



Effective Inactivation of *Listeria monocytogenes* Biofilms on Stainless Steel by Peroxyacetic Acid: Advancing Food Safety Protocols

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Abstract

Listeria monocytogenes biofilms are highly resilient on food-contact surfaces, posing a persistent risk in the food industry. Effective strategies to control these biofilms are essential for ensuring food safety. This study quantitatively evaluated the efficacy of a commercial peroxyacetic acid (PAA) disinfectant in inactivating *L. monocytogenes* biofilms on stainless steel (SS) surfaces. Biofilms established on SS coupons were visualized using field-emission scanning electron microscopy (FESEM) and assessed *via* culturable cell counts. FESEM revealed that treatment with 240 ppm PAA for 15 min had minimal impact, with regrowth occurring within 48 h, highlighting the higher resistance of biofilm-embedded cells compared to planktonic cells (MIC: 60 ppm). Untreated biofilms exhibited regrowth within 24 h. Higher concentrations (480 and 720 ppm) induced pronounced morphological changes, including visible holes and cell damage. Regrowth occurred at 480 ppm within 72 h, whereas 720 ppm completely prevented bacterial recovery (log reduction >6.0) for up to 168 h (7 days), irrespective of 5- or 10-min exposure. These results demonstrate the dose-dependent efficacy of PAA and support the use of 720 ppm for at least 5 min as an effective strategy to disrupt *L. monocytogenes* biofilms and prevent regrowth in food-processing environments.

Introduction

L. monocytogenes, a Gram-positive, facultative anaerobe, remains the primary etiological agent of human listeriosis, a severe foodborne infection that disproportionately affects immunocompromised

individuals, pregnant women, neonates, and the elderly (Ravindhiran et al., 2023). Outbreaks of listeriosis are notable for their high rates of hospitalization and mortality, and the disease poses a significant burden on public health systems and food industries worldwide (Panebianco et al., 2024). Transmission to humans

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typically occurs through the ingestion of foods contaminated with *L. monocytogenes*, particularly ready-to-eat deli meats, dairy products (e.g., soft cheeses), seafood, and unpasteurized or undercooked meats (Arthur et al., 2025). One of the major challenges in controlling *L. monocytogenes* in food-processing environments is its ability to survive and grow under extreme conditions: it can proliferate at refrigeration temperatures (0–4°C), and persist on common industrial surfaces such as stainless steel (SS), polyvinyl chloride (PVC), and glass under unfavorable conditions (Rohilla et al., 2024).

A key contributor to the persistence of *L. monocytogenes* in food-processing environments is its ability to form biofilms — structured microbial assemblages encased in extracellular polymeric substances (EPS) that adhere tenaciously to surfaces (Arthur et al., 2025). The EPS matrix acts as a protective barrier, reducing penetration of biocides and contributing to the tolerance and recalcitrance of biofilm-associated cells (Pracser et al., 2024; Arthur et al., 2025). Environmental conditions and surface properties influence biofilm formation and resistance to disinfectants (Skowron et al., 2019). Within the food industry, biofilms pose significant risks, serving as reservoirs of persistent contamination and facilitating cross-contamination of food products and processing equipment during production cycles (Panebianco et al., 2024).

In practice, the success of biofilm removal depends not only on the inherent resistance of embedded cells but also on the choice of sanitizer (type, concentration), exposure time, and the cleaning protocol (e.g., whether preceded by physical removal). Differences in biofilm age, thickness, and presence of organic soiling further complicate disinfection efficacy (Hua et al., 2019; Pracser et al., 2024). Within the food industry, a variety of disinfectants are approved and commonly used, including: quaternary ammonium compounds (Quats /QACs), chlorine-based compounds (e.g., sodium hypochlorite, chlorine dioxide), hydrogen peroxide, peroxyacetic acid (PAA), organic acids (e.g., acetic, citric, and lactic acids), and natural antimicrobials (e.g., thymol, plant extracts). Among these, PAA stands out as a “green” option because it decomposes into benign residues (e.g., water, acetic acid, and oxygen) and leaves minimal harmful by-products (Arthur et al., 2025). Its strong oxidizing power contributes to its disinfectant potential, and it is often considered effective against biofilms (Skowron et al., 2019). However, the literature has also reported limitations in the use of PAA against *L. monocytogenes*

