# Atmospheric Pressure, Low Temperature Plasma applications for decontamination of agrifood products

D Aceto(*)1, P R Rotondo[2], M Ambrico[1], G Dilecce[1], F Faretra[2], R M De Miccolis Angelini[2], P F Ambrico[1]

[1] *CNR Istituto per la Scienza e Tecnologia dei Plasmi – Sede di Bari – c/o Dipartimento Interateneo di Fisica - Università degli Studi di Bari "A. Moro", Via Giovanni Amendola 173 - 70126 Bari (BA)*

[2] *Dipartimento di Scienze del Suolo, della Pianta e degli Alimenti (Di.S.S.P.A.), Università degli Studi di Bari "A. Moro", Via Giovanni Amendola 165/A - 70126 Bari (BA)*

(*) domenico.aceto@istp.cnr.it

Over the past ten years, the demand for effective, novel, and non-chemical approaches to food production and plant protection has driven the development of new technologies. These tools aim to enhance microbial decontamination, trigger self-defense mechanisms against pathogens, and improve the biometric and nutraceutical properties of fruits and plants. Among these innovations, low-temperature plasma (LTP) has emerged as a groundbreaking tool in modern agriculture, offering diverse applications ranging from seed treatment to soil enhancement [1]. Such applications involve exposing agricultural systems to LTP, leading to the generation of reactive species such as reactive oxygen species (ROS) and reactive nitrogen species (RNS), which are widely regarded as responsible for the reported beneficial effects exhibiting significant potential in influencing plant growth, stress response, and overall crop performance. In this contribution, we report on various approches we have undertaken in an effort to exploit the potential application of LTP in the decontamination of agrifood product.

We used a volume dielectric barrier discharge (VDBD) reactor to directly treat fungal spores deposited on different agarized media to assess the decontamination potential of plasma technologies. VDBD is the richest plasma environment in terms of antimicrobial agents, exposing the samples to radiation (UV/VIS/NIR), direct impact of ions and electrons, radical and atomic species. Plasma was characterized in terms of Plasma Induced Emission (PIE) and electrical characteristic. From PIE a strong electric field was inferred together with a fast thermal heat shock (lasting hundreds of μs).

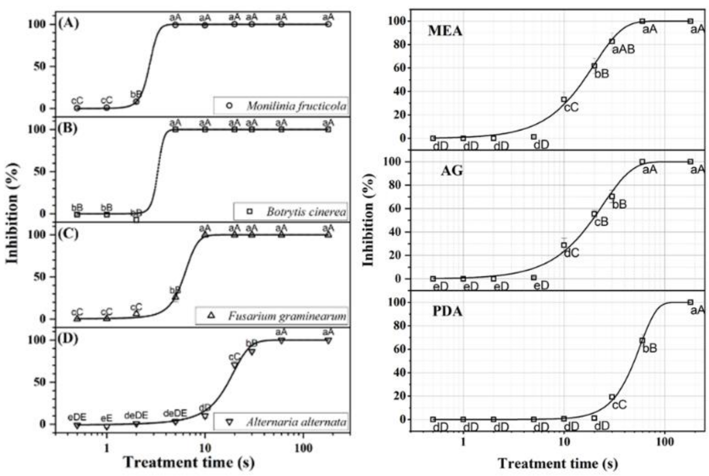


*Figure 1 – A) Response of different fungal species to VDBD treatments in conidial germination tests on WA; B) Response of A. carbonarius to VDBD treatments in conidial germination tests on different agarized media.*

The electrical characteristics of the discharge apparatus was shown to be dependent on the agarized medium used. In vitro studies on water agar (WA) showed that *B. cinerea* and *M. fructicola,* with unicellular conidia and similar melanin content, reacted similarly to the treatment (Figure 1A). *F. graminearum* and *A. alternata*, both having multicellular conidia, were more resistant, showing different sensitivity likely due to a different content in melanin. In the case of *A. carbonarius* conidia the inhibition was influenced by the complexity and composition of the medium used, being PDA the artificial medium that more hindered the plasma treatment (Figure 1B). Low temperature plasma could thus be useful in the control of fungal species but different factors can influence antimicrobial activity, and treatment conditions must be carefully chosen to achieve a complete decontamination [2].

