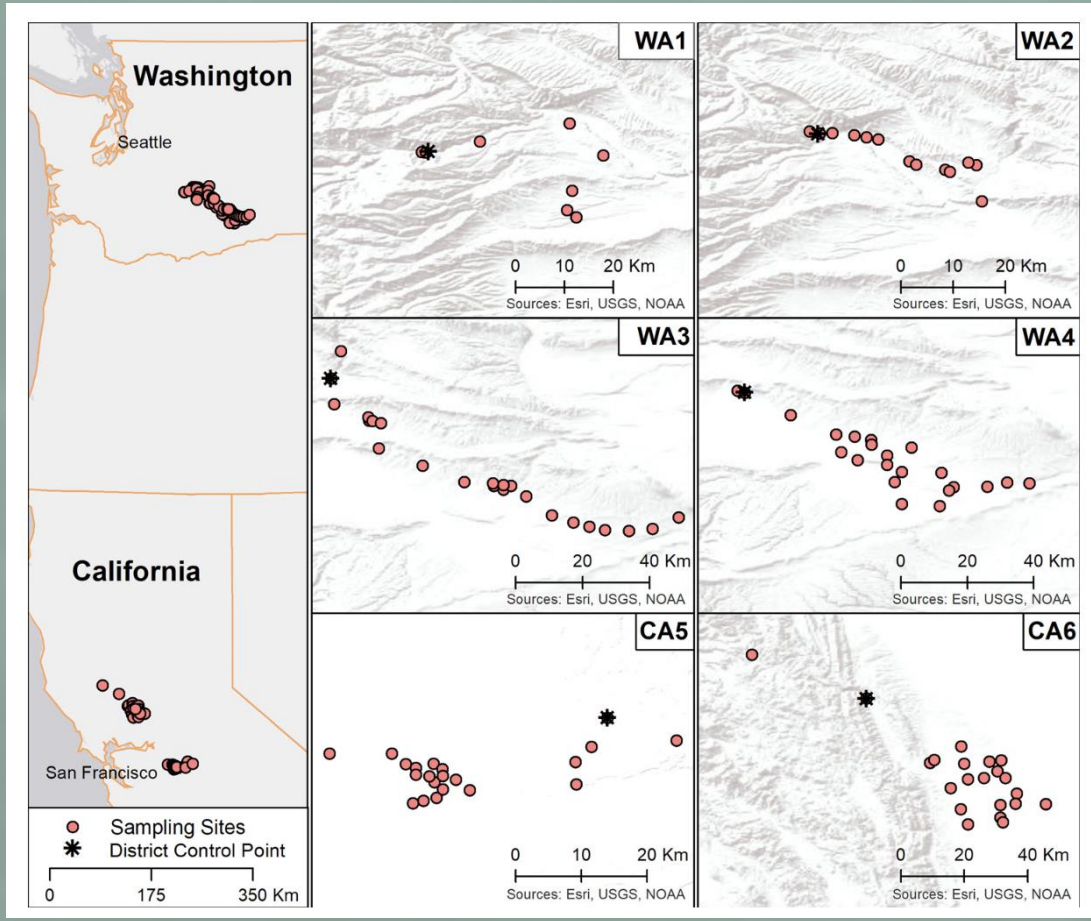
Existing Tree Fruit Research To Support Risk Assessments and Mitigation Measures

Microbial Quality of Irrigation Districts – Data from Partyka et al., 2018



Monthly Sampling of:

- Physiochemical measurements
- Generic *E. coli*
- Fecal coliforms
- *Enterococci*
- *Salmonella*
- *E. coli* O157:H7
- Non O157:H7 STEC

Microbial Quality of Irrigation Districts – Data from Partyka et al., 2018

Districts		Log_{10} EC†	Log_{10} FC†	Log_{10} EN†	Log_{10} turbidity	Temperature	pH	Dissolved oxygen	Specific conductivity
		——— CFU‡ 100 mL^{-1} ———			NTU	°C		mg L^{-1}	µS cm^{-1}
WA (*n* = 330)	mean (SD)	1.30 (0.58)	1.76 (0.66)	1.45 (0.51)	0.72 (0.31)	16.90 (3.95)	7.81 (0.4)	9.46 (0.92)	91.63 (58)
	min.–max.	0–2.93	0–3.86	0.15–2.57	0.14–1.82	6.20–25.30	6.90–9.01	7.33–13.75	1.0–483.1
WA-1 (*n* = 40)	mean (SD)	0.57 (0.37)	0.70 (0.46)	0.73 (0.29)	1.27 (0.1)	12.40 (4.5)	7.90 (0.5)	10.0 (0.8)	55.60 (14.7)
	min.–max.	0–1.56	0–1.70	0.15–1.15	1.18–1.45	6.20–19.9	7.30–8.52	9.21–11.48	40.80–73.0
WA-2 (*n* = 65)	mean (SD)	1.15 (0.41)	1.40 (0.49)	1.42 (0.35)	0.60 (0.30)	14.20 (3.10)	7.60 (0.30)	9.90 (0.80)	64.70 (23.70)
	min.–max.	0.34–1.84	0.34–2.21	0.34–2.02	0.21–1.74	8.60–19.8	7.20–8.20	8.41–11.71	2.80–105.0
WA-3 (*n* = 115)	mean (SD)	1.23 (0.57)	1.93 (0.50)	1.61 (0.42)	0.70 (0.30)	17.80 (3.80)	8.0 (0.50)	9.30 (0.80)	80.30 (21.70)
	min.–max.	0–2.93	0.41–2.92	0.48–2.55	0.14–1.82	9.50–24.80	7.20–9.01	7.76–11.71	1.0–109.40
WA-4 (*n* = 110)	mean (SD)	1.73 (0.36)	2.18 (0.38)	1.55 (0.53)	0.75 (0.25)	18.20 (3.20)	7.70 (0.40)	9.30 (1.0)	124.10 (81.80)
	min.–max.	0.48–2.60	1.32–3.86	0.40–2.57	0.14–1.51	10.70–25.30	6.90–8.70	7.33–13.75	2.90–483.10