biofilms. In many cases, standard industrial dosages (e.g., 50–200 ppm PAA, exposure 1–2 min) result in only partial inactivation of adherent cells (Arthur et al., 2025). Some studies show sublethal injury rather than complete kill, leading to potential biofilm regrowth or persistence. For example, in a comparative study of four sanitizers, PAA at 160–200 ppm reduced *L. monocytogenes* biofilm populations by log 4.0–4.5 over 5 min contact on SS and other surfaces, but did not fully eradicate biofilm under all conditions (Hua et al., 2019). In other studies, PAA treatment (0.5%, v/v) partially inactivated biofilms on SS surfaces after 60 sec, and nearly “complete” damage was only achieved after 180 sec, highlighting the importance of adequate exposure time and concentration (Lee et al., 2017). Moreover, *L. monocytogenes* biofilms are known to develop increased tolerance to repeated cleaning and disinfection cycles over time, which complicates long-term control strategies (Fagerlund et al., 2017). Given these challenges, there remains a pressing need for quantitative evaluations of commercial PAA-based disinfectants under conditions that closely replicate industrial environments. Future studies should assess their efficacy across a range of food-contact surfaces, using longer exposure durations, higher concentrations, and repeated treatments to more closely simulate real sanitation practices. Integrating these assessments with structural (e.g., FESEM) and viability analyses would provide deeper insight into the mechanisms of biofilm disruption, including matrix degradation and cell damage. Such comprehensive evaluations will facilitate the optimization of PAA-based formulations and support the development of more effective, evidence-based disinfection strategies for controlling *L. monocytogenes* biofilms in food-processing environments.

In the present study, we quantitatively evaluated the effectiveness of a commercial PAA-based food disinfectant (FC-01) in controlling *L. monocytogenes* biofilms formed on SS, a ubiquitous surface in food-processing facilities.

Materials and methods

1. Bacterial culture and growth conditions

L. monocytogenes ATCC® 13932™ (Fisher Scientific, USA) was maintained on BHI (Brain Heart Infusion) agar slants (HiMedia, India) at 4°C. For experimental use, a working stock was streaked onto fresh BHI agar and incubated at 30°C for 24 h. A single

colony from this working stock was then inoculated into BHI broth supplemented with 0.5% (w/v) sodium chloride and grown aerobically at 30°C with shaking (200 rpm) for 18 h to reach the stationary phase.

2. MIC determination

The MIC of the commercial PAA-based disinfectant (FC-01, Flussig Chem Co., Ltd., Thailand; 2.4% PAA stock) against planktonic *L. monocytogenes* was determined using the broth microdilution method according to Clinical and Laboratory Standards Institute (2023) and ISO 20776-1 (International Organization for Standardization, 2019), with minor modifications. Briefly, an overnight culture was adjusted to approximately 3×10^8 CFU/mL, corresponding to a 0.5 McFarland turbidity standard. In sterile 96-well plates, 200 μ L of the bacterial suspension was mixed with two-fold serial dilutions of FC-01 to obtain final PAA concentrations of 0 (negative control), 15, 30, 60, 120, 240, 480, and 720 ppm, and exposed for 5 or 10 min. Following incubation at 30°C for 24 h, 100 μ L from each well was plated onto BHI agar and incubated at 30°C for 48 h. The MIC was defined as the lowest concentration at which no visible colony growth was observed.

3. Preparation of SS coupons

Coupons (10 mm $\times$ 10 mm $\times$ 1 mm) made of AISI 304 (food-grade) stainless steel (SS) were used as substrata for biofilm formation. Before use, each coupon was immersed in 70% ethanol for 30 min, then thoroughly rinsed with sterile distilled water and sterilized by autoclaving at 121°C for 15 min.