However, direct plasma treatment are confined to the surface of the samples, preventing interaction with the entire plant tissues, may expose them to harsh conditions and present a difficult to overcome technological challenge in their adaptation to the industrial pipeline. Consequently, alternative strategies are essential for specific applications, such as the production of plasma-activated media as means to vehiculate the reactive species produced in the plasma to the biological target of the treatment. Plasma Activated Water (PAW) has assumed a prominent interest, offering promising potential as a decontaminating agent. Using a custom-made surface dielectric barrier discharge (SDBD) reactor we produced PAW to elucidate its decontaminating potential against fungal (*B. cinerea*) and bacterial (*B. subtilis* and *X. campestris*) microorganisms. Almost complete decontamination was achieved by using PAWs produced in treatments of different duration (subjected to different plasma doses) highlighting the role of the concentration of RONS (in particular $H_2O_2$, $NO_2^-$ and $NO_3^-$, shown in figure 2) in the inhibition process [3].

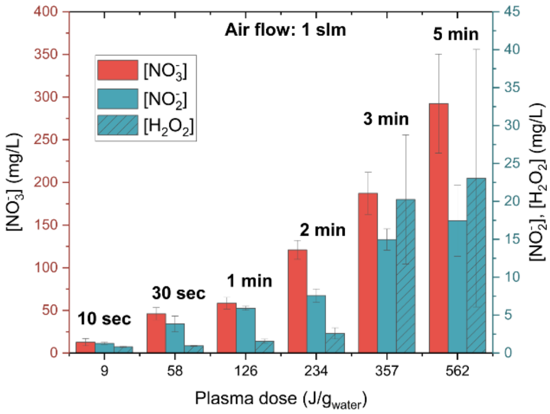


*Figure 2 – Quantification of reactive species dissolved in PAW produced through a SDBD.*

Finally, we present a novel and promising technological application of LTP to effectively eliminate harmful pathogens and chemical contaminants present on agricultural produce. In our approach, we utilized the effluent gas from a VDBD reactor (cylindrical geometry, coaxial electrodes) to nebulize water via the Venturi effect, resulting in the creation of Plasma Activated Fog (PAF). PAF can be conveyed in a treatment chamber, achieving an antimicrobial environment without apparently compromising the integrity or nutritional value of the food. RONS are vehiculated to the biological substrate by the microdroplets, thus increasing the possibility of their interaction with the sample. Moreover, the dimension of the droplets (< 5 μm) prevent the sample for becoming wet during the treatment, thus further limiting the rotting process and extending the shelf-life of the treated produce. Notably, our preliminary findings include successful decontamination against various fungal pathogens, the elimination of chemical pesticides and insecticides, as well as a potential insecticidal effects [4].

**Acknowledgments**

D.A. and P.F.A. Acknowledge the project ''Plasma Reactors for Agrifood industry (PlasmaReA)'' b5667f07, in the framework of POC PUGLIA FESRT-FSE 2014/2020 Fondo Sociale Europeo (C(2015)5854 del 13/08/2015) Riparti (assegni di Ricerca per riPARTire con le imprese).

**References**

[1] E M Konchecov et al, *J. nt. J. Mol. Sci.* **2023**, *24*(20), 15093
[2] P R Rotondo et al, *Plasma Chem Plasma Process* **2023**, 43, 1819–1842
[3] P R Rotondo et al., „*Antimicrobial activity of plasma activated water against bacteria and fungi affecting the quality of plant products*", under submission
[4] D Aceto et al, „*Plasma activated fog: a novel response to the agrifood industry demands*", under submission