Microbial Quality of Irrigation Districts – Data from Partyka et al., 2018

Table 2. Prevalence of bacterial pathogens (*Salmonella* spp., non-O157 Shiga toxin-producing *E. coli* [STEC], and *E. coli* O157, and in small-volume (SV = 1 L) and large-volume (LV = 10 L) samples collected in Washington and California during summer 2015.

Location	*Salmonella*		STEC		O157	
	SV	LV	SV	LV	SV	LV
	no. of positive samples (%)					
WA (N_{SV} = 330, N_{LV} = 104)	54 (16.4)	36 (34.6)	25 (7.6)	11 (10.6)	3 (0.9)	1 (1.0)
CA (N_{SV} = 187, N_{LV} = 45)	78 (41.7)	32 (71.1)	20 (10.7)	5 (11.1)	9 (4.8)	6 (13.3)
TOTAL (N_{SV} = 517, N_{LV} = 149)	132 (25.5)	68 (45.6)	45 (8.7)	16 (10.7)	12 (2.3)	7 (4.7)

Microbial Quality of Irrigation Districts – Data from Partyka et al., 2018

Table 3. Multiple logistic regression model used to estimate the probability of detecting *Salmonella* spp. based on district, collection of paired small-volume (SV)–large-volume (LV) samples, location of sample within the irrigation network, and Euclidean distance from point of district control during the 2015 irrigation season in California and Washington.

	Coefficient	Odds ratio	*P*-value	OR 95% CI†
Intercept	–4.019	0.018	0.000	(0.002, 0.160)
District				
WA-1	0.000‡	1.000		
WA-2	1.865	6.456	0.097	(0.714, 58.384)
WA-3	2.427	11.326	0.031	(1.251, 102.542)
WA-4	1.667	5.296	0.142	(0.572, 49.059)
CA-5	2.352	10.501	0.037	(1.147, 96.177)
CA-6	3.296	26.991	0.003	(3.024, 240.921)
Paired SV-LV				
Not collected	0.000‡	1.000		
Collected	1.608	4.991	0.000	(3.101, 8.032)
Network location				
River (source)	0.000‡	1.000		
Canal	1.162	3.196	0.035	(1.087, 9.400)
Lateral	1.326	3.766	0.027	(1.161, 12.223)
Pipe	1.931	6.894	0.112	(0.636, 74.712)
Distance from district control (km)	–0.025	0.976	0.000	(0.962, 0.989)

† Confidence interval of the odds ratio.

‡ Referent category.

Influence of land use, and environmental characteristics

Structural Equation Models Suggest That On-Farm Noncrop Vegetation Removal Is Not Associated with Improved Food Safety Outcomes but Is Linked to Impaired Water Quality

Daniel L. Weller,[a,b] Tanzy M. T. Love,[b] Donald E. Weller,[b] Claire M. Murphy,[c] Brian G. Rahm,[d] Martin Wiedmann[a]

Temporal Stability of *Salmonella enterica* and *Listeria monocytogenes* in Surface Waters Used for Irrigation in the Mid-Atlantic United States

Seongyun Kim [1 2], Yakov Pachepsky [1], Shirley A. Micallef [3], Rachel Rosenberg Goldstein [4], Amy R. Sapkota [4], Fawzy Hashem [5], Salina Parveen [5], Kalmia E. Kniel [6], Manan Sharma [1]

Distribution, Diversity, and Seasonality of Waterborne Salmonellae in a Rural Watershed[▽]

Bradd J. Haley,[1]† Dana J. Cole,[1,2] and Erin K. Lipp[1]*

Predicting *Salmonella* Populations from Biological, Chemical, and Physical Indicators in Florida Surface Waters

Rachel McEgan,[a] Gabriel Mootian,[b] Lawrence D. Goodridge,[c] Donald W. Schaffner,[b] Michelle D. Danyluk[a]

Corrective measures	• Re-inspecting the entire affected agricultural water system under the farm's control and, among other steps, making necessary changes **OR** • Treating the water in accordance with the standards in FSMA PSR
Mitigation measures	• Making necessary changes such as repairs • Increasing time interval between last direct application and harvest (microbial die-off) • Increasing time interval between harvest and end of storage (microbial die-off) • Other activities that result in die-off or removal • Changing water application method • Treating water (PSR standards) • Taking alternative mitigation measures supported by scientific information