4. Biofilm formation on SS coupons

Biofilm formation was performed according to the method of Lee et al. (2017) with minor modifications. A sterile SS coupon was placed in each 35-mm-diameter well of a 6-well polystyrene plate (Corning, USA). Each well received 2 mL of BHI broth containing *L. monocytogenes* at approximately 1×10^8 CFU/mL (0.5 McFarland) and 0.5% NaCl. Plates were incubated statically at 30°C for 5 days to allow biofilm development. After incubation, biofilm cells were quantified by transferring two coupons into 10 mL BHI broth, gently vortexing, serially diluting in 0.1% peptone water, plating in duplicate on BHI agar, and incubating at 37°C for 24 h.

5. Adhesion and crystal violet staining

Bacterial adhesion on SS coupons was assessed using the Gram staining method (Stepanović et al., 2007). Biofilm-coated SS coupons were gently washed 3 times with 1 $\times$ PBS (pH 7.4; Gibco, USA) to remove unattached

cells. Coupons were fixed in absolute ethanol for 15 min and air-dried. Each coupon was stained with 0.1% (w/v) crystal violet (M&P IMPEX, Thailand) for 30 min. Excess dye was washed off with deionized water, and the coupons were air-dried.

6. Disinfection of *L. monocytogenes* biofilms on SS coupons

After 5 days of biofilm growth, coupons were gently rinsed three times with PBS to remove planktonic cells. Each coupon was placed in a 24-well plate and treated with freshly diluted FC-01 disinfectant at 1% (240 ppm), 2% (480 ppm), and 3% (720 ppm) for 5, 10, or 15 min. The reaction was stopped with 0.5 mL sodium thiosulfate solution to neutralize residual PAA (Baldry, 1983). Controls included a positive control (biofilm-containing coupon treated with PBS (no disinfectant) and a negative control (a sterile coupon without biofilms). After treatment, coupons were transferred into fresh BHI broth (1 mL) and incubated at 37°C for 24–168 h. Turbidity and plating results were recorded as “+” (growth) or “–” (no growth).

7. FESEM analysis of biofilms

Biofilm morphology before and after disinfectant treatment was examined using FESEM, following protocols adapted from Arunachalam & Davoodbasha (2021). Briefly, coupons were rinsed 3 times with PBS, fixed in 2.5% glutaraldehyde (in 0.1 M sodium cacodylate buffer) for 2 h at room temperature or overnight at 4°C, and washed 3 times with PBS (10 min each). Samples were dehydrated through a graded ethanol series (50%, 60%, 70%, 80%, 90%, 95%, and 99.8% $\times$ 2, 15 min each), followed by critical-point drying. Dried samples were sputter-coated with gold and visualized using a FESEM (MIRA3, Tescan, Czech Republic) at the Science and Technology Research Equipment Center, Silpakorn University.

8. Statistical analysis

All experiments were conducted in triplicate using independent cultures and freshly prepared media. Biofilm cell counts (CFU/cm²) were log-transformed before calculating means $\pm$ SEM (standard error of the means). Statistical analyses were performed using one-way analysis of variance (ANOVA) to evaluate differences among FC-01 concentrations at each exposure time. When significant differences were detected, Tukey’s post hoc test was applied for multiple comparisons. Differences were considered statistically significant at $p < 0.05$.

Results and discussion

1. Antibacterial activity of PAA against planktonic *L. monocytogenes* cells

The MIC of FC-01, a PAA-based disinfectant, against planktonic *L. monocytogenes* was determined to be 60 ppm, which effectively reduced the bacterial population from approximately 8.5 log CFU/mL to undetectable levels within 10 min (see Table 1). This MIC aligns well with previously reported values ranging from 60 to 75 ppm, depending on strain variability, culture conditions, and assay design (Arvaniti et al., 2021).

Table 1 Dose-dependent effects of PAA-based FC-01 on the growth of planktonic *L. monocytogenes*

Concentration (ppm)	Cell count after treatment (CFU/mL)		Log reduction	
	Exposure duration at 5 min	Exposure duration at 10 min	Exposure duration at 5 min	Exposure duration at 10 min
15	$(1.0 \pm 0.06) \times 10^3$	$(0.9 \pm 0.07) \times 10^3$	5.65 ± 0.10 ^a	5.60 ± 0.03 ^a
30	$(1.7 \pm 0.2) \times 10^3$	$(1.2 \pm 0.2) \times 10^3$	5.42 ± 0.05 ^a	5.57 ± 0.03 ^a
60	$(2.0 \pm 0.3) \times 10^2$	ND	6.35 ± 0.07 ^b	>6.0 ^b
120	ND	ND	>6.0 ^b	>6.0 ^b
240	ND	ND	>6.0 ^b	>6.0 ^b
480	ND	ND	>6.0 ^b	>6.0 ^b
720	ND	ND	>6.0 ^b	>6.0 ^b

