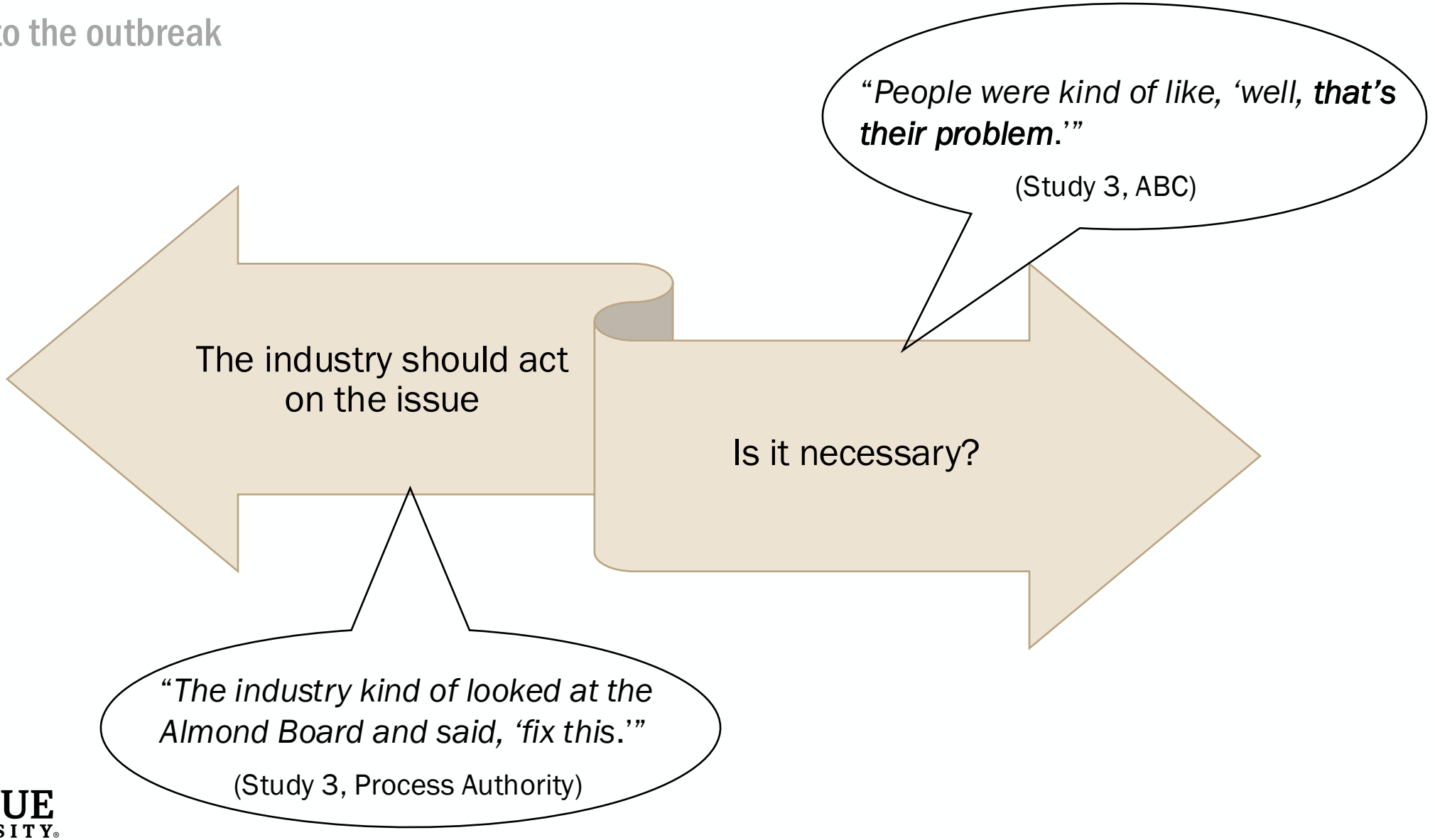
Different views within the industry

In response to the outbreak



Almond Board of California took the lead in responding

Looking for information to understand why the outbreak happened and how to minimize the risks

Initiated and funded various research projects	Developed various food safety resources and materials (e.g., GAPs and GMPs)
Engaged with regulatory agencies	Ongoing meetings with industry members

*"It was a little bit of **a scary time** because you're still collecting data, and you don't necessarily have the information that you need to make all the decisions you finally need to make."*

(Study 3, Consulting and laboratory service company)

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The second outbreak in 2004: The confirmed threat

2004 *Salmonella* outbreak associated with raw whole almonds (*S.* Enteritidis PT 9c)
# of illness: 47

The New York Times https://www.nytimes.com/2004/05/29/us/raw-almonds-are-recalled-after-reports-of-salmonella.html

Raw Almonds Are Recalled After Reports Of Salmonella

By The Associated Press
May 29, 2004

Outbreak of *Salmonella* Serotype Enteritidis Infections Associated with Raw Almonds --- United States and Canada, 2003--2004

On June 4, this report was posted as an MMWR Dispatch *on the* MMWR *website* (http://www.cdc.gov/mmwr).

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The outbreak gave a sense of urgency to take actions

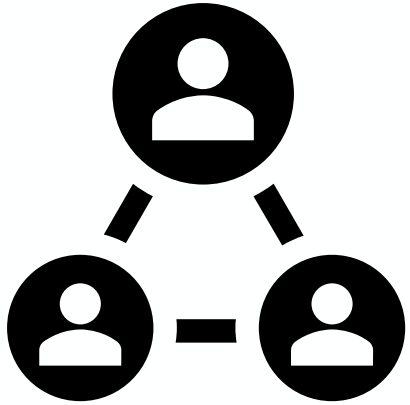
Perceived the urgency to act

*"If there are two outbreaks with the same commodity, they are likely to be **another** until we can put something in place."*

(Study 3, Regulator)

*"There were a lot of the **smaller handlers and growers** that aren't in tune with all this. They really didn't understand that this was for real."*

(Study 3, Process Authority)



*"When the second one happened, we were much **more prepared.**"*

(Study 3, ABC)

Still in doubt

Less surprised

ABC pushed for industry-specific food safety programs

*"It was a matter of **stepping up the work we were doing** with other companies, manufacturers, as well as researchers, and government authorities to really start determining what steps and procedures we could put in place to avoid a third outbreak."*

(Study 3, ABC)

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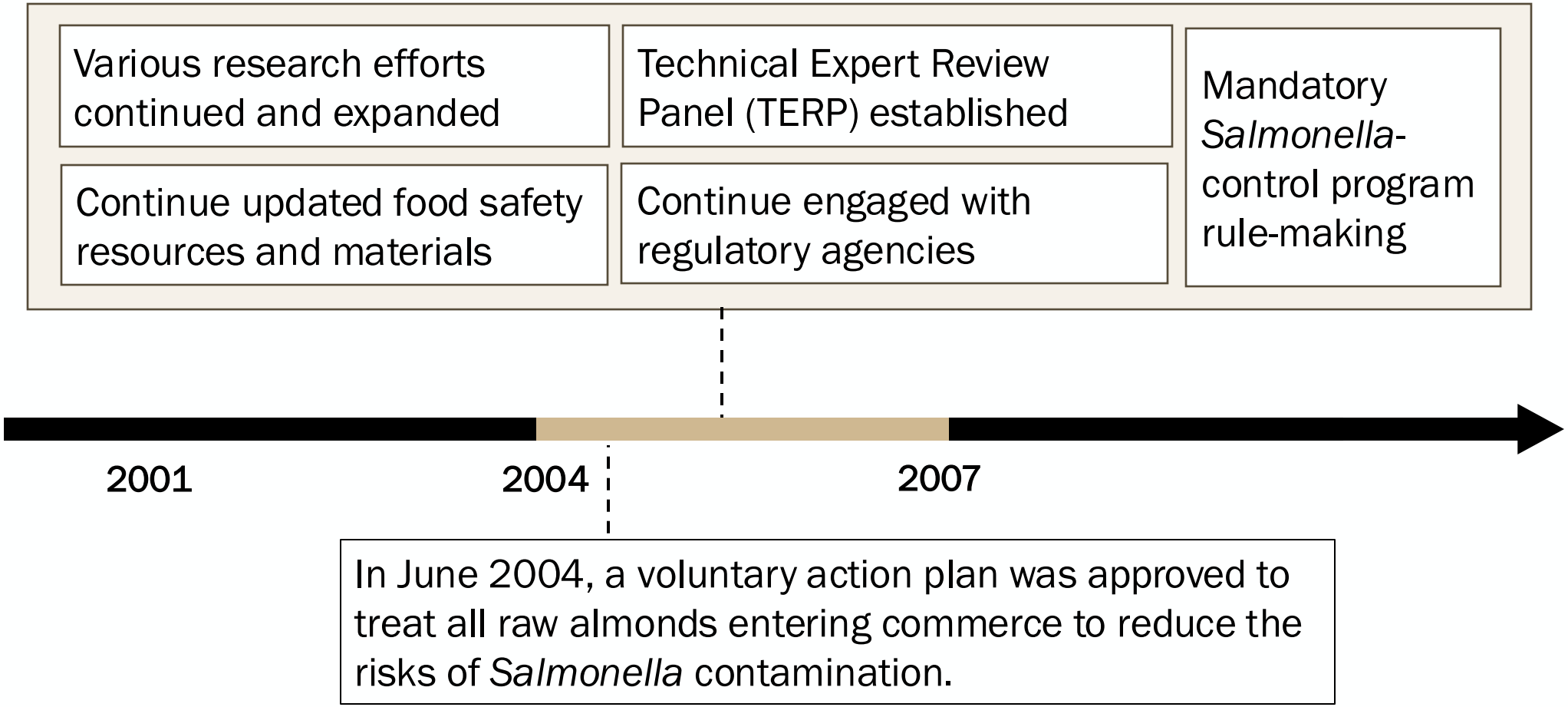
ABC increased efforts to improve food safety



Developing a mandatory Salmonella-control program

Extensive discussions and debates throughout the rule-making process

Capacity and availability of proper treatment technologies

Getting industry members on board and prepared

"I think the challenge with any industry group is getting widespread buy-in and commitment to do something different…. It just requires a little ***more effort, extra time, extra information, and extra data.****"*

(Study 3, Regulator)

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Efforts brought more industry members on board

Ongoing research

Extensive industry outreach and engagement

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Efforts brought more industry members on board

- Ongoing research
- Extensive industry outreach and engagement

The two most influential activities highlighted

Public meeting involving regulator and epidemiologist

*"He scared me. But I think he woke us all up. We needed to have that awakening…he said, '**if you don't fix this problem, we'll fix it for you, and you likely won't like it.**'"*

(Study 3, Industry Member)

Video of affected processors of the first outbreak

*"There was a video taken of the processor talking about the whole experience of the outbreak, and the lessons that were learned along the way. I think that's what convinced a number of the people in the industry that **this is a problem we all have to face now.**"*

(Study 3, ABC)

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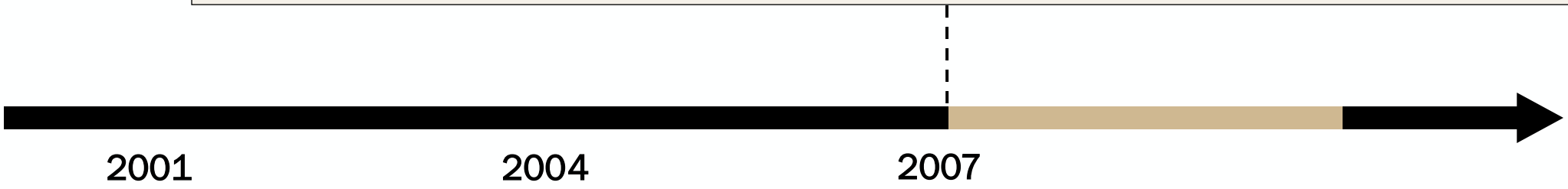
A mandatory Salmonella-control program went into effect on September 1st, 2007

Implementation of a mandatory *Salmonella*-control program for California almonds:

"All almonds sold in the U.S., Canada, or Mexico are required to be treated to achieve a minimum 4-log reduction in Salmonella before shipment, unless they are sold to a board-approved manufacturer who has validated treatment to achieve the desired log reduction."