Making Changes

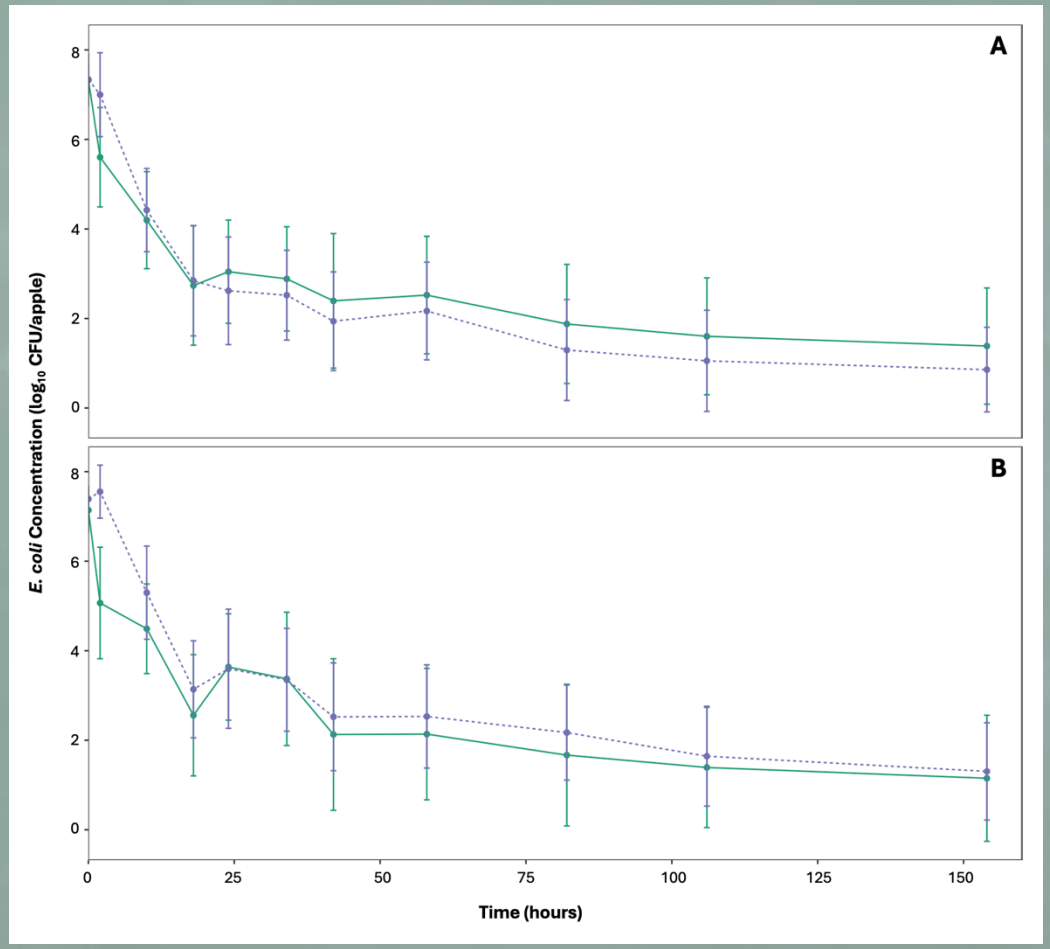
Time to Harvest Interval: Die-Off

Scientific Data on Time-to-Harvest Intervals for Washington Apples

- **Apple varieties:** Gala, Golden Delicious, and Fuji
- **Evaporative cooling treatments:** conventional, misting, and untreated
- **Canopy locations:** High and low within the tree canopy Inside and outside the canopy (for the low portion)
- **Canopy structure**: vertical fruiting wall or free standing
- **Fruit maturity:** Mature and immature apples
- **Growing region:** Wenatchee, WA, and Prosser, WA
- **Year:** 2014, 2015, and 2016
- **Sunlight exposure:** Full sun and shaded
- **Inoculation level:** 7 log CFU/apple and 3.5 log CFU/apple

Scientific Data on Time-to-Harvest Intervals for Washington Apples

- Significant reductions (>2 log) on high inoculated apples by 10h (aka overnight) and 18h on low inoculated
- Die off pattern was not linear



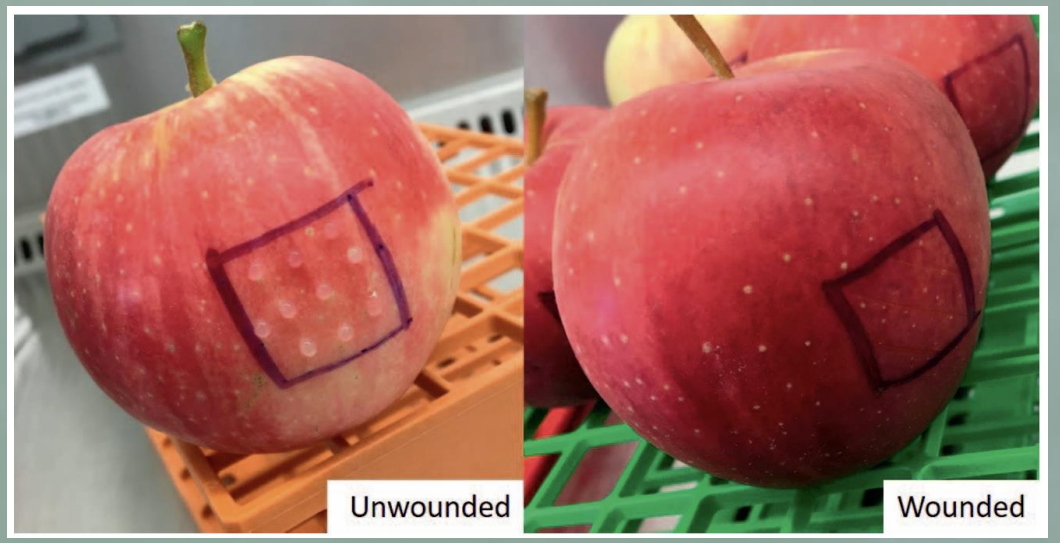
Scientific Data on Time-to-Harvest Intervals for Washington Apples