Remark: Data are presented as mean±SEM from at least 3 independent experiments. Different superscript letters within the same column indicate significant differences (p<0.05), as determined by one-way ANOVA followed by Tukey's post hoc test. ND denotes no detectable cells after treatment; the Initial cell concentration was ~4.5×10⁸ CFU/mL.

The potent and rapid bactericidal effect of PAA can be attributed to its strong oxidative potential, which causes irreversible damage to bacterial cell envelopes, disrupts membrane permeability, and induces protein denaturation and DNA degradation (Kim & Huang, 2021). Compared with traditional disinfectants such as sodium hypochlorite, PAA exhibits superior antimicrobial activity even at lower concentrations and retains efficacy in the presence of organic load (Mahamud et al., 2025). Our findings reinforce the utility of PAA as an efficient sanitizer for controlling *L. monocytogenes* in aqueous systems and on food-contact surfaces.

2. Efficacy of PAA against *L. monocytogenes* biofilm cells on SS coupons

The bactericidal efficacy of FC-01 against *L. monocytogenes* biofilms was evaluated on SS coupons, with treatment concentrations of 240, 480, and 720 ppm for exposure times of 5, 10, and 15 min (Table 2). At 240 ppm, bacterial regrowth was observed after 48 h, indicating incomplete inactivation of biofilm-embedded cells. In contrast, the untreated control exhibited visible

regrowth within 24 h, while sterile negative controls remained free of contamination for at least 120 h. Increasing the concentration to 480 ppm extended the delay in regrowth to 72 h, whereas 720 ppm completely inhibited bacterial recovery for up to 168 h (7 days), independent of exposure time. Statistical analysis did not apply to Table 2 because the data are presented as binary outcomes (presence or absence of regrowth), which do not allow for meaningful statistical comparison. It should also be noted that biofilm cell quantification was performed at 37°C to assess bacterial recovery under optimal growth conditions, providing a conservative, worst-case scenario. However, biofilm formation and treatment experiments were conducted at 30°C to better reflect typical conditions in food-processing environments.

The persistence of biofilm-associated *L. monocytogenes* cells despite disinfectant treatment is likely due to the limited diffusion of PAA through the extracellular polymeric substances (EPS) matrix, which serves as a physical and chemical barrier (Maillard & Centeleghe, 2023). Additionally, biofilm cells often adopt metabolically dormant or stress-adapted states, conferring enhanced tolerance to oxidative and chemical stressors (Klopper et al., 2023). Such resilience underscores the need for optimized sanitization parameters that ensure both adequate concentration and sufficient exposure time for complete inactivation.

Table 2 Dose-dependent effects of PAA-based FC-01 on *L. monocytogenes* biofilm cells on SS coupons

PPA Concentration (ppm)	Exposure duration (min)	Post-treatment regrowth (h)
Untreated control	0	+ (24)
	5	+ (24)
240	10	+ (48)
	15	+ (48)
480	5	+ (48)
	10	+ (48)
	15	+ (72)
720	5	– (168)
	10	– (168)
	15	– (168)

Remark: All assays were conducted in triplicate with independent bacterial cultures. Symbols: (+) regrowth observed; (–) no regrowth detected following treatment. The initial sessile cell population on stainless steel (SS) coupons was ~1.0×10⁷ CFU/coupon.

3. Disruption of *L. monocytogenes* biofilm Integrity by PAA treatment

FESEM analysis provided direct visualization of biofilm disruption following PAA exposure. Untreated biofilms exhibited dense, multilayered cell clusters embedded within intact EPS, strongly adhering to the SS

surface (Fig. 1A). After treatment with 240 ppm PAA for 15 min, only minor surface irregularities were observed, and much of the biofilm structure remained intact (Fig. 1B). However, treatments with 480 ppm and 720 ppm for the same duration (Figs. 1C and 1D, respectively) resulted in pronounced ultrastructural damage, including cell shrinkage, membrane collapse, EPS perforation, and detachment from the substrate. Insets in Figs. 1C-D highlights these severe morphological disruptions, which correlate with the prolonged inhibition of bacterial regrowth observed microbiologically.