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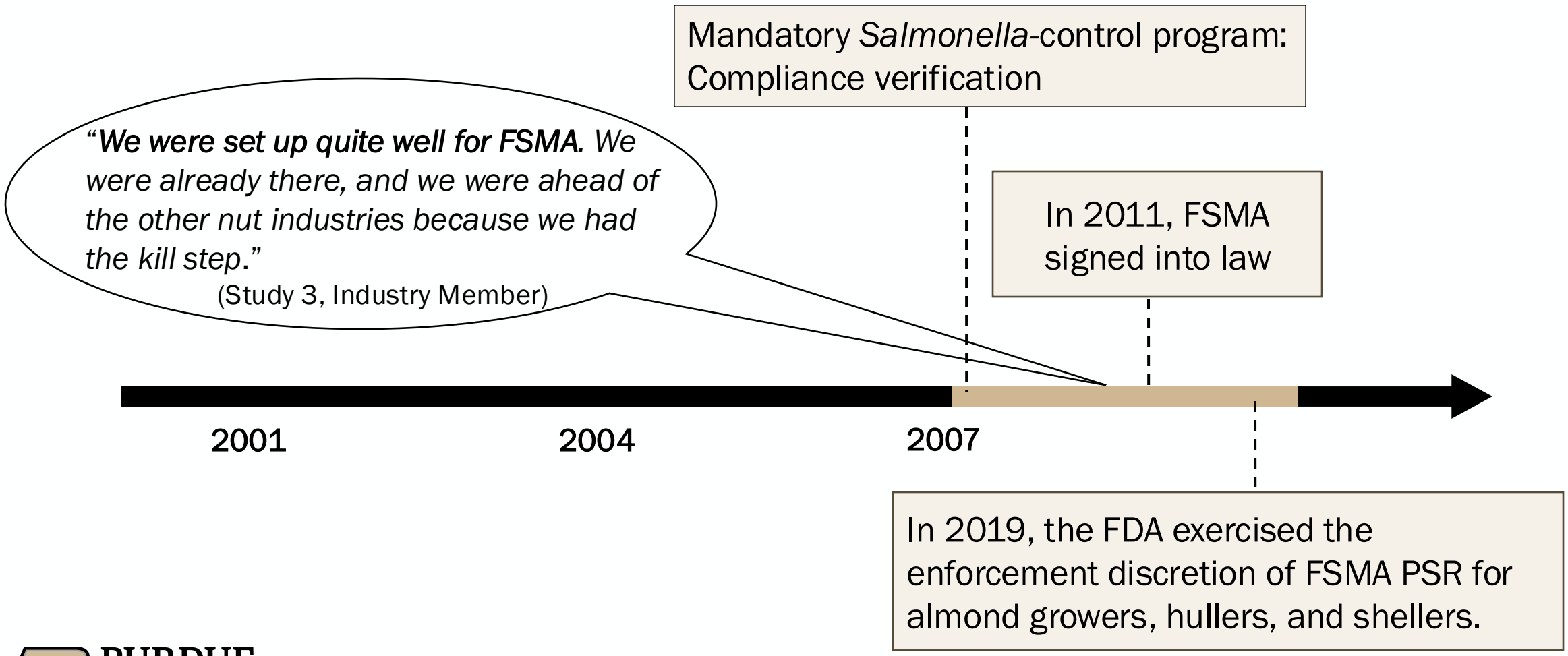
Post-2007: Program compliance

The almond industry was prepared for the new regulations



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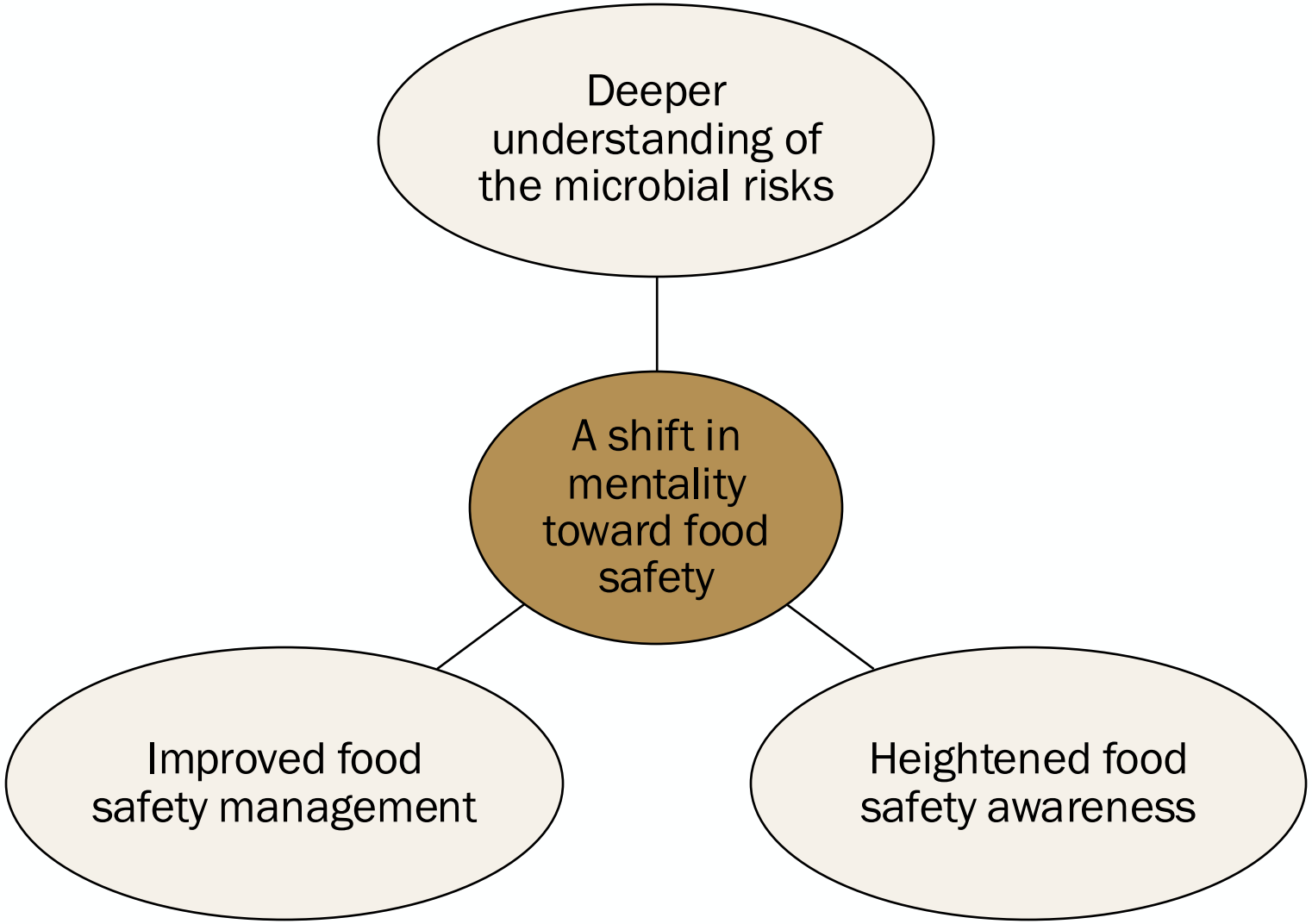
Industry mentality change towards food safety

From “quality mentality” to “safety mentality”



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Two most significant contributing factors driving improvements in food safety management systems

The two outbreaks

"*Certainly **repeated outbreaks, large numbers of illnesses, increased scrutiny by government regulators**, the industries shifted in how they viewed food safety as a priority.*"

(Study 3, Regulator)

ABC's leadership in taking proactive actions

"***All the work that the Almond Board has done has been outstanding.** I've seen the industry change the attitude on food safety.*"

(Study 3, Process Authority)

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Remembering the journey

It wasn't easy, and that's why it needs to continue

"A lot of the people who were involved in this initial process are getting towards retirement age. So, hopefully, that **awareness of what happens if you don't keep the food safety practices in mind is there and is continued in future generations.**"

(Study 3, Consulting and laboratory service company)

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Significance

Future generations of almond growers and producers	• Preserve the remarkable history and keep the lessons from past outbreaks
Other industry sectors	• Provide example for industry-driven food safety improvements and self-regulation
Researchers and government agencies	• Demonstrate the dynamics and complexity of cultural transformation

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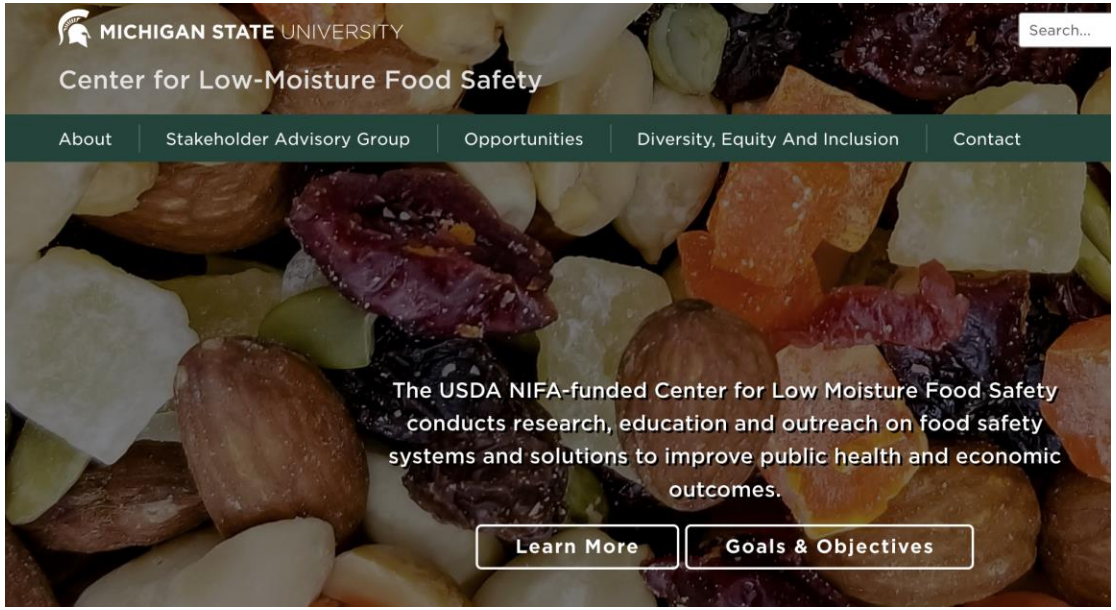
Acknowledgment

This work is supported by the Agriculture and Food Research Initiative, Sustainable Agricultural Systems Program grant no. 2020-68012-31822 from the USDA National Institute of Food and Agriculture



References

1. Isaacs, S., Aramini, J., Ciebin, B., Farrar, J. A., Ahmed, R., Middleton, D., Chandran, A. U., Harris, L. J., Howes, M., Chan, E., Pichette, A. S., Campbell, K., Gupta, A., Lior, L. Y., Pearce, M., Clark, C., Rodgers, F., Jamieson, F., Brophy, I., & Ellis, A. (2005). An international outbreak of salmonellosis associated with raw almonds contaminated with a rare phage type of Salmonella Enteritidis. *Journal of Food Protection*, *68*(1), 191–198. https://doi.org/10.4315/0362-028x-68.1.191
2. Centers for Disease Control and Prevention. 2004. “Outbreak of *Salmonella* serotype Enteritidis infections associated with raw almonds -– United States and Canada, 2003--2004.” Retrieved September 24, 2024, from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5322a8.htm

Thank you!

Connect with us:

25 Years of Food Safety: How a foodborne outbreak serendipitously shaped a career

Linda J. Harris, Ph.D.,
Professor of Cooperative Extension Emeritus

December 10, 2025, Sacramento, CA

University of California
Agriculture and Natural Resources

UCDAVIS
FOOD SCIENCE AND TECHNOLOGY

WESTERN CENTER for FOOD SAFETY
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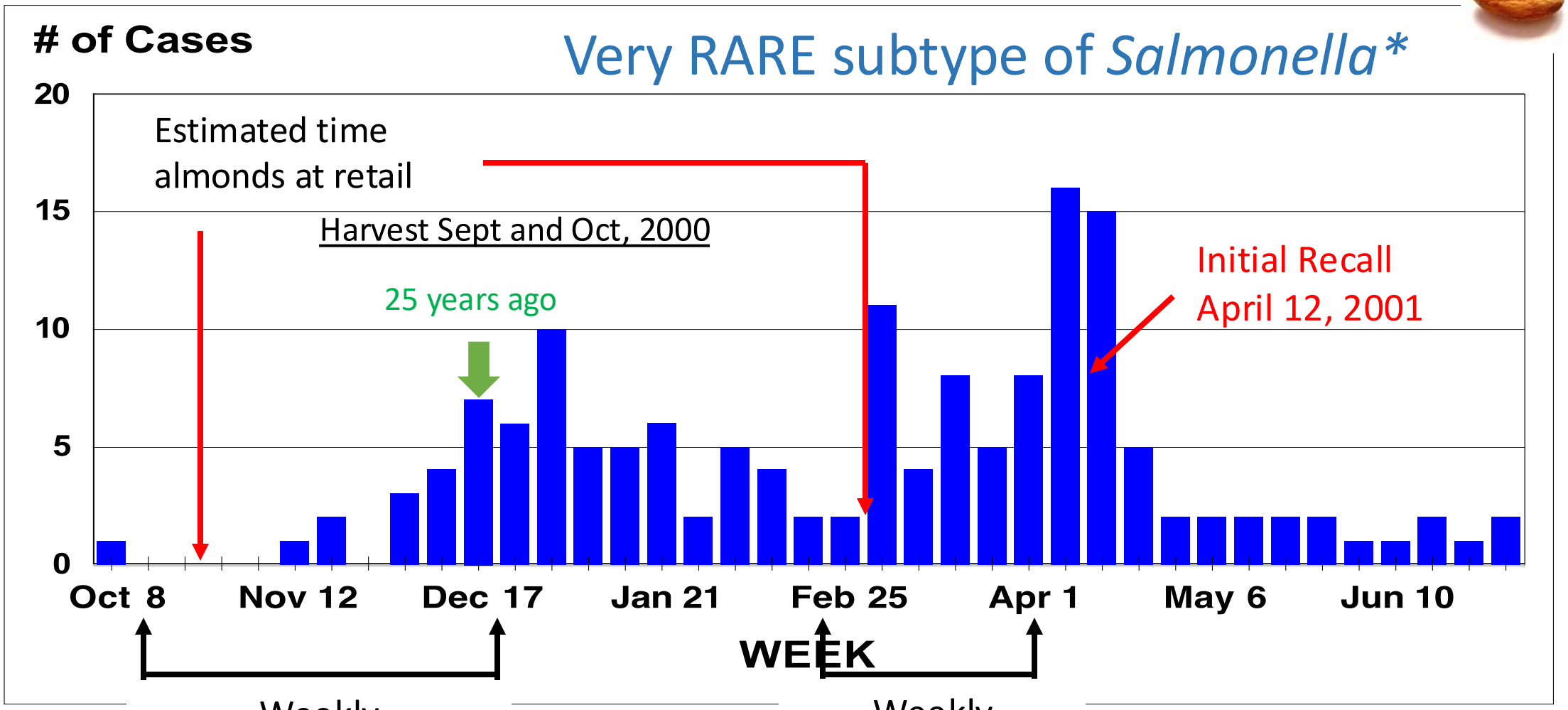
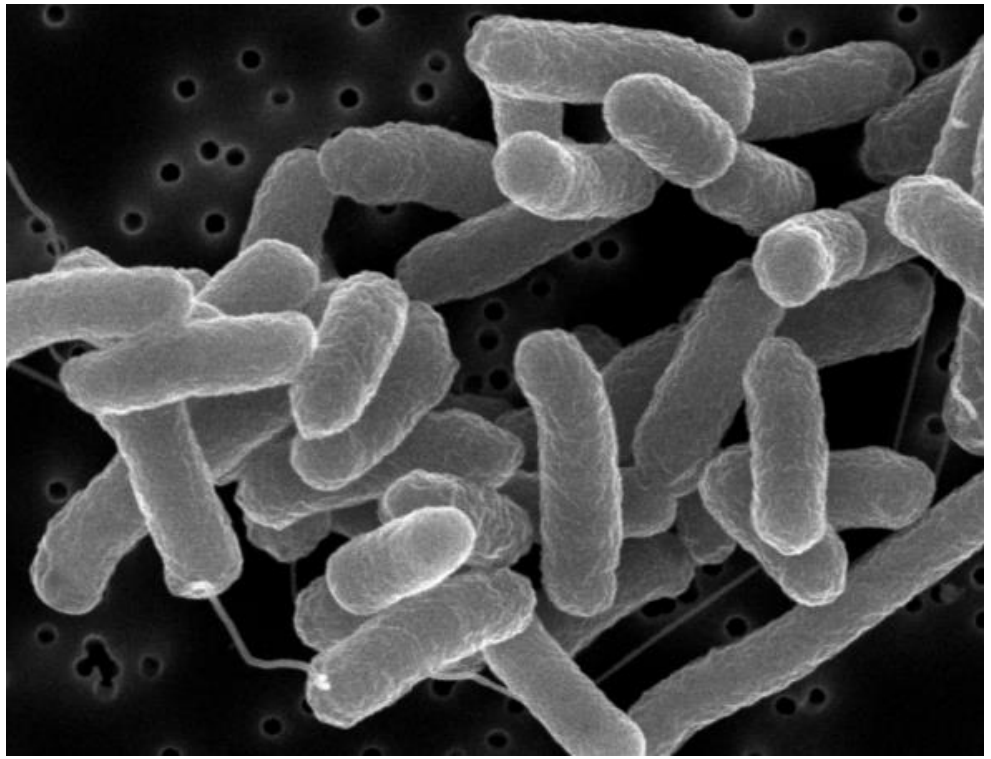
2001 almond outbreak: Onset Dates of *Salmonella* Enteritidis Phage Type (PT) 30 Cases in Canada/Raw* Almond Shipments from California