- **Apple varieties:** Apple variety affected *E. coli* die-off rates, but the difference (0.10 log CFU/apple/day) was not biologically significant
- **Evaporative cooling treatments:** Employing either conventional or misting evaporative cooling after the initial inoculation **did not significantly impact** the die-off rate of *E. coli* on apple surfaces compared to apples not treated with evaporative cooling.
- **Canopy locations:** Die-off rates **did not** differ by canopy location
- **Growing region:** Die-off rates **did not** differ by orchard location
- **Year:** Die-off rates **did not** differ by year
- **Sunlight exposure:** *E. coli* populations on fruit located in **full sun decreased at a faster rate** than those in full shade.
- **Inoculation level:** The rate of *E. coli* die-off was **quicker for the high-inoculated apples** compared to the low-inoculated apples

Storage Die-Off

Listeria innocua on apples - Hamilton et al, 2021

- Gala and Cosmic Crisp
- *Listeria innocua*
- Fecal coliforms
- Co-inoculated *with B. cinerea or P. expansum*
- wounded and unwounded
- Held in CA for 11 month



Listeria innocua on apples - Hamilton et al, 2021

TABLE 1. *Mean populations of* L. innocua *on Gala apples during 3 months of controlled atmosphere cold storage by treatment, wound status, and time in storage*[a]

Months (days) in storage	Mean ± SE populations (Log CFU/cm^2) per treatment[b]					
	LI only		LI+BC		LI+PE	
	No wound	Wound	No wound	Wound	No wound	Wound
0.25 (8)	6.01 ± 0.14 A a (a)	6.92 ± 0.05 A a (a)	4.35 ± 0.10 A a (a)	6.57 ± 0.07 A a (b)	3.37 ± 0.01 A a (a)	4.81 ± 0.09 A b (b)
1 (30)	2.61 ± 0.06 B a (a)	5.56 ± 0.07 B a (b)	3.54 ± 0.08 A b (a)	5.43 ± 0.08 A a (a)	2.53 ± 0.06 B c (a)	3.06 ± 0.12 B b (b)
3 (93)	2.46 ± 0.03 B a (a)	4.62 ± 0.08 C a (b)	2.68 ± 0.05 B b (a)	4.00 ± 0.14 B a (b)	2.64 ± 0.06 C a (a)	2.64 ± 0.08 B b (a)

TABLE 3. *Percentage of samples for which the presence of* L. innocua *was detected on Gala apples during 6, 9, and 11 months of storage*[a]

Months (days) in storage	% (no./total no.) of samples per treatment[b]					
	LI only		LI+BC		LI+PE	
	No wound	Wound	No wound	Wound	No wound	Wound
6 (183)	100 (30/30)	96.7 (29/30)	76.7 (23/30)	100 (30/30)	46.7 (14/30)	43.3 (13/30)
9 (272)	60.0 (18/30)	86.7 (26/30)	60.0 (18/30)	90.0 (27/30)	33.3 (10/30)	26.7 (8/30)
11 (334)	3.3 (1/30)	53.3 (16/30)	6.9 (2/29)[c]	82.8 (24/29)	4.0 (1/25)	12.0 (3/25)

Listeria innocua on apples - Hamilton et al, 2021

TABLE 2. *Mean populations of* L. innocua *on WA 38 apples during 3 months of controlled atmosphere cold storage by treatment and time in storage*[a]

Months (days) in storage	Mean ± SE populations (Log CFU/cm^2) per treatment[b]		
	LI only	LI+BC	LI+PE
0.25 (9)	3.55 ± 0.08 A a	5.41 ± 0.06 A b	3.40 ± 0.11 A c
1 (30)	2.77 ± 0.06 B a	4.06 ± 0.09 A b	2.77 ± 0.08 B c
3 (93)	2.46 ± 0.03 C a	2.55 ± 0.05 B a	2.37 ± 0.01 C b

TABLE 4. *Percentage of samples for which the presence of* L. innocua *was detected on WA 38 apples during 6, 9, and 11 months of storage*[a]

Months (days) in storage	% (no./total no.) of samples per treatment[b]		
	LI only	LI+BC	LI+PE
6 (183)	66.7 (20/30)	50.0 (15/30)	33.3 (10/30)
9 (272)	56.7 (17/30)	27.3 (6/22)[c]	10.0 (2/20)
11 (334)	50.0 (15/30)	17.7 (3/17)	7.7 (1/13)

Pears – Ongoing CPS projects

Title	Principal Investigator	Date Started	End Date	RFP Year	Resources
Interaction of resident microbiome and Listeria on pears during cold storage	Meijun Zhu, Ph.D.	January 2023	December 2024	2022	Zhu 2022 - 2 Poster Zhu 2022 - 2 Poster 2
A metagenomic approach to food safety risk mitigation in pears	Laura Strawn, Ph.D.	January 2023	December 2024	2022	Strawn 2022 - Poster Strawn 2022 - Poster 2