These morphological observations are consistent with the quantitative findings, reinforcing that higher PAA concentrations are critical for achieving complete biofilm eradication. Microscopic evidence revealed extensive structural disruption of the *L. monocytogenes* biofilm architecture, including cell lysis, surface pitting, and collapse of the EPS network. Such alterations indicate that PAA acts not only as a potent antimicrobial agent but also as a strong oxidizing compound capable of degrading key biochemical components of the biofilm matrix. Specifically, oxidative cleavage of polysaccharides and denaturation of matrix-associated proteins compromise the structural integrity of the EPS, thereby weakening cell–cell and cell–surface interactions (Olaimat et al., 2024). This matrix degradation ultimately facilitates biofilm detachment, reduces the likelihood of regrowth, and prevents recolonization on food-contact surfaces during subsequent processing cycles.

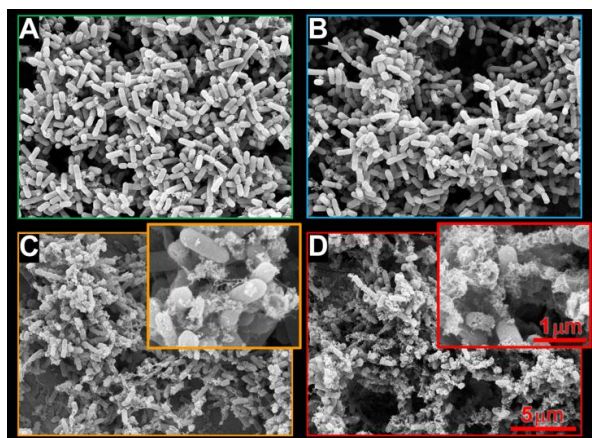


Fig. 1 FESEM images (10,000×magnification) of *Listeria monocytogenes* biofilms on SS coupons after 15-min exposure to the PAA-based disinfectant FC-01 at three concentrations: (B) 240 ppm, (C) 480 ppm, and (D) 720 ppm. Panel (A) shows the untreated control. Insets in panels (C) and (D) (50,000×magnification) reveal pronounced ultrastructural damage to biofilm cells, including cell shrinkage, perforated biofilm matrices, and extensive degradation of EPS.

4. Implications for food sanitation and biofilm management

Collectively, these results emphasize the complexity of *L. monocytogenes* control in industrial environments, where sublethal disinfectant levels may enable survival and regrowth. Continuous or improper exposure to low PAA concentrations can even select for stress-resistant phenotypes, complicating long-term sanitation efforts (Siderakou et al., 2022). Therefore, sanitation programs must adopt evidence-based optimization of both concentration and contact time to achieve complete biofilm elimination without compromising material integrity or safety standards. Moreover, *L. monocytogenes* often coexists with other environmental microbes, particularly *Pseudomonas* spp., in multispecies biofilms that further enhance resistance and resilience (Zhu et al., 2022). Future disinfection strategies should thus consider biofilm composition, microbial interactions, and surface characteristics when evaluating PAA or other oxidizing agents for industrial sanitation. Integrating advanced monitoring tools, such as confocal laser scanning microscopy or metabolomic profiling, could also improve understanding of residual viability and aid in developing next-generation disinfectant systems with improved biofilm-penetrating capabilities.

Conclusion

The present study demonstrates that complete inactivation of *L. monocytogenes* biofilms requires optimized PAA concentrations (≥ 720 ppm) and adequate exposure durations (≥ 5 min). Suboptimal conditions resulted in partial inactivation, allowing biofilm cells to survive and potentially recolonize food-contact surfaces. These findings emphasize the importance of optimizing disinfection parameters to ensure effective control of biofilm in food-processing environments. Incorporating validated PAA-based treatments, such as FC-01, into routine cleaning protocols can markedly reduce contamination risks, enhance food safety, and promote environmentally sustainable sanitation practices, as PAA decomposes into non-toxic by-products. Furthermore, the results highlight the inherent resistance of *L. monocytogenes* biofilms to chemical disinfectants, underscoring the challenge of their eradication under industrial conditions. Overall, this work reinforces the necessity of carefully balancing disinfectant concentration and contact time to achieve consistent and reliable biofilm elimination, thereby supporting the development of

evidence-based, sustainable hygiene management strategies for the food industry.