Isaacs et al. 2005. JFP 68:191-198

Pre-2001 nut-adjacent *Salmonella* outbreaks

- 1953, 1960-61, 1999
  - desiccated coconut (Australia/England)
- 1994-1995
  - peanuts in a savory snack (UK)
- 1996
  - peanut butter Australia
- 2001
  - peanuts UK, Australia, Canada



Before:
Pulsenet fingerprinting
Whole Genome Sequencing

Salmonella Enteritidis Phage Type 30

UC Davis Lab

UCD Lab
San Bernardino

USDA Lab
Nebraska

2000-2001 Almond Outbreak Investigation

Growers

Farm A + | Farm B + | Farm C + | Farm D

Positive Drag Swabs (6/01 – 7/01)

Salmonella Enteritidis PT 30

Huller/ Sheller(s)

Facility A + | Facility B | Facility C | Facility D

4 of 8 Environmental Samples (6/01)

Salmonella Enteritidis PT 30

Handler/ Processor

Processor A +

2 of 8 Environmental Samples (6/01)

Retail/ Distributor

Bulk Raw* Almonds

7 of 11 Lots (5/01 – 8/01)

Salmonella Enteritidis PT 30

Consumer

168 Cases of salmonellosis

(10/00 – 7/01)

Isaacs et al. 2005. JFP 68:191-198

RAW Almond Outbreaks 04, 06

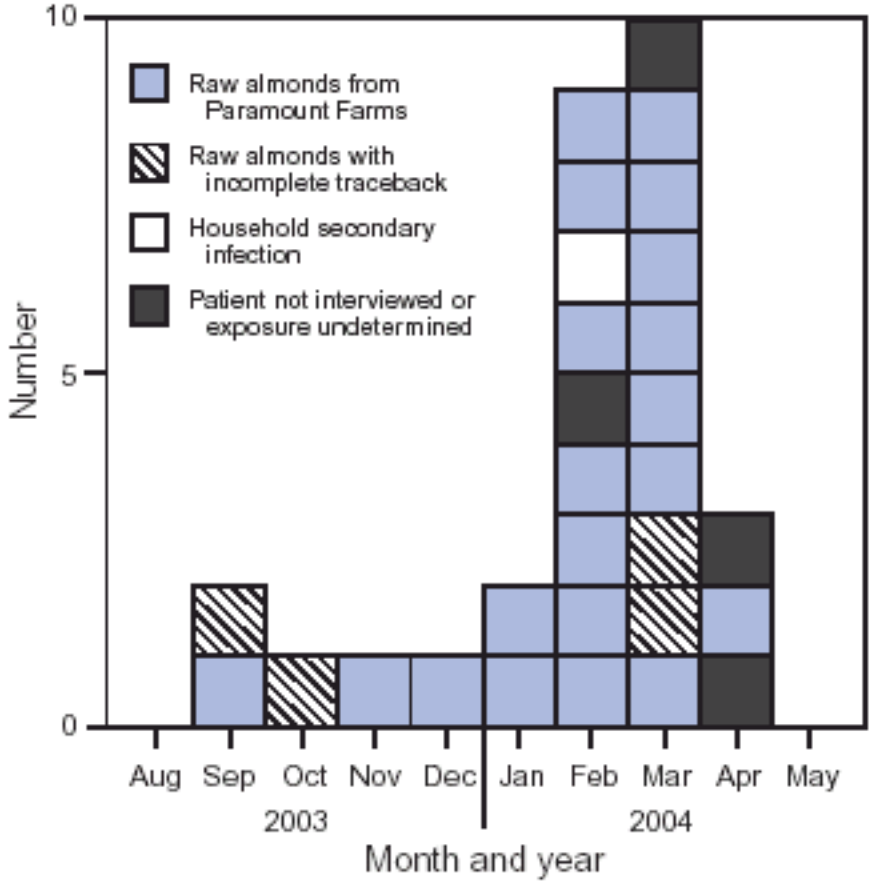
- 9/2003 – 6/2004
  - *Salmonella* Enteritidis PT 9c
    - Very rare phage type
    - 47 cases in U.S. and Canada
  - Handler (processor) unrelated to 2001 outbreak

- 12/2005 – 8/2006

(raw almond-link suspected)

  - *Salmonella* Enteritidis PT 30
    - 15 cases Sweden

FIGURE. Number* of PFGE† -matched cases of salmonellosis associated with raw almonds, by date of illness onset and mode of exposure — United States and Canada, September 2003–April 2004



*N = 29.
† Pulsed-field gel electrophoresis.

MMWR 53(22):484-487

2001 15/32 - 150 acre orchards positive *Salmonella* Enteritidis PT 30 (10 sq miles/26 sq km)

Origin of *Salmonella* Enteritidis PT 30 never identified

Farm 1

Farm 2

Farm 3

Orchard sampled from 2001 through 2006:
53 of 228 (25%) pooled swabs positive for *Salmonella* Enteritidis PT 30

Uesugi et al., 2007

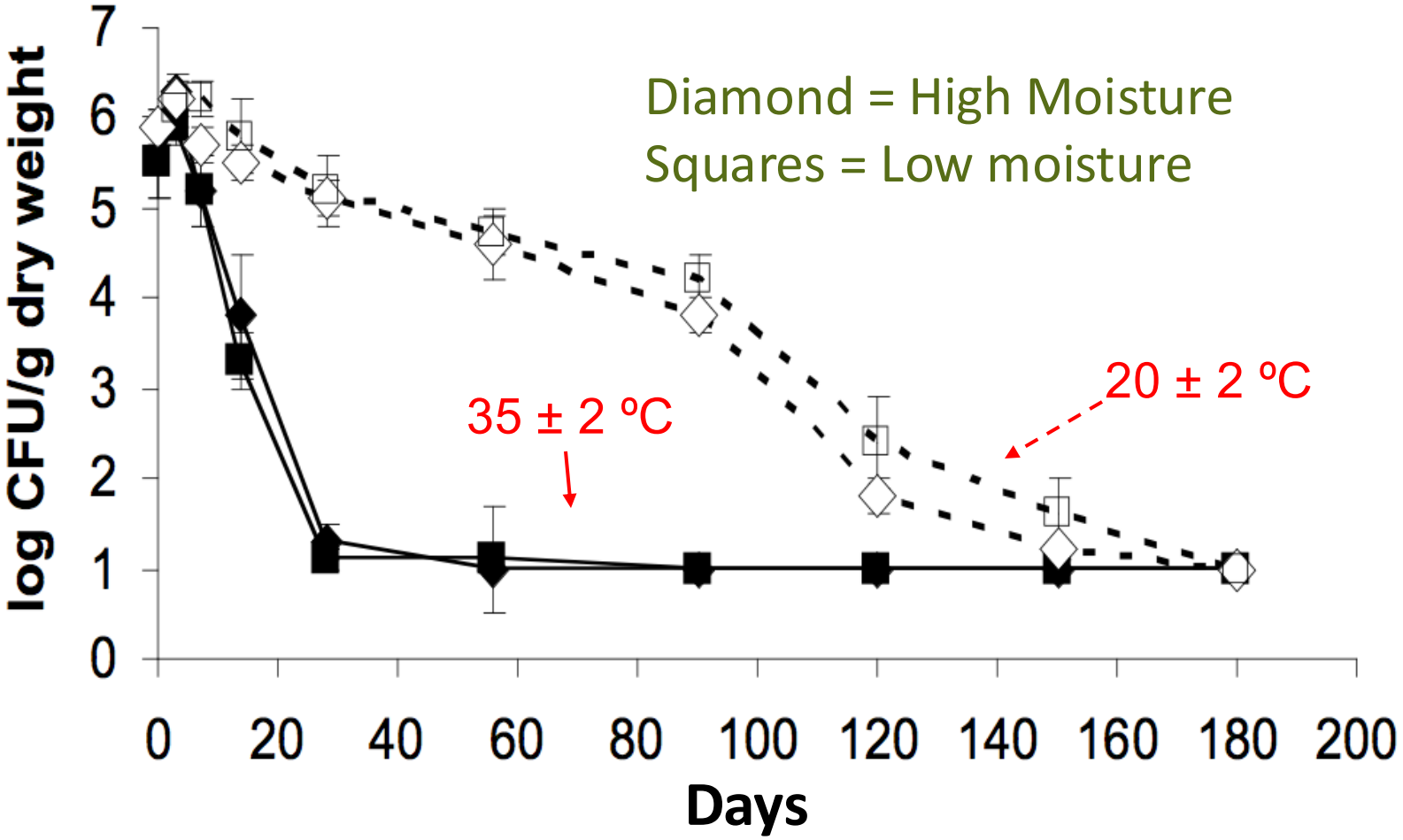
Possible Factor Contributing to Outbreak:

Questionnaire revealed:
almonds on ground OR
swept into windrows

Significant rain
10/9 - 10/10, 2000

Clay-like soil, difficult to harvest,
high level of soil carry-over

Does *Salmonella* Enteritidis PT 30 survive in soil?



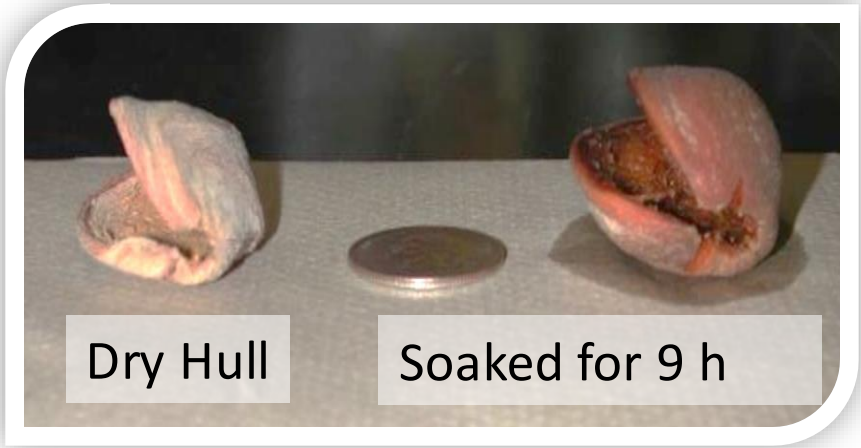
Clay loam OR Sandy loam

Temperature influenced survival of *Salmonella* in soil more than moisture or soil type

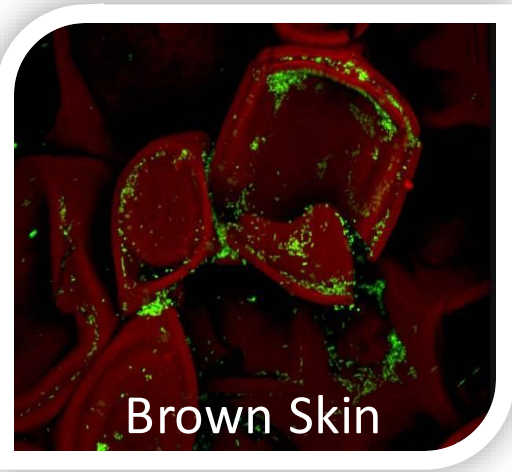
Danyluk et al., 2008

What happens when dry hulls or shells get wet?

