Abstract

In this PhD. thesis, we investigate the combination of the plasma-activated water with a pulsed electric field treatment for bacterial decontamination. Three different devices were used to produce the plasma-activated water (PAW), the transient spark electrospray generated in an open-air condition, and the transient spark batch in a closed-air environment in a large reactor and in a small reactor. We measured the chemical concentration of NO_2^-, NO_3^-, and H_2O_2, pH, the conductivity, and the temperature in the plasma-activated water. The evolution of the concentration in NO_2^- and H_2O_2 was measured post-discharge. The open-air discharge showed H_2O_2concentration twice superior to NO_2^- , while the closed-air batch system after 3 min exposure time showed 6 times more NO_2^- than H_2O_2. Increased exposure time can increase this NO_2^- dominance over H_2O_2 in the closed reactor. The NO_2^- and H_2O_2 concentrations post-discharge decrease due to their mutual recombination to form peroxynitrous acid ONOOH.

The antibacterial effect was measured on Gram-negative bacteria *E. coli* and Gram-positive *S. epidermidis*. The antibacterial effect of PAW on *S. epidermidis* increased with the exposure time and the incubation time, and was stronger for the small compared to the large batch reactor. The antibacterial effect against *E. coli* was similar for the large, closed reactor as for the electrospray system. We observed an antibacterial synergy of the non-lethal pulsed electric field (PEF) treatment in combination with the incubation in PAW in the presence of both NO_2^- and H_2O_2 in the PAW. We link this synergy to the generation of peroxynitrous acid which is unstable and generates radicals $^{\bullet}OH$ and $NO_2^{\bullet}$. $^{\bullet}OH$ radical is known to peroxidize the lipids of the cell membrane, increase the membrane viscosity, decrease its resistivity, and decreases its thickness that fragilizes the cells to the PEF treatment. The lipid peroxidation induced by the PAW was measured by TBARS standardized method. The fragilization of the membrane by the PAW to the PEF treatment was estimated with microscopy observation on unilamellar vesicles of phospholipids. A Comsol Multiphysics calculation of the electric field on the droplet suggested that the electric field of the transient spark electrospray was too low for generating permeabilization. However, the combination PAW + PEF is promising for bacteria decontamination, as well as for further agriculture, cosmetic, food industry, and therapeutic

applications. Both the chemical effect of the reactive oxygen and nitrogen species and the physical effect of the PEF need to be considered