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Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative Artificial Intelligence in the Writing Process

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing and clarity. The authors carefully reviewed and edited the output and take full responsibility for the accuracy and integrity of the final content.

References

- Arthur, M., Afari, E.L., Alexa, E.A., Zhu, M.J., Gaffney, M.T., Celayeta, J.M.F., & Burgess, C.M. (2025). Recent advances in examining the factors influencing the efficacy of biocides against *Listeria monocytogenes* biofilms in the food industry: A systematic review. *Comprehensive Reviews in Food Science and Food Safety*, 24(1), e70083. <https://doi.org/10.1111/1541-4337.70083>
- Arunachalam, R., & Davoodbasha, M. (2021). Imaging bacteria and biofilm by field emission scanning electron microscopy. In Nag, M. & Lahiri, D. (Eds.), *Analytical Methodologies for Biofilm Research* (pp. 205–222). Springer. https://doi.org/10.1007/978-1-0716-1378-8_9
- Arvaniti, M., Tsakanikas, P., Papadopoulou, V., Giannakopoulou, A., & Skandamis, P. (2021). *Listeria monocytogenes* sublethal injury and viable-but-nonculturable state induced by acidic conditions and disinfectants. *Microbiology Spectrum*, 9(3), e01377-21. <https://doi.org/10.1128/Spectrum.01377-21>
- Baldry, M.G.C. (1983). The bactericidal, fungicidal and sporicidal properties of hydrogen peroxide and peracetic acid. *Journal of Applied Bacteriology*, 54(3), 417–423. <https://doi.org/10.1111/j.1365-2672.1983.tb02637.x>
- Clinical and Laboratory Standards Institute. (2023). *Performance standards for antimicrobial susceptibility testing* (33rd ed.; CLSI supplement M100). <https://iaclid.com/UpFiles/Documents/672a1c7c-d4ad-404e-b10e-97c19e21cdce.pdf>
- Fagerlund, A., Møretro, T., Heir, E., Briandet, R., & Langsrud, S. (2017). Cleaning and disinfection of biofilms composed of *Listeria monocytogenes* and background microbiota from meat processing surfaces. *Applied and Environmental Microbiology*, 83, e01046-17. <https://doi.org/10.1128/AEM.01046-17>
- Hua, Z., Korany, A.M., El-Shinawy, S.H., & Zhu, M.J. (2019). Comparative evaluation of different sanitizers against *Listeria monocytogenes* biofilms on major food-contact surfaces. *Frontiers in Microbiology*, 10, 2462. <https://doi.org/10.3389/fmicb.2019.02462>
- International Organization for Standardization. (2019). *ISO 20776-1:2019–Susceptibility testing of infectious agents and evaluation of performance of antimicrobial susceptibility test devices – Part 1: Broth micro-dilution reference method*. International Organization for Standardization. <https://www.iso.org/standard/70464.html>
- Kim, J., & Huang, C.H. (2021). Reactivity of peracetic acid with organic compounds: A critical review. *ACS ES&T Water*, 1(1), 15–33. <https://doi.org/10.1021/acsestwater.0c00029>
- Klopper, K.B., Bester, E., & Wolfaardt, G. M. (2023). *Listeria monocytogenes* biofilms are planktonic cell factories despite peracetic acid exposure under continuous flow conditions. *Antibiotics*, 12(2), 209. <https://doi.org/10.3390/antibiotics12020209>
- Lee, S.H.I., Barancelli, G.V., Corassin, C.H., Rosim, R.E., Coppa, C.F.S.C., & Oliveira, C.A.F. (2017). Effect of peracetic acid on biofilms formed by *Listeria monocytogenes* strains isolated from a Brazilian cheese processing plant. *Brazilian Journal of Pharmaceutical Sciences*, 53(3), e00071. <https://doi.org/10.1590/s2175-97902017000300071>
- Mahamud, A.S.U., Nahar, S., & Ha, S.D. (2025). Peracetic acid (PAA) exhibits higher antimicrobial efficacy compared to chlorine-based disinfectants against *Salmonella* Typhimurium on chicken skin and food-contact surfaces. *Poultry Science*, 104(9), 105450. <https://doi.org/10.1016/j.psj.2025.105450>
- Maillard, J.Y., & Centeleghe, I. (2023). How biofilm changes our understanding of cleaning and disinfection. *Antimicrobial Resistance & Infection Control*, 12, 95. <https://doi.org/10.1186/s13756-023-01290-4>
- Olaimat, A.N., Ababneh, A.M., Al-Holy, M., Al-Nabulsi, A., Osaili, T., Abughoush, M., ... Holley, R.A. (2024). A review of bacterial biofilm components and formation, detection methods, and their prevention and control on food contact surfaces. *Microbiology Research*, 15(4), 1973–1992.