hull shell kernel



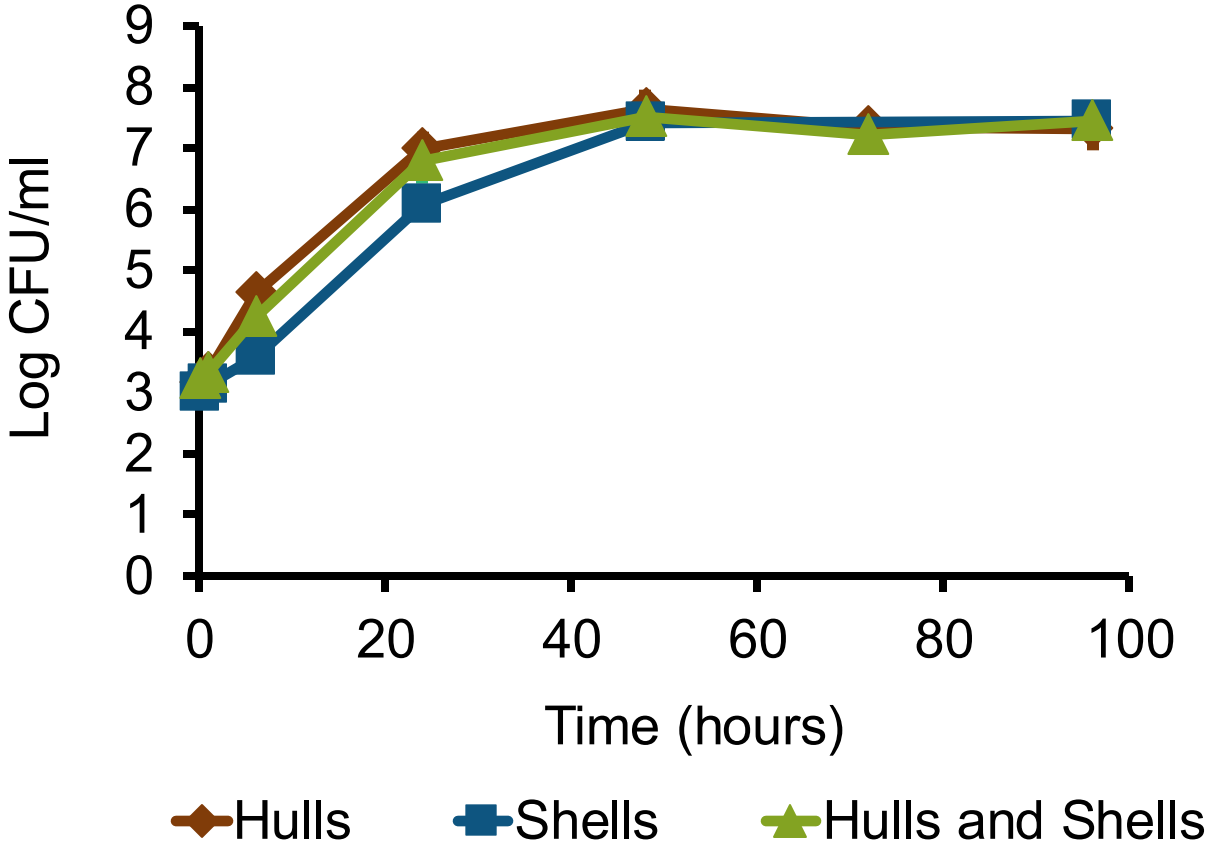
Water uptake to 300% of initial weight



Salmonella migration through almond hull and shell

Uesugi and Harris, 2006; Danyluk, Brandl, and Harris, 2008

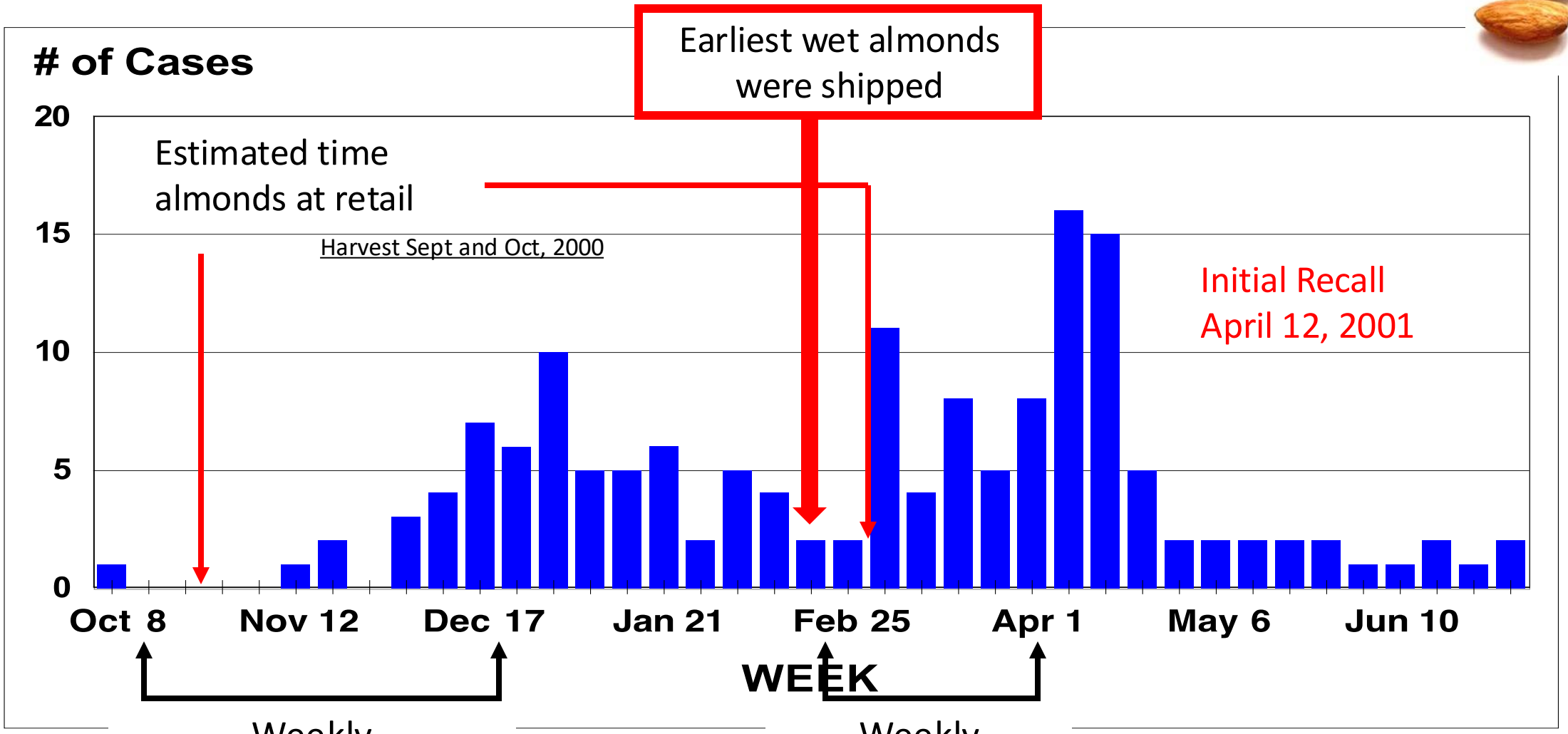
Can *Salmonella* Enteritidis PT 30 multiply in wet almond hulls and shells at 25°C (75°F)?



Wet weather potentially amplified *Salmonella* in the orchard

Uesugi and Harris, 2006

2001 almond outbreak: Onset Dates of *Salmonella* Enteritidis PT30 Cases Canada/Raw Almond Shipments from California



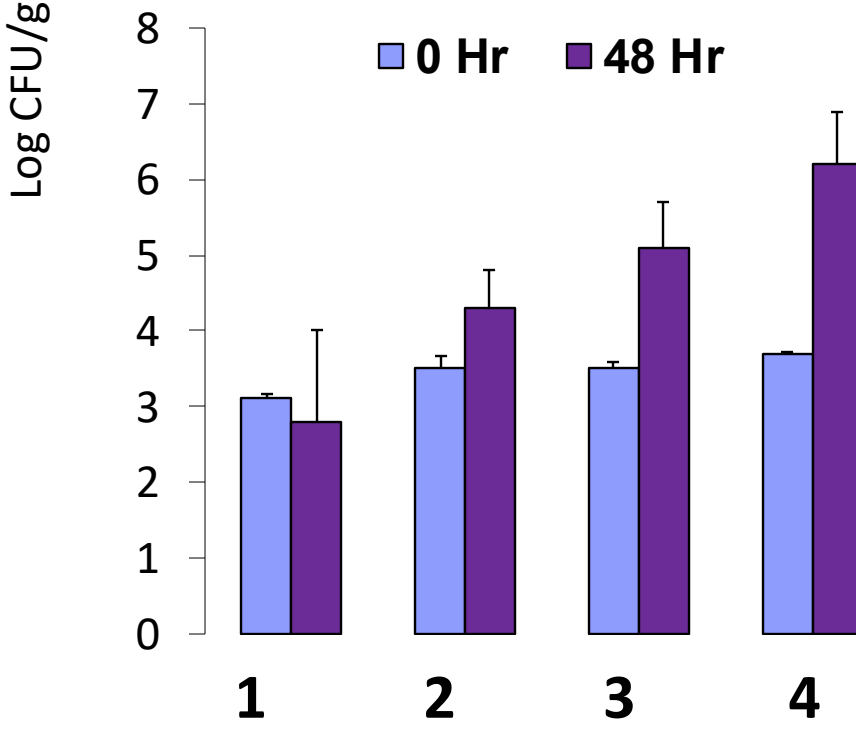
Isaacs et al. 2005. JFP 68:191-198

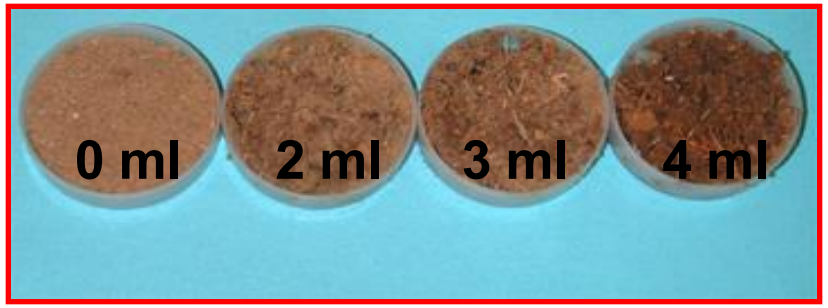
Huller and Sheller: Almonds

- Receiving Pit
- Pre-Cleaning
- Remove hulls/shells
- Sort kernels from debris
- Transport to handler
- Storage

Water matters after harvest

- *Salmonella* CAN multiply in the presence of even small amounts of water in “almond dust” at 30°C/86°F



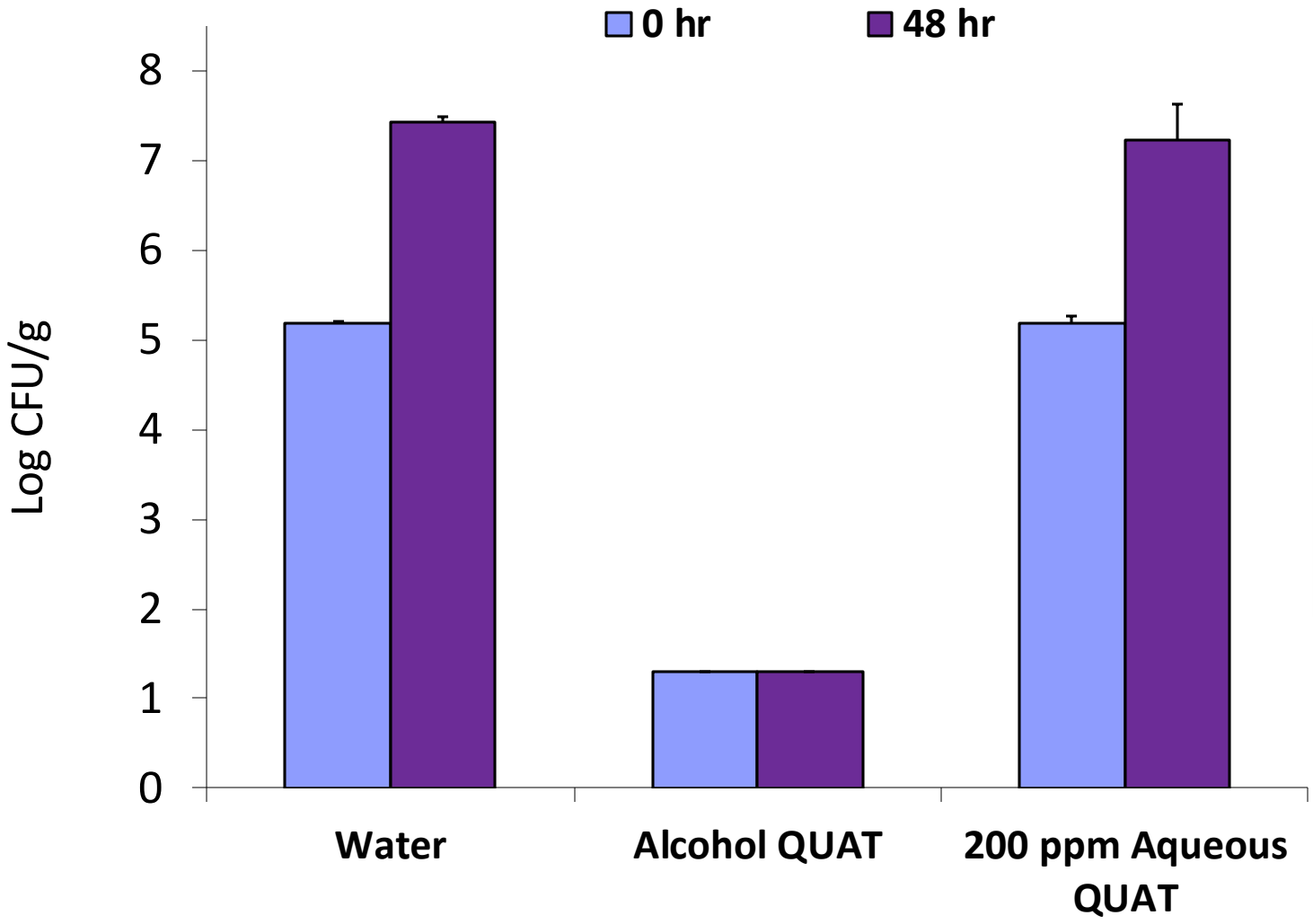


Dust A (1 g) Mixed With Water

Milliliters of water per gram of almond dust

Du et al., 2010. J. Food Sci.