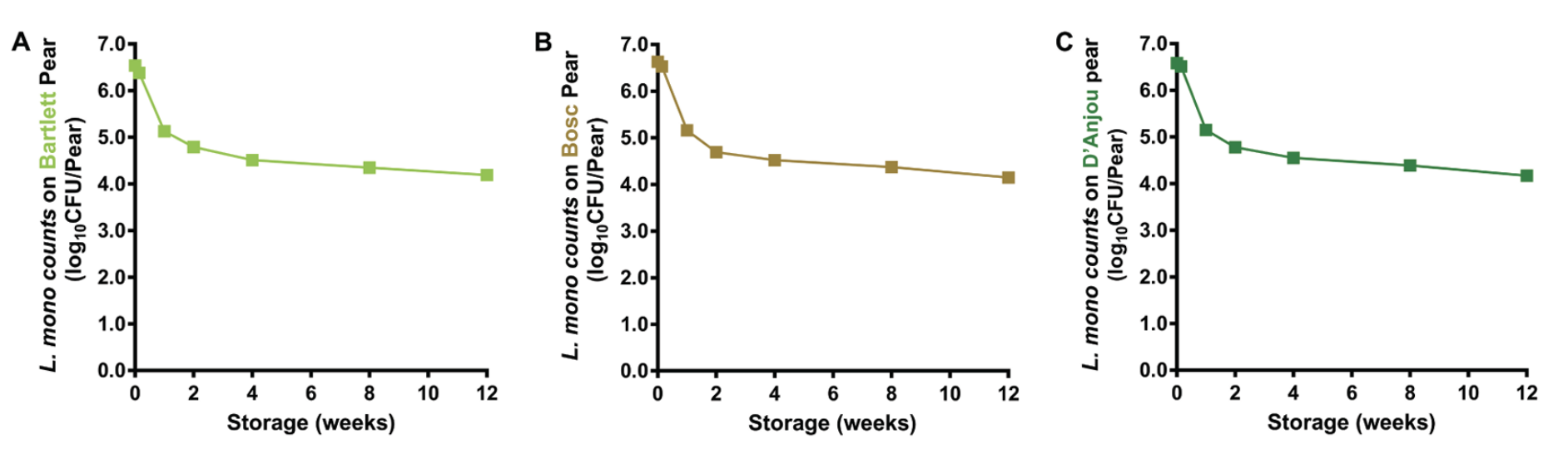
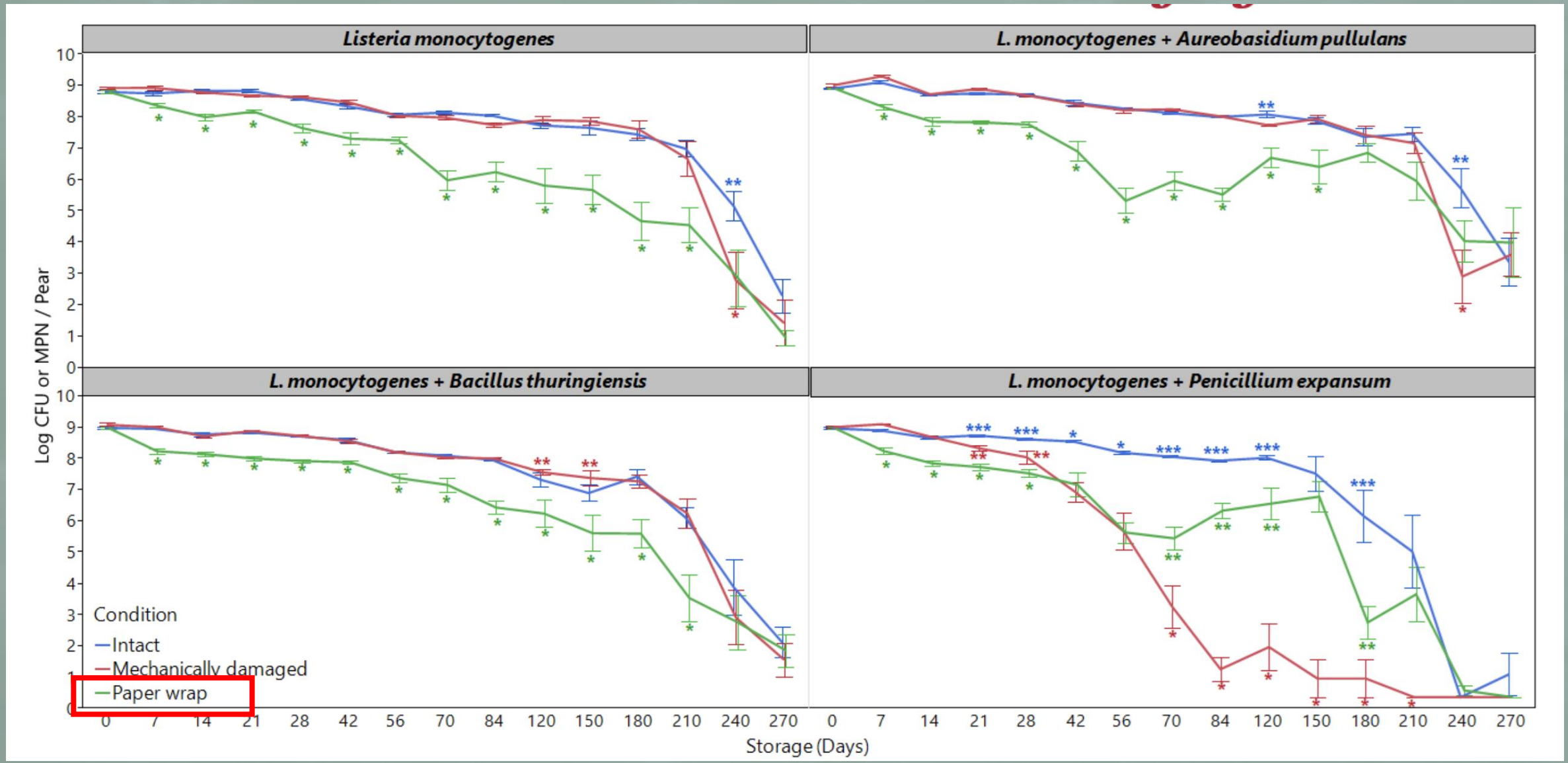


