Analysis and Simulation of Transport of Plasma-Activated Mist in Food Safety Applications

LORENZ E. (1,2), KARWE M. (2)
1 PepsiCo, Valhalla, United States
2 Rutgers University, New Brunswick, United States

Non-thermal plasma (NTP) is an emerging technology that has the ability to treat foods to extend their shelf lives and reduce microbial loads. The reactive oxygen and nitrogen species (RONS) in air-based plasma are the primary antimicrobial agents; however, current NTP methods do not generate these species in high enough concentrations for NTP to become a commercial technology in the food industry. Plasma-activated mist (PAM) is an emerging application of NTP which contains RONS such ozone, hydrogen peroxide, and peroxynitrite. These RONS are in higher concentrations in PAM than other NTP methods as a result of the high surface to volume ratios that allow effective mass transfer of the RONS. However, in order apply the PAM treatment commercially, it is essential to ensure that the PAM treatment effectively covers the target surface where microbial inactivation is desired. As such, analyses of the fundamental transport mechanisms are necessary in order to understand how PAM is transported in space and how effectively it transfers the antimicrobial charge load to the target surface.

To understand this mechanistically, COMSOL Multiphysics® was used to develop a fluid-flow model to simulate the transport of PAM particles with diameters between 2 µm and 20 µm within a 36 L chamber. This included fluid dynamics, particle-particle-surface electrostatic interactions, and chemical reactions. Computational fluid dynamics and particle-tracing were used to track the flow of PAM microdroplets and evaluate non-uniformity of exposure to PAM.

Numerical simulations demonstrated that PAM microdroplets did not evenly distribute within the model chamber, but rather, separated based on particle size. 20 µm particles do not progress far from the PAM inlet source, whereas 2 µm droplets follow the air flow streamlines and transport more evenly throughout the chamber. In turbulent simulations, less than 50% of PAM microdroplets attached to the bottom surface of the chamber where the microbial inactivation was being evaluated. This uneven distribution will require further research so as to consider all aspects of fluid transport when implementing PAM in a commercial setting.