Aqueous QUAT is not effective in reducing *Salmonella* and preventing growth in almond dust (86°F/30°C)

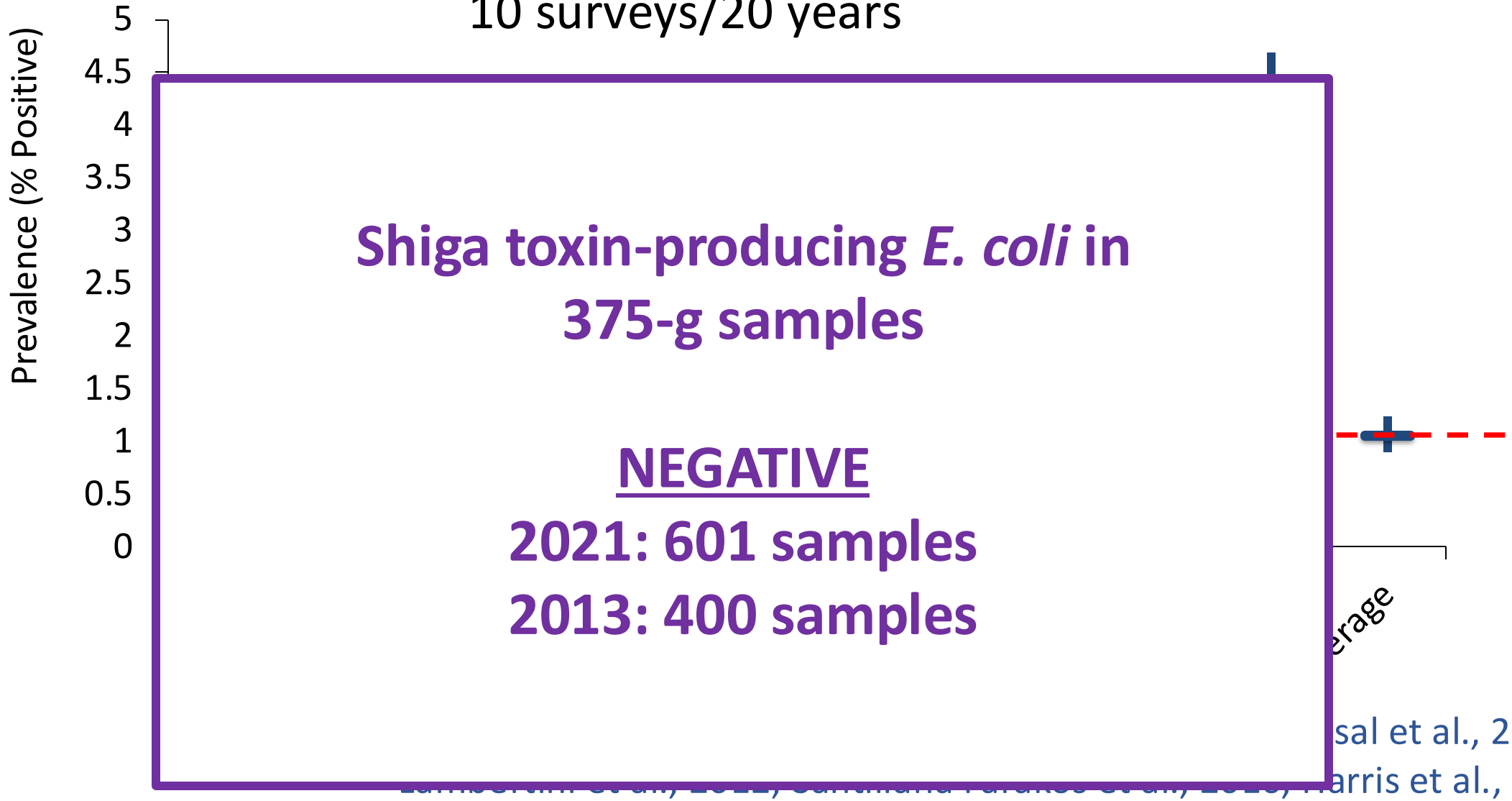


Du et al., 2007. Food Protection Trends

Prevalence of *Salmonella* in 100-g Raw Almond Kernels at Harvest

With 95% Confidence Intervals

10 surveys/20 years



Shiga toxin-producing *E. coli* in 375-g samples

NEGATIVE

2021: 601 samples

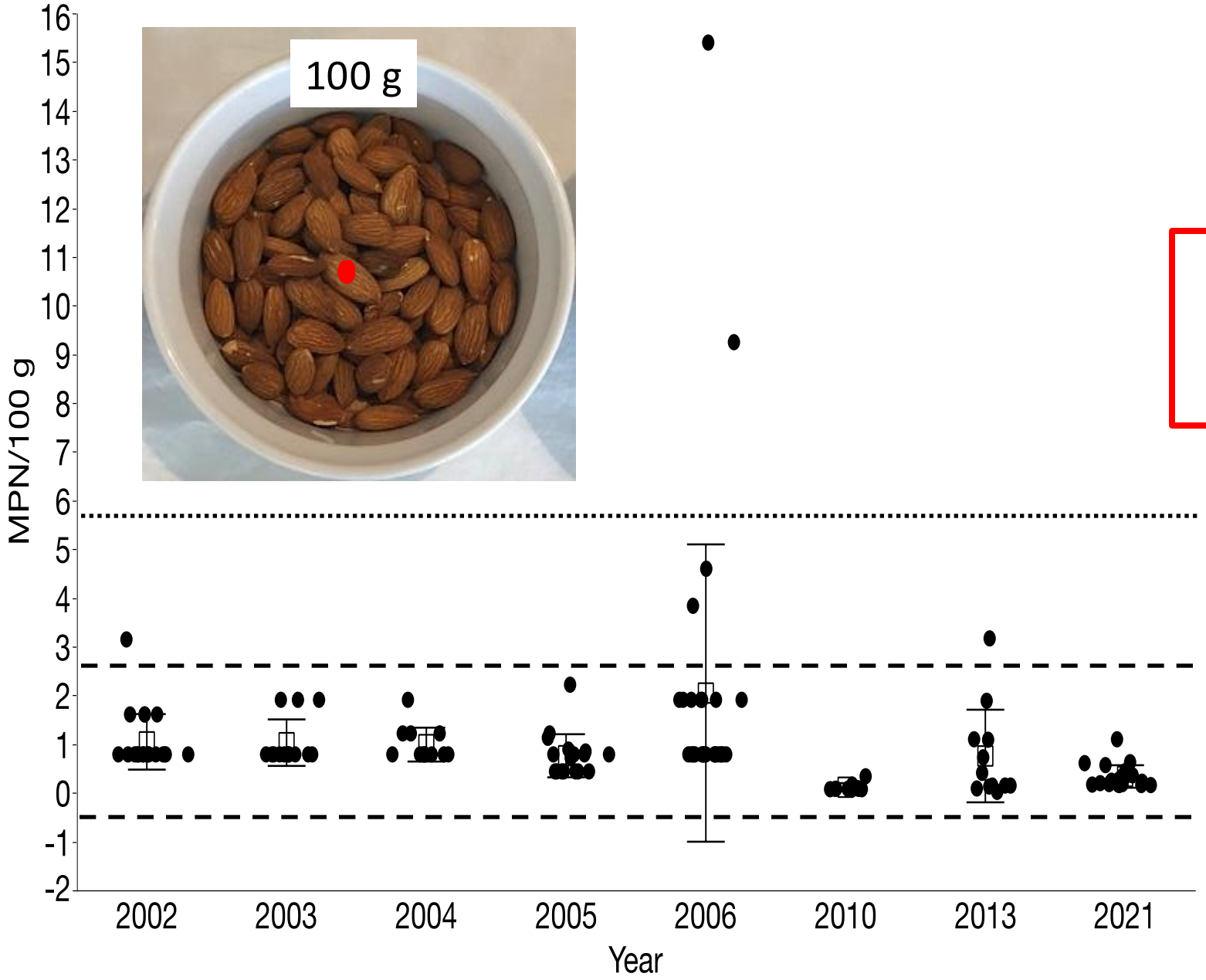
2013: 400 samples

sal et al., 2010;

arris et al., 2025

Levels of *Salmonella* in positive almonds

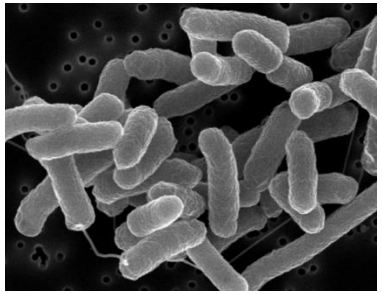
Salmonella
Most Probable Number (MPN)
Total 139 positive lots

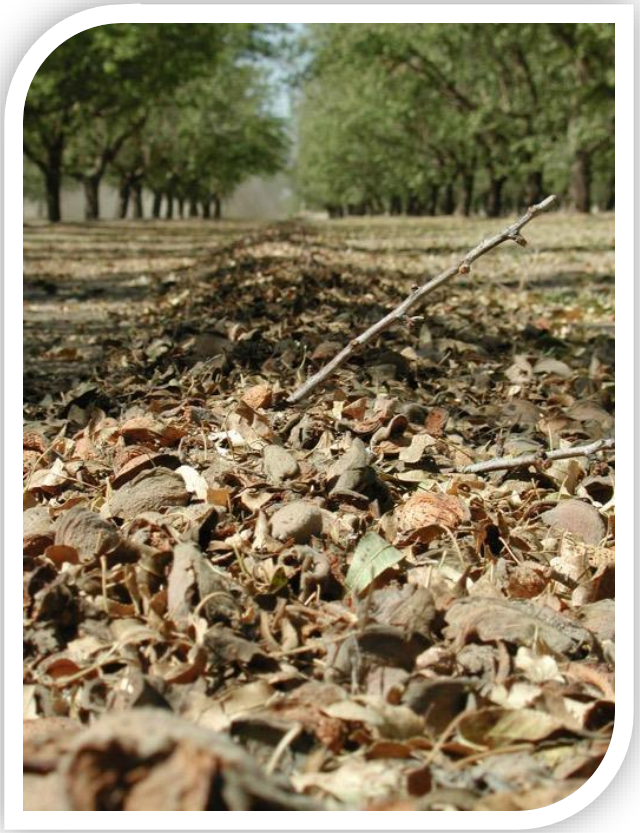


Average:
1.0 ± 1.6 MPN/100 g

Hypothesis: Contamination Source

- Evidence suggests under normal circumstances contamination on the farm and during harvest/hulling/shelling is:
  - Environmental
  - Sporadic
  - Random
  - Low levels





APPLIED MICROBIOLOGY, Aug. 1970, p. 208–214

Vol. 20, No. 2
Printed in U.S.A.

Almond Harvesting, Processing, and Microbial Flora

A. DOUGLAS KING, JR., MARY JO MILLER, AND LINDA C. ELDRIDGE

Western Regional Research Laboratory and Biometrical Services Staff, Agricultural Research Service, Albany, California 94710

Received for publication 23 March 1970

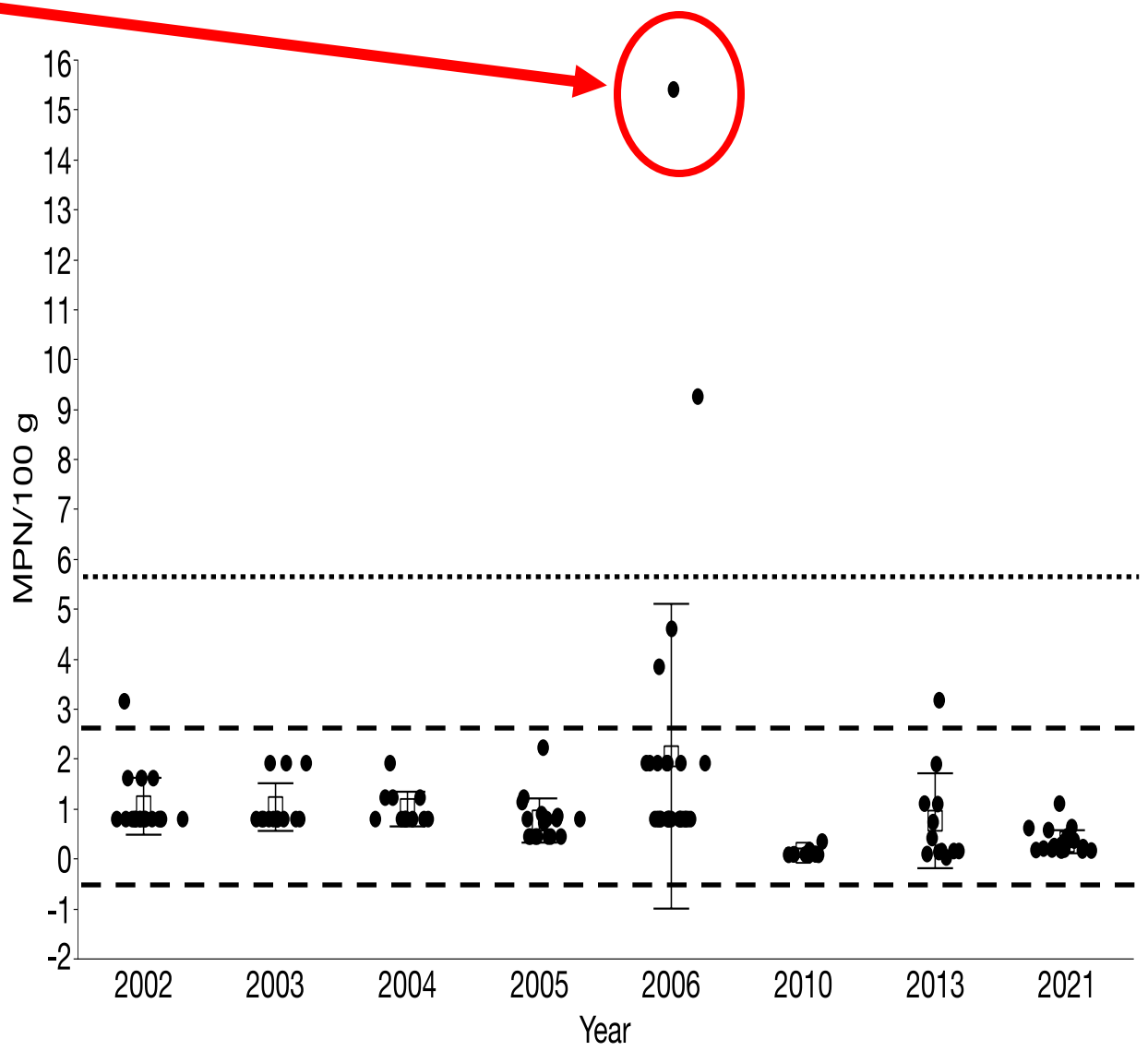
Research at the request of the almond industry to determine microbial quality of almonds. 1967 harvest

The data reported in this paper reflect the microbial population on the surface of almond meats. A portion of the bacterial contamination stems from soil and dust contact with nutmeats. This is shown by the lower counts for hard-shelled varieties which have a more complete shell and less chance for soil contamination. The effect of soil contact is also reflected in the lower counts for nuts harvested on cloths as opposed to those collected from the ground.