Figure 3. Survival of *L. monocytogenes* on pears during 12 weeks of cold storage. A: Bartlett pear; B. Bosc pear; C: D'Anjou pear. Mean ± SEM, n = 12. The selected varieties were inoculated with *L. monocytogenes* at ~6.5 $\log_{10}$ CFU/apple, then subjected to cold storage 24 hours after inoculation.


Listeria monocytogenes
L. monocytogenes + Aureobasidium pullulans
L. monocytogenes + Bacillus thuringiensis
L. monocytogenes + Penicillium expansum
Log CFU or MPN / Pear
Storage (Days)
Condition
Intact
Mechanically damaged
Paper wrap
0 7 14 21 28 42 56 70 84 120 150 180 210 240 270

Average concentrations (log CFU/pear) of a generic *E. coli* on D'Janjou Pears over time.

Day	Bulk	Wrapped
0	7.07 ± 0.16 Aa[a]	7.07 ± 0.16 Aa
1	7.17 ± 0.27 Aa	7.00 ± 0.13 Aa
7	6.12 ± 0.30 Ab	5.92 ± 0.18 Bb
14	5.88 ± 0.28 Ab	5.23 ± 0.42 Bc
28	5.46 ± 0.30 Ab	5.32 ± 0.34 Ac

Alternatives/Other Activities

Antimicrobial Wax - Sanchez-Tamayo, et al 2024

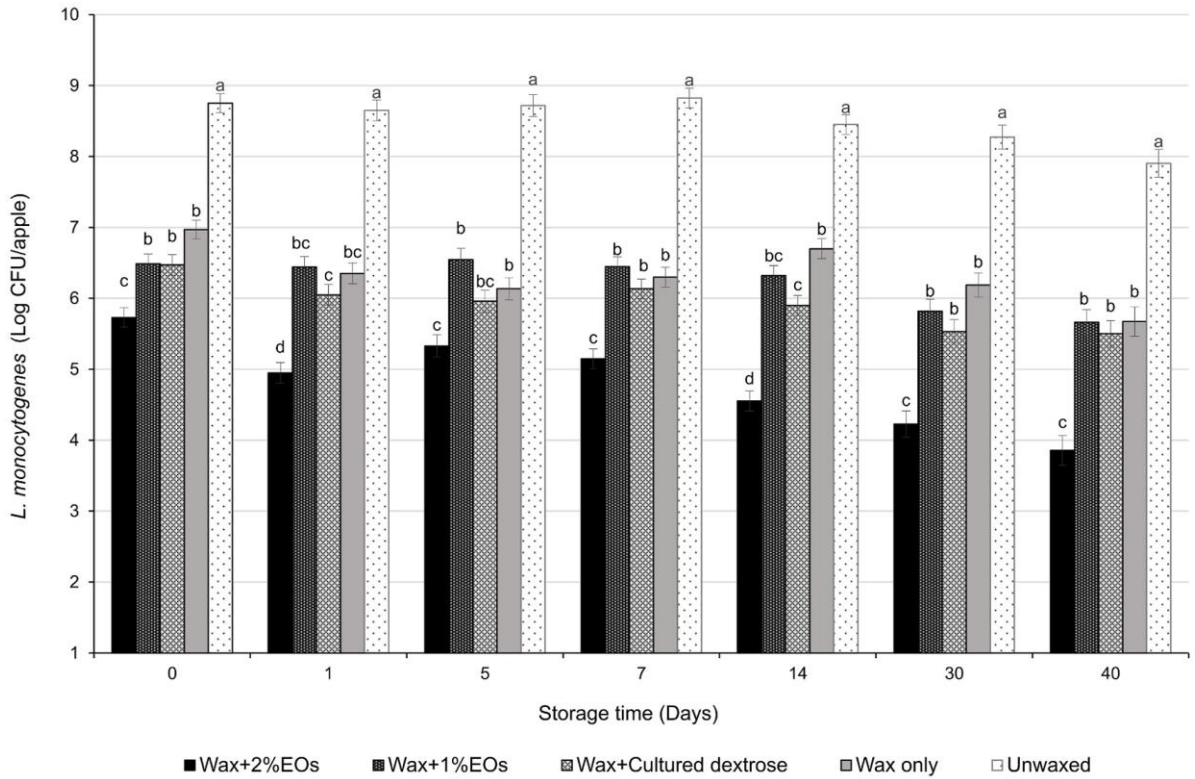


Fig. 2. Population of *Listeria monocytogenes* on Gala apples during storage at 20 °C up to 40 days. All results were reported as means ± standard error. Different letters above bars indicate significant differences in the mean ($P \leq 0.05$) for each storage time.

