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Plasma assisted sanitation of food and packaging materials

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Foodborne diseases remain a major global health challenge, resulting in more than 420,000 deaths each year (WHO). This underscores the need for the agri-food industry to adopt innovative, sustainable processes that ensure food safety, quality, and nutrition. Food packaging is crucial in this context, serving as a barrier against external contaminants to maintain safety and quality. However, if not correctly managed, packaging materials can pose additional risks [1].

Cold plasma technology (CAP) and plasma-activated water (PAW) show great promise due to their efficiency in generating antimicrobial reactive species [2], [3]. This study presents two plasma-based systems for packaging and food decontamination. The packaging decontamination system uses a surface dielectric barrier discharge (SDBD) plasma source [4]. It achieves inactivation rates higher than 3.5 Log for *Staphylococcus epidermidis* (Gram-positive) and higher than 4.5 Log for *Acinetobacter baumannii* (Gram-negative) [5]. Statistical analysis highlights key factors that enhance its biocidal effect, including a smaller treatment chamber, higher duty cycle, and mist injection, with Gram-negative bacteria showing greater sensitivity.

The food decontamination system combines a corona plasma source with an ultrasonic nebulizer to generate reactive oxygen and nitrogen species-rich plasma-activated aerosol (PAA) from various liquids. Integrated into a 4 L treatment chamber, this system achieved a Log reduction higher than 4.5 for *S. epidermidis* on glass within 10 minutes using deionized water. Experiments with phosphate-buffered saline (PBS) and sodium thiosulfate solutions ($Na_2S_2O_3$) suggest that peroxynitrite ($ONOO^-$) could play a key role in inactivation, as Log reductions dropped below 2.5 with PBS and below 1.0 with sodium thiosulfate. A scaled-up 14 L version further improved treatment uniformity, achieving complete inactivation of *S. epidermidis*, *Escherichia coli,* and *Candida albicans* on glass surfaces. These results demonstrate the potential of these systems based on CAP technology and provide insight into antimicrobial mechanisms.

References

[1] C. Maccaferri *et al.*, "Evaluating atmospheric pressure cold plasma decontamination techniques for packaging materials: a systematic review and meta-analysis", *Frontiers in Physics*, 12, 2024, doi: 10.3389/fphy. 2024.1399720.

[2] P. Isabelli *et al*., "Rotating Dielectric Barrier Discharge Plasma Source for Effective Bacterial Decontamination of Bioaerosols", *Plasma medicine*, 14, 1, 2024, doi: 10.1615/PlasmaMed.2024053628.

[3] R. Montalbetti *et al.* "Production and Chemical Composition of Plasma Activated Water: A Systematic Review and Meta-Analysis'', *Plasma Processes and Polymers,* e2400249, 2025, doi: 10.1002/ppap.202400249.

[4] C. Maccaferri *et al.,* "Evaluation of the Antimicrobial Efficacy of a Large-Area Surface Dielectric Barrier Discharge on Food Contact Surfaces", *Plasma Chemistry and Plasma Processing*, 43, 6, 2023, doi: 10.1007/s11090-023-10410-2.

[5] C. Maccaferri *et al.*, "Optimisation of plasma processes for decontamination of bacterial contaminants on polymeric food packaging materials", *J Phys D Appl Phys*, 58, 5, 2025, doi: 10.1088/1361-6463/ad8d63.

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