Why/When?
How often?

- *Salmonella*, not drawn to scale

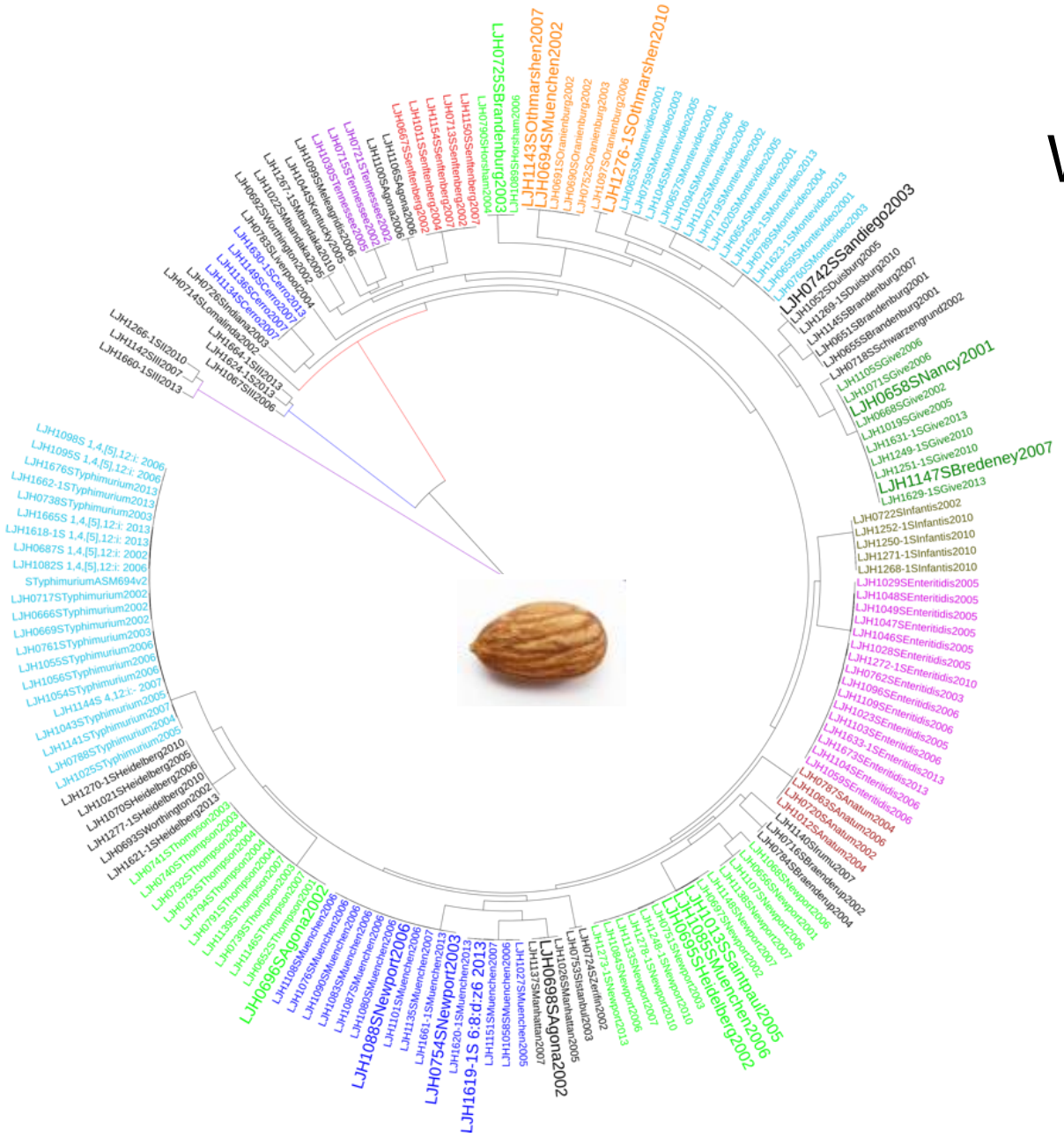
Levels of *Salmonella* in almonds per 100 g



Why? How often?

2001 Outbreak
Est. up to 120 cells/100 g
Recalled almonds

- *Salmonella*, not drawn to scale



Whole Genome Sequence Analysis

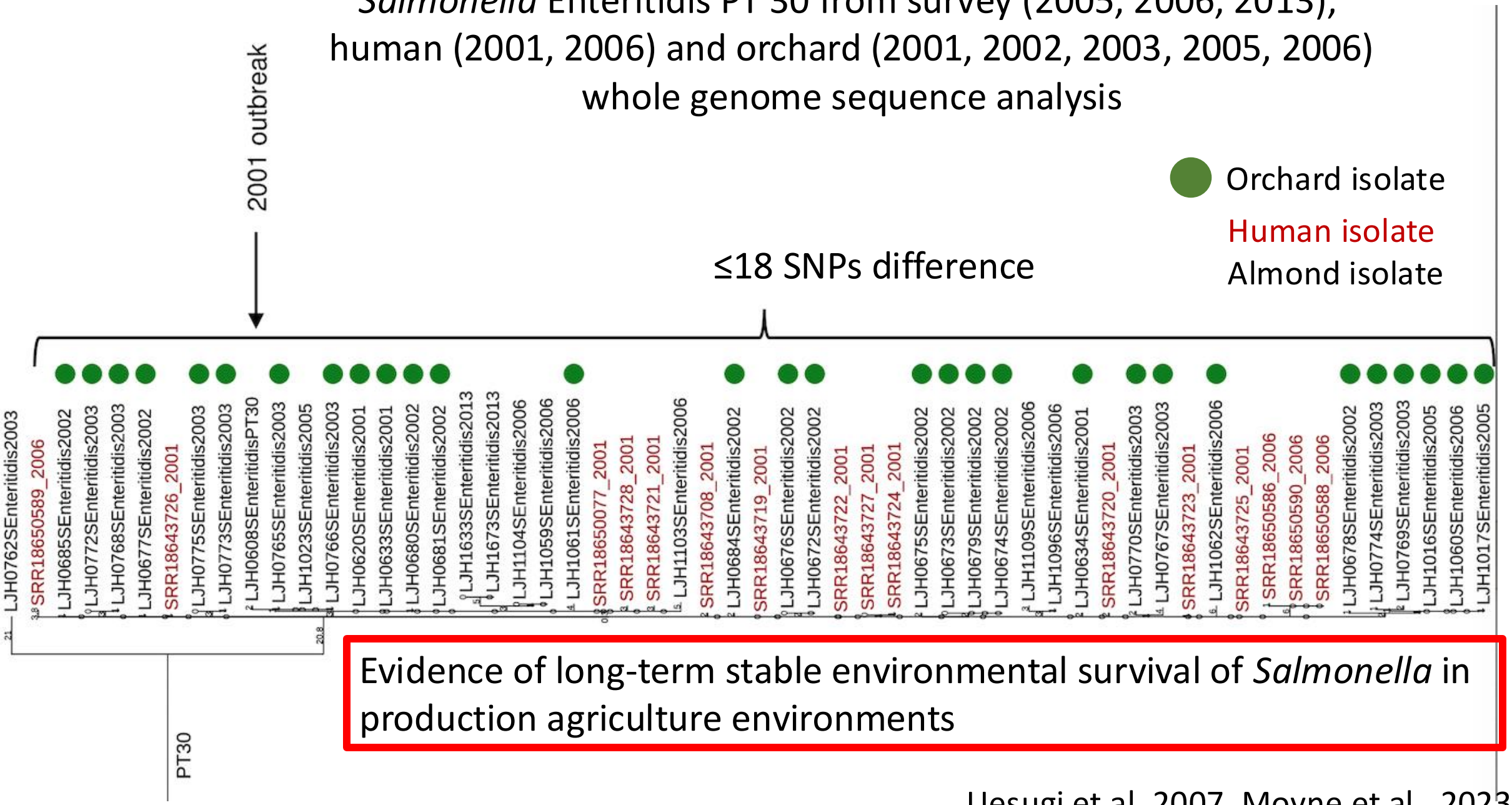
208 isolates from almond kernels
10 different years, 15,530 samples
20-year timespan 2001-2021

Wide range of *Salmonella* types

35 unique serovars
11 serovars isolated single times

Moyne et al., 2023; Harris et al., 2025

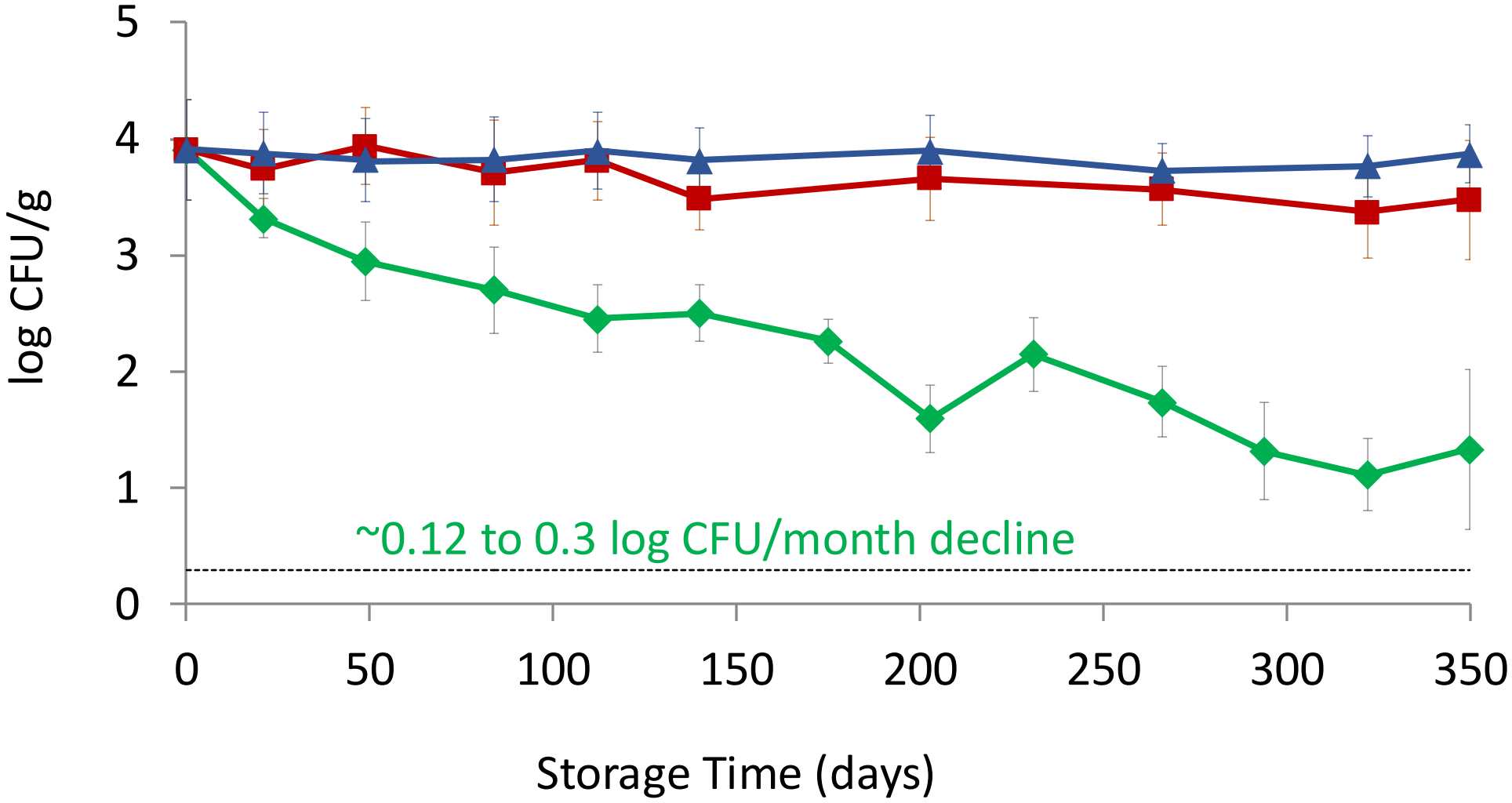
Salmonella Enteritidis PT 30 from survey (2005, 2006, 2013), human (2001, 2006) and orchard (2001, 2002, 2003, 2005, 2006) whole genome sequence analysis



Evidence of long-term stable environmental survival of *Salmonella* in production agriculture environments

Uesugi et al. 2007, Moyne et al., 2023

Survival of *Salmonella* (6-strain cocktail) during storage of almonds at 23°C (73°F), 4°C (39°F), and -20°C (-4°C).