Antimicrobial Wax - Sanchez-Tamayo, et al 2024

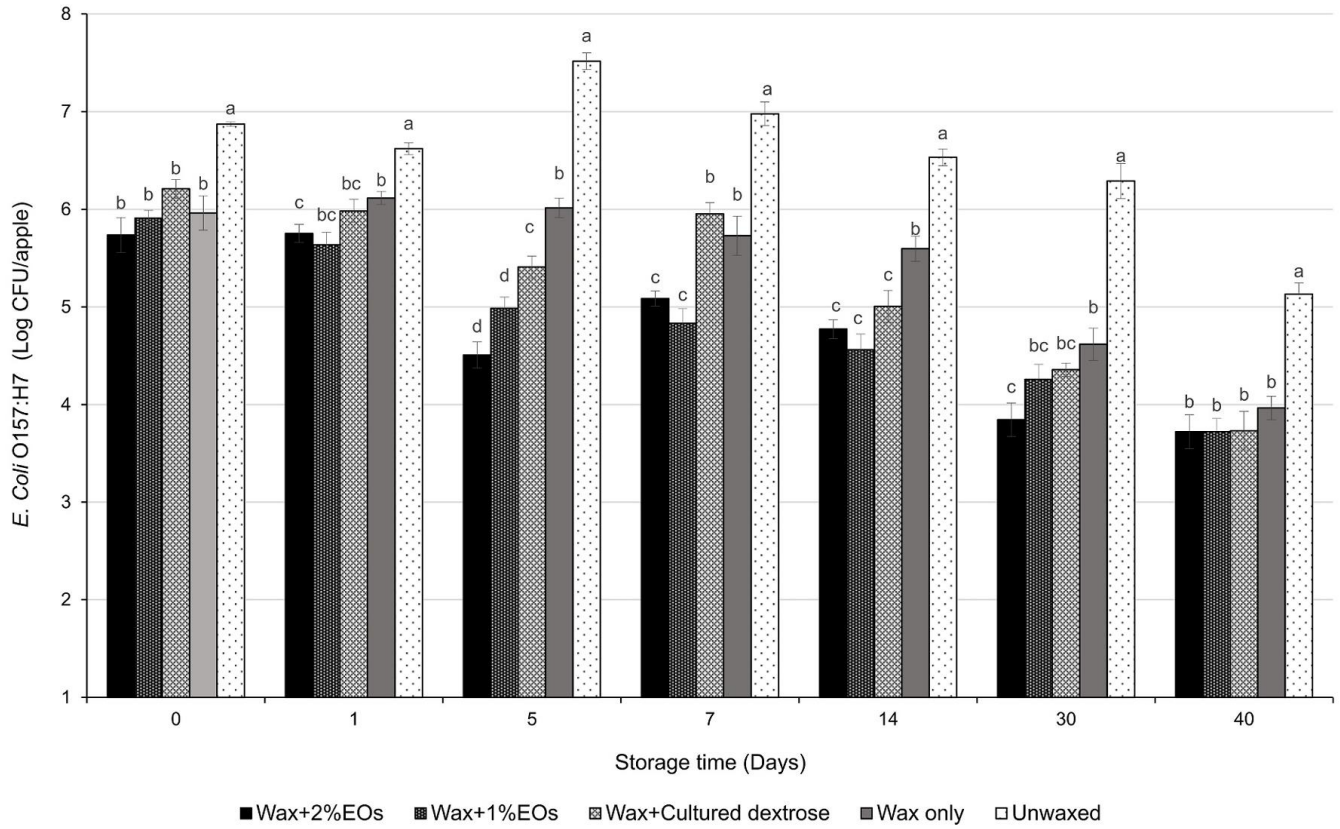


Fig. 3. Population of *Escherichia coli* O157:H7 on Gala apples during storage at 20 °C up to 40 days. All results were reported as means ± standard error. Different letters above bars indicate significant differences in the mean ($P \leq 0.05$) for each storage time.

