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Effects induced on the bacterial cells of *E. coli* by the cold air plasma and/or cold air plasma activated water

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Cold air plasmas in direct contact with liquids and air plasma activated water (PAW) and liquids are nowadays of the great interest, since they induce chemical changes via formation of reactive oxygen and nitrogen species (RONS) in the liquid phase. Thanks to the synergistic effects of the plasma agents (electric field, electrons and ions, UV radiation, RONS) and the induced chemical changes in the liquid, cold air plasmas and PAW are known for their bactericidal or cytotoxic effects in biomedicine or food processing [1-3].
In this work, we investigated the effects of the direct cold air plasma treatment and indirect treatment of PAW on model bacterial cells (cell viability, membrane damage by electric field or RONS, and metabolic activity). Self-pulsing transient spark (TS) discharge with the electro-spray was used for the treatment of either the bacterial suspensions of *Escherichia coli* or aqueous solutions with different buffering capacities and pH. The electrospray enhanced the mass transfer of gaseous reactive species into the treated liquid solutions [4]. Direct treatment of bacteria in non-buffered solution showed 6 log reduction in contrast with 2 logs in the buffered solution. Strong bactericidal effect is linked mainly with the peroxynitrites chemistry associated with the acidification and formation of cytotoxic radicals as $OH^{\cdot}$ and $NO_2^{\cdot}$. Fluorescent staining of the cell membrane after the direct plasma treatment did not show membrane poration due to the TS-induced electric field. This indicated formation of only temporary and reversible membrane electroporation, which most likely enhanced the oxidative damage of the membrane by RONS. This resulted in the cells death confirmed by the measured minimal metabolic activity of the directly treated bacteria in non-buffered solution.
Indirect treatment was performed as the incubation of bacteria with the plasma treated solutions for a certain time. 10 min incubation with PAW showed 1-2 log reduction of bacteria and it was increasing with the increasing incubation time (up to 4-5 log in 60 min). Very weak bactericidal effect (only 0.1-0.3 log) achieved by the indirect treatment with plasma activated buffer solution pointed at the importance of the peroxynitrites chemistry. Peroxynitrite acidic decay to $OH^{\cdot}$ and $NO_2^{\cdot}$ radicals is responsible for the strong bactericidal effect of PAW. Furthermore, peroxynitrite chemistry is temperature dependent and with the decreasing temperature or with deep freezing PAW may preserve the bactericidal properties (Fig. 1).

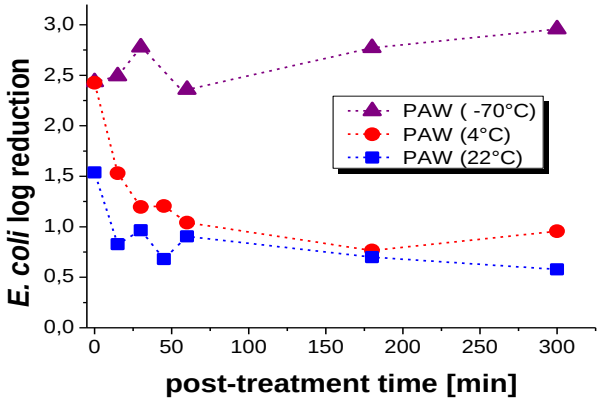

Fig. 1 Bactericidal effects of plasma activated water in post-treatment time at different PAW storage temperatures, 10 min incubation in PAW.

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References

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