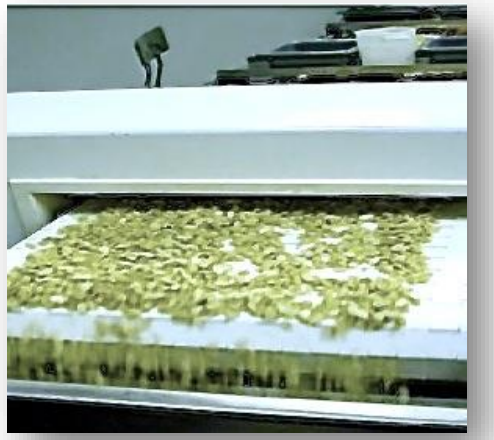
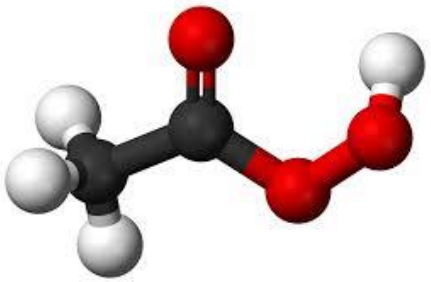
Kimber et al., 2012

70°C/158°F hot water immersion

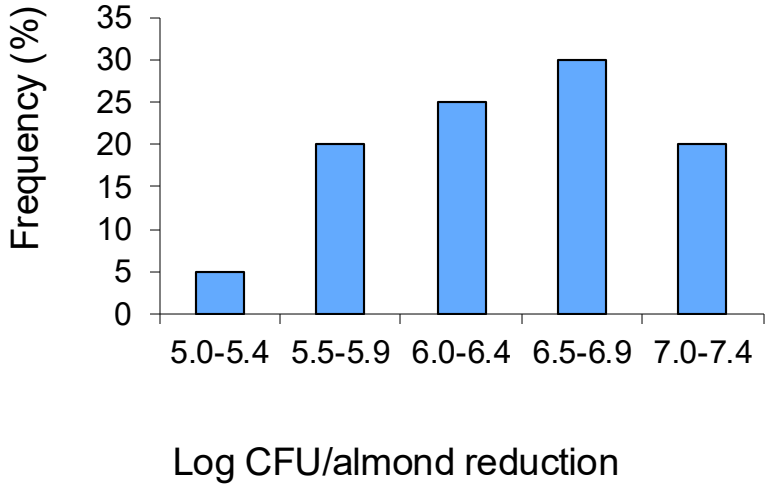
5-log (100,000-fold) reduction of *Salmonella*

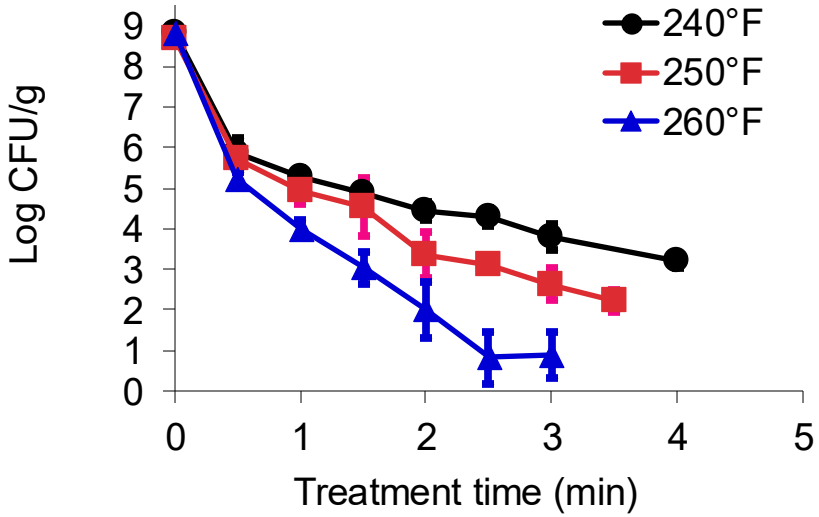
10 seconds in uncured beef patty: 360 seconds on almonds

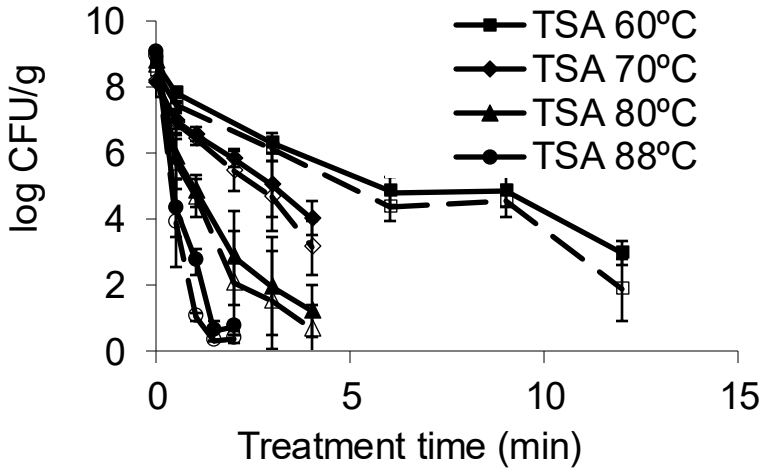
Postharvest Treatment Options

Wet Heat	Dry Heat	Nonthermal	Gas	Other Chemical
				
Steam Water Humidity Re-wetting Vacuum	Convection Baking, Roasting, Infrared, radio frequency	Radiation, Plasma, High pressure, ??	Propylene or Ethylene Oxide, Ozone	Acids, Mixtures ??

Process Validation – Safe Harbors – no surrogate Letters of Determination from FDA 5-log reduction







Danyluk et al., 2005. J. Food Prot. 68:1613–22

Du, et al., 2010. J. Food Prot. 73:1238–46

Harris, et al., 2012. Food Res. Int. 45:1093–98

7 CFR Part 981.442b Effective Sept. 1, 2007

- Regulation (USDA-AMS) under the Federal Marketing Order:

Why

4 log (100,000-fold) reduction?

- Data must be reviewed and accepted by:
  - ABC Technical Expert Review Panel (TERP)
    - Independent group of scientists
  - Annual audits by approved auditors

Quantitative Microbial Risk Assessment Model Outline/Overview

Salmonella* prevalence at harvest

Salmonella* concentration at harvest

Pre-process storage*

Post-harvest treatment

Post-process storage*

Retail storage*

Consumer storage*

Consumer treatment

Serving size

Number of servings

Dose-Response model

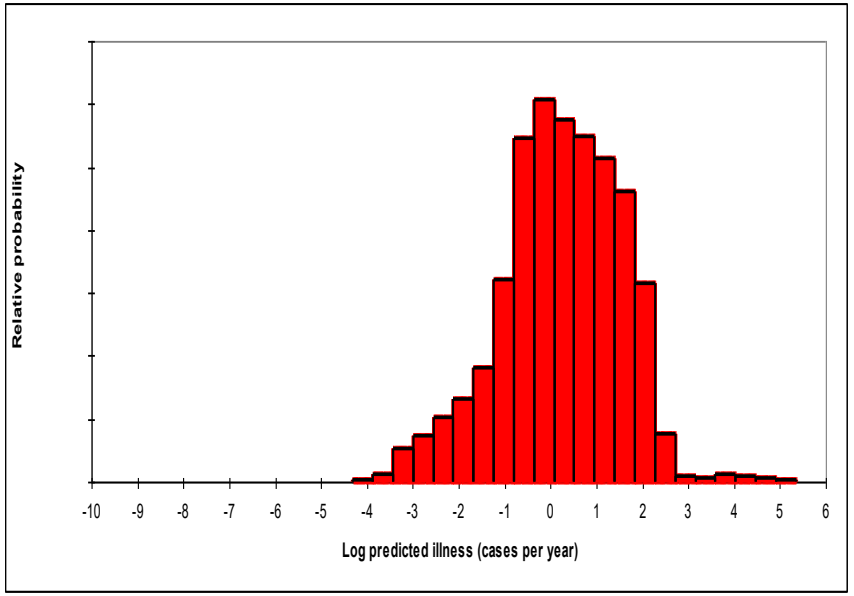
Risk of illness per annum & risk per billion servings

Data:
Prevalence and levels, survival during storage, treatment effects

Diagram FDA

4-log Reduction of *Salmonella* as a Process Criterion for Almonds

2005 UC Davis Risk Assessment



- 5±1 log reduction
  - reduced to <1% chance of >1 case

Subsequent analysis same true for:

- 4±1 log reduction

Danyluk et al. 2006 JFP

2012 UC Davis Risk Assessment

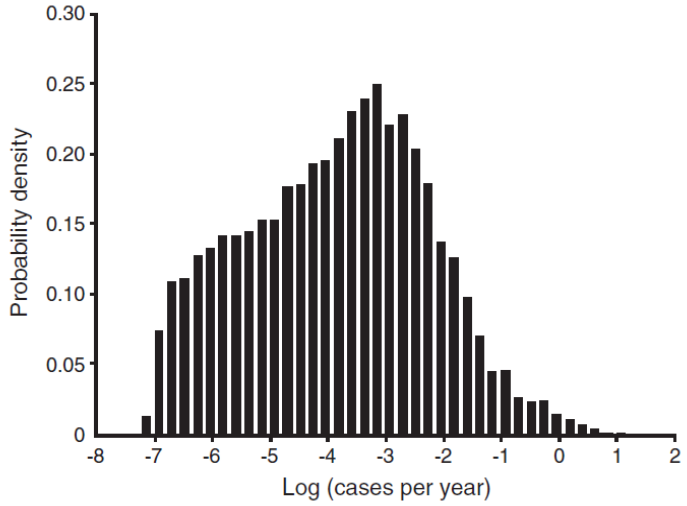


Fig. 4. Number of salmonellosis episodes per year, as decimal logarithm, under the current production and treatment scenario.

- Confirmed effectiveness of ≥ 4-log treatment performance standard
- 4-log reduced predicted cases to <1/year even at assumed worst case scenarios and modeled 2001 outbreak

Lambertini et al. 2012 Food Res. Int.

2017 FDA Risk Assessment

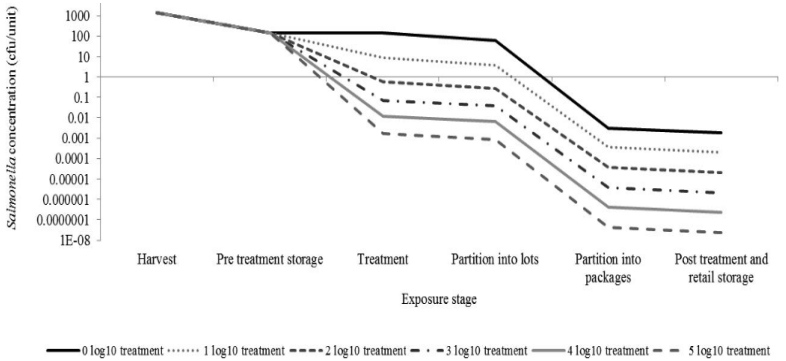
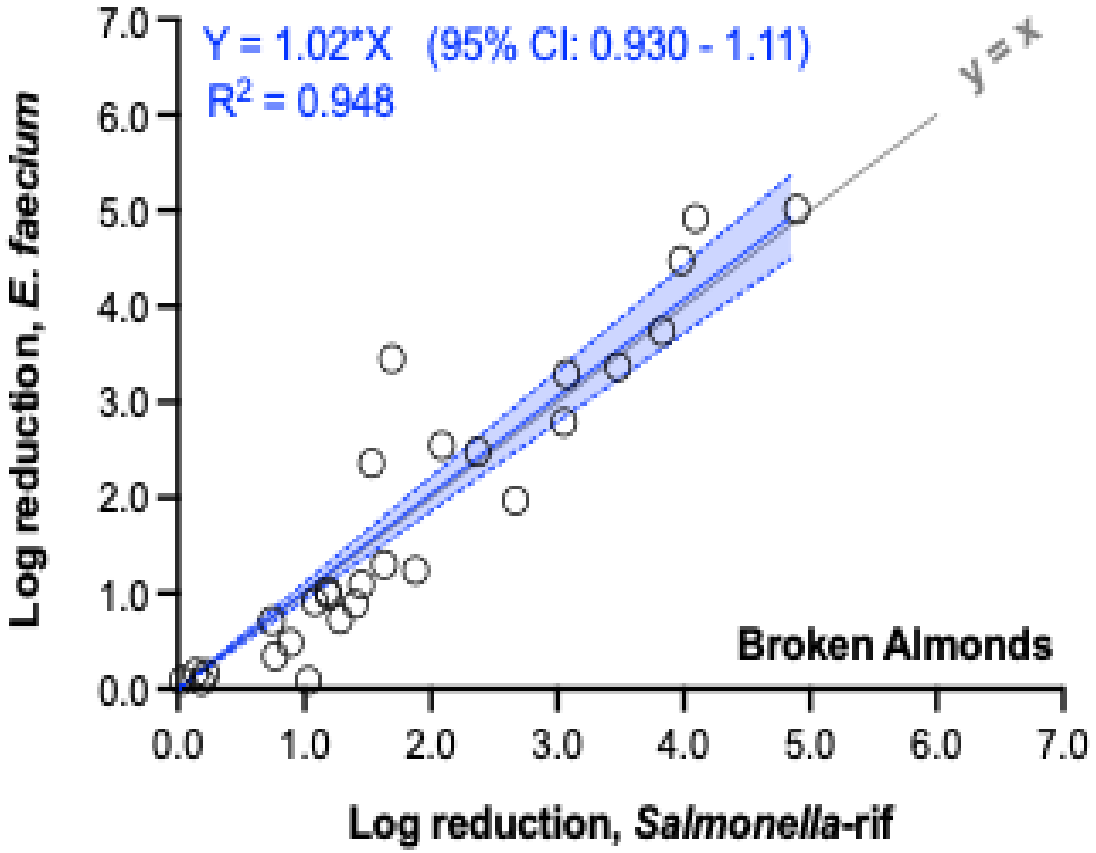