- Panebianco, F., Lovisolo, S., Rubiola, S., Civera, T., & Di Ciccio, P. (2024). Will *Listeria monocytogenes* biofilm in the food industry withstand the eco-friendly technologies? Recent findings on electrolyzed water, plasma-activated water, ozone, and enzymes. *Current Opinion in Food Science*, 56, 101126. <https://doi.org/10.1016/j.cofs.2024.101126>
- Pracser, N., Voglauer, E.M., Thalgueter, S., Pietzka, A., Selberherr, E., Wagner, M., & Rychli, K. (2024). Exploring the occurrence of *Listeria* in biofilms and deciphering the bacterial community in a frozen vegetable-producing environment. *Frontiers in Microbiology*, 15, 1404002. <https://doi.org/10.3389/fmicb.2024.1404002>
- Ravindhiran, R., Sivarajan, K., Sekar J.N., Murugesan, R., & Dhandapani, K. (2023). *Listeria monocytogenes*: an emerging pathogen: A comprehensive overview on listeriosis, virulence determinants, detection, and anti-listerial interventions. *Microbial Ecology*, 86, 2231–2251. <https://doi.org/10.1007/s00248-023-02269-9>
- Rohilla, A., Kumar, V., & Ahire, J.J. (2024). Unveiling the persistent threat: recent insights into *Listeria monocytogenes* adaptation, biofilm formation, and pathogenicity in foodborne infections. *Journal of Food Science and Technology*, 61, 1428–1438. <https://doi.org/10.1007/s13197-023-05918-6>
- Siderakou, D., Zilelidou, E., Poimenidou, S., Paramithiotis, S., Mavrogonatos, E., Zoumpopoulou, G., ... Skandamis, P.N. (2022). *In vitro* virulence potential, surface attachment, and transcriptional response of sublethally injured *Listeria monocytogenes* following exposure to peracetic acid. *Applied and Environmental Microbiology*, 88(2), e0158221. <https://doi.org/10.1128/AEM.01582-21>
- Skowron, K., Wałęcka-Zacharska, E., Grudlewska, K., Grudlewska, K., Gajewski, P., Wiktorczyk, N., ... Gospodarek-Komkowska, E. (2019). Disinfectant susceptibility of biofilm formed by *Listeria monocytogenes* under selected environmental conditions. *Microorganisms*, 7(9), 280. <https://doi.org/10.3390/microorganisms7090280>
- Stepanović, S., Vuković, D., Hola, V., Di Bonaventura, G., Djukić, S., Ćirković, I., & Ruzicka, F. (2007). Quantification of biofilm in microtiter plates: Overview of testing conditions and practical recommendations for assessment of biofilm production by staphylococci. *APMIS*, 115(8), 891–899. https://doi.org/10.1111/j.1600-0463.2007.apm_630.x
- Zhu, J., Liu, J., Hong, X., & Sun, Y. (2022). Synergism with ε-Polylysine hydrochloride and cinnamon essential oil against dual-species biofilms of *Listeria monocytogenes* and *Pseudomonas lundensis*. *Frontiers in Microbiology*, 13, 885502. <https://doi.org/10.3389/fmicb.2022.885502>