Antimicrobial Wax - Sanchez-Tamayo, et al 2024

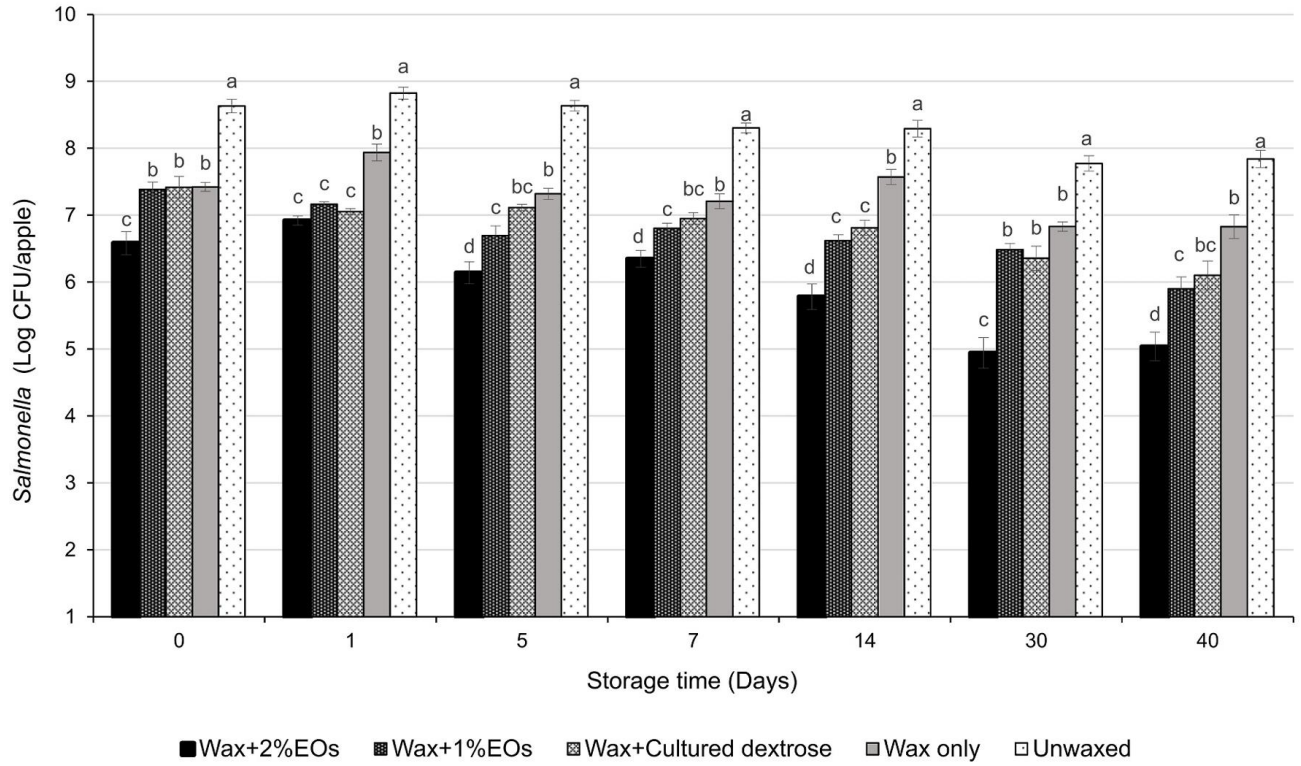


Fig. 4. Population of *Salmonella* on Gala apples during storage at 20 °C up to 40 days. All results were reported as means ± standard error. Different letters above bars indicate significant differences in the mean ($P \leq 0.05$) for each storage time.

Antimicrobial intervention**** - Su et al, 2024

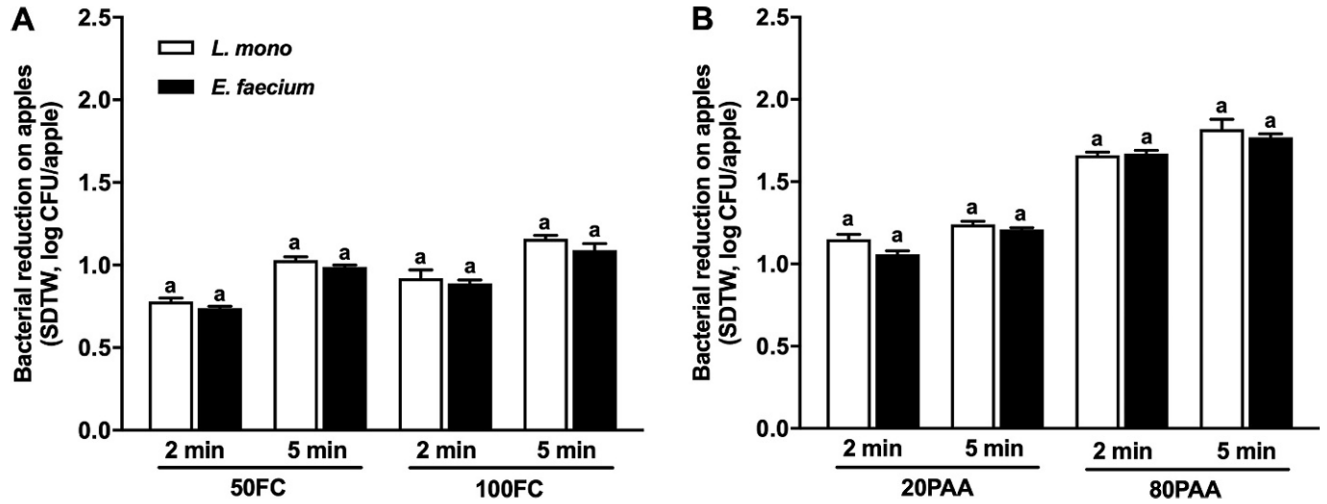


Fig. 2. Reduction of *L. monocytogenes* and *E. faecium* NRRL B-2354 on Granny Smith apples after 2 or 5 min exposure to sanitizer-treated simulated dump tank water (SDTW) with 1000 ppm chemical oxygen demand (COD). (A) Chlorine; (B) PAA. FC, free chlorine (ppm). Data shown as Mean ± SEM, averaged from three independent studies with 10 apples per independent test. [a-a] Bars labeled with the same letter indicate no significant difference within each treatment.

Research on all crops, locations, pathogens, and environment is not available

Ongoing Research

- Cherries
- Pears
- UVC and Far-UVC
- Ozone
- Antimicrobial Coatings