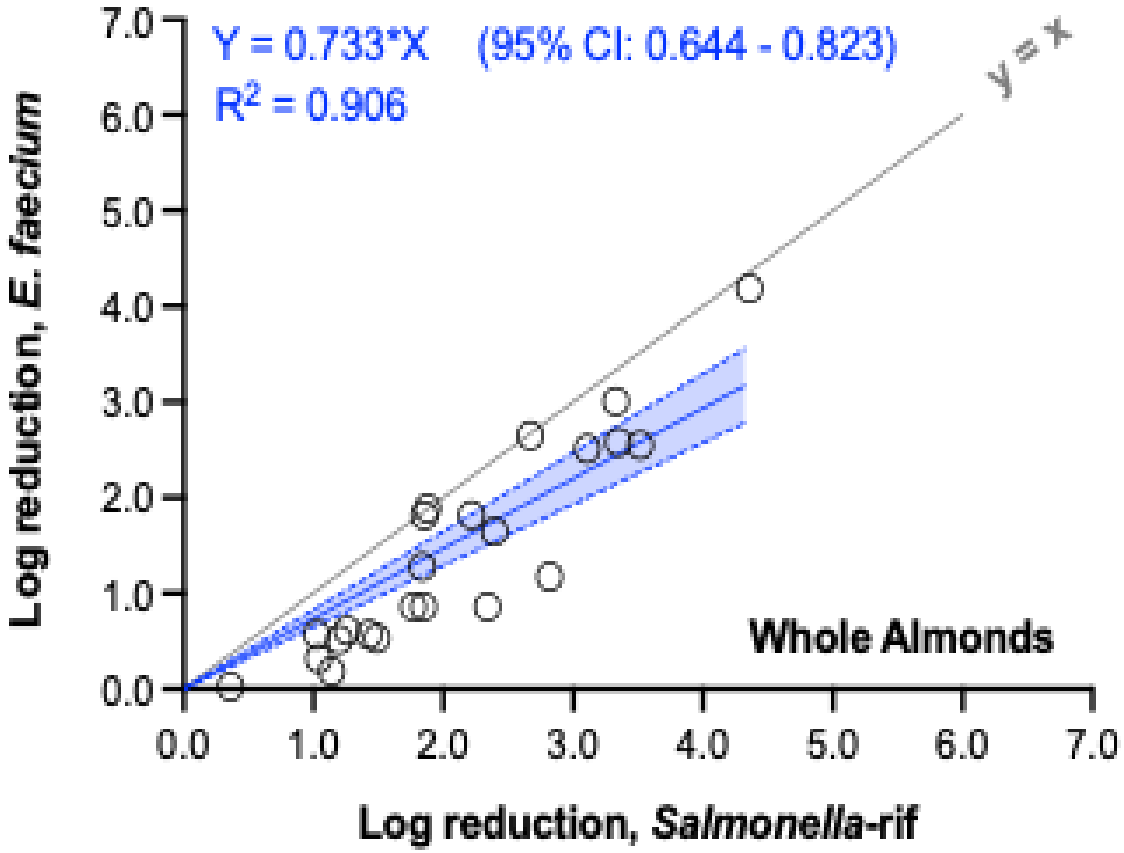
FIGURE 2. *Mean* Salmonella *concentration levels in each of the exposure assessment stages for a simulated no treatment and for 1-, 2-, 3-, 4-, and 5-log reduction treatments (where the log reduction treatment levels in* Salmonella *cells are defined in CFU per unit of product being treated).*

- ≥ 4-log reduction treatment: estimated illness <1 case/year
- ≥ 4-log reduction treatment sufficient to prevent the 2001 outbreak in 2001 (exceptional circumstances)

Santillana Farakos et al. 2017. JFP

Reduction of *Enterococcus faecium* NRRL B-2354 and *Salmonella* on whole and broken almonds at 335°F (168°C) dry heat





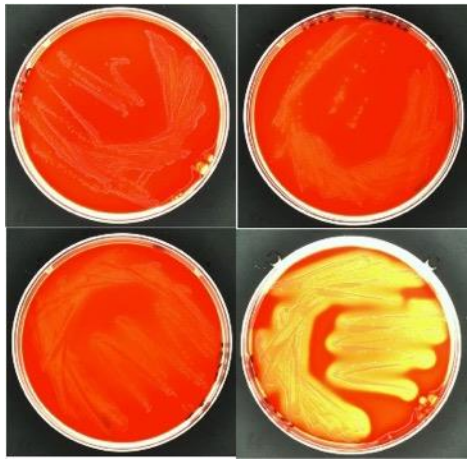
Xie et al., 2025

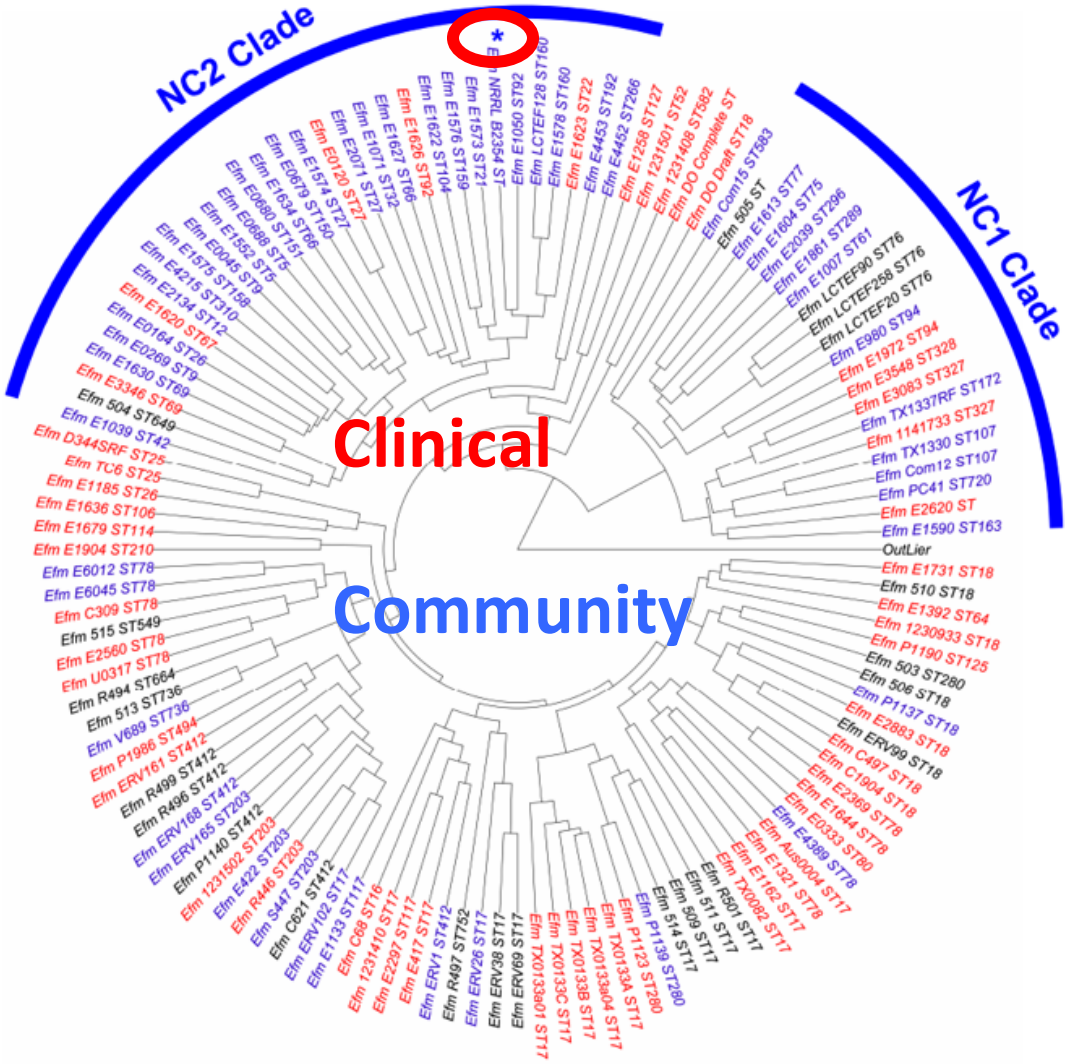
Enterococcus faecium NRRL B-2354 and ATCC 8459

ATCC successfully petitioned to change classification to BSL1

- Genome sequenced using Illumina and PacBio technologies
  - Chromosome (2.6 Mbp)
  - One plasmid (214 kbp)

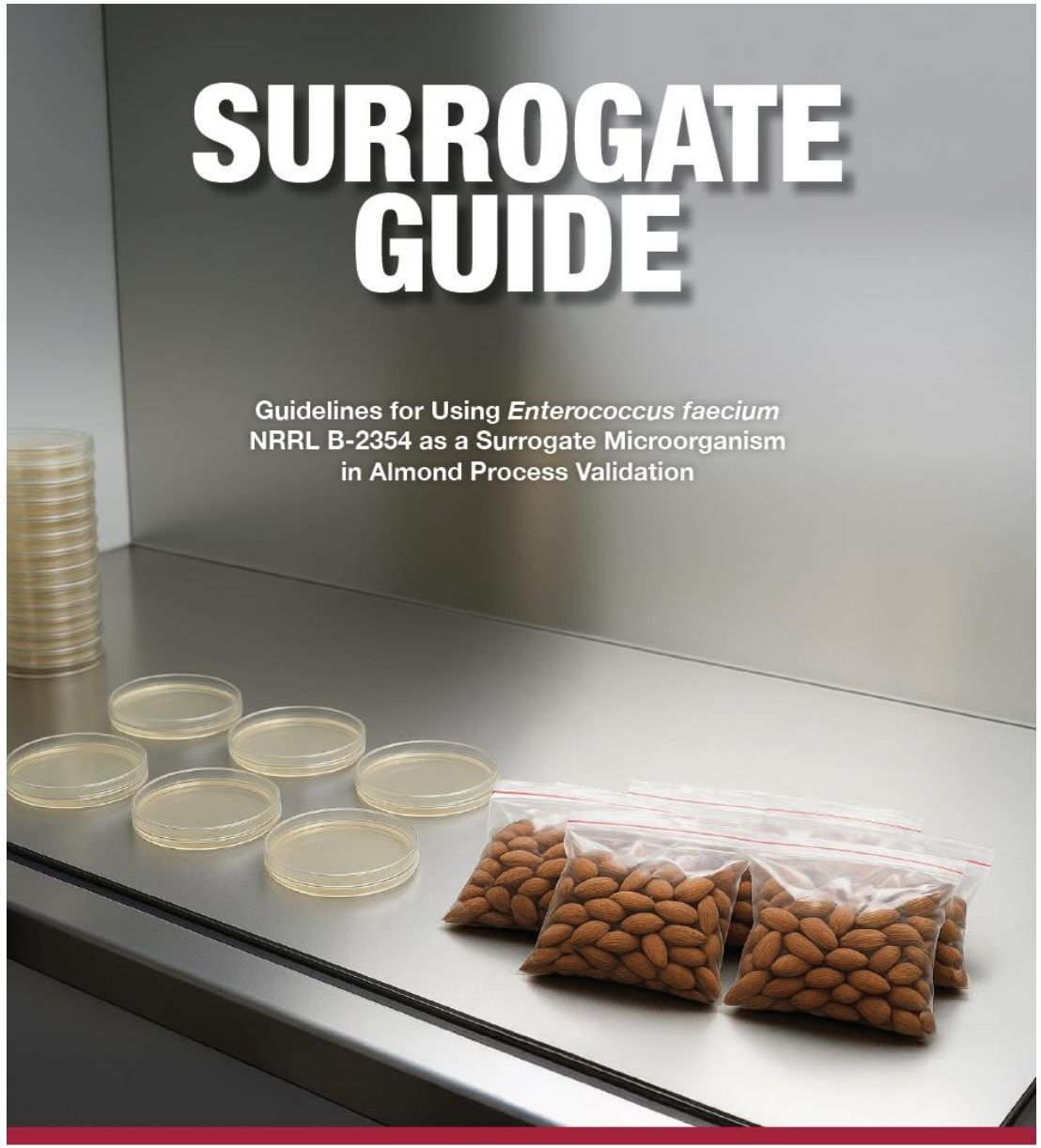
- Lacks virulence factors
- Compared to 128 *E. faecium* genomes
  - Most similar to community strains
- Phenotypic:
  - Sensitive to antibiotics





Kopit et al., 2014. AEM 80(6):1899–1909

2007, 2014, 2026



california almonds
Almond Board of California

Scientific Publications: Microbiology of Almonds

1939 → 2001 → 2025

10 publications over 62 years
(1 every 6 years)

most recent in 1986

>165 publications over 25 years
~7 per year

first (non-outbreak pub) in 2005

Journal of Food Protection, Vol. 68, No. 8, 2005, Pages 1613–1622

Survival of *Salmonella* Enteritidis PT 30 on Inoculated Almonds after Commercial Fumigation with Propylene Oxide

MICHELLE D. DANYLUK, AARON R. UESUGI, AND LINDA J. HARRIS*

The next *Salmonella* outbreak from California almonds – Harris Prediction

1) Unusually high contamination of a lot during production or harvest
   - Contamination exceeds the capacity of a 4-log treatment
   - Should be addressed in grower food safety plan
   - Should be addressed in huller/sheller GMP program

2) Recontamination of adequately treated product
   - Handler cross contamination
   - Should be addressed in handler food safety plan

3) Consumption of raw product (sold outside of North America)
   - Should be addressed in handler food safety plan
   - Treatment at final destination

EVERYONE PLAYS A ROLE IN FOOD SAFETY

Grower

Huller/
Sheller

Handler

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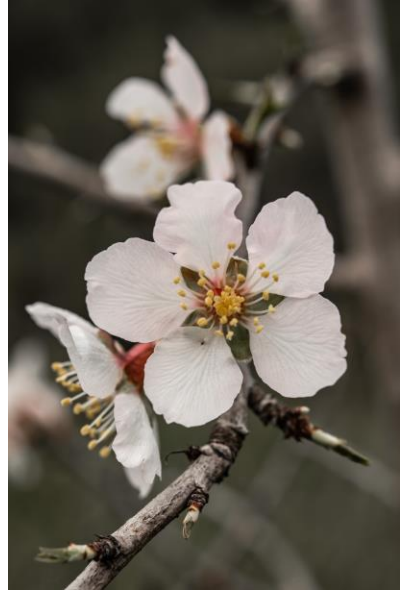

USDA National Institute of Food and Agriculture
U.S. DEPARTMENT OF AGRICULTURE

THE ALMOND CONFERENCE 2025






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MANY MEMBERS OF THE CALIFORNIA ALMOND INDUSTRY

Remain vigilant

Continually assessing trends across the supply chain and potential food safety risks


THANK
YOU!
2025
THE ALMOND
CONFERENCE
CULTIVATING A HEALTHIER
FUTURE