606c Experimental and Theoretical Challenges of Uv Dose Distribution Studies in Food Liquids

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Commercial UV reactors are flow-through systems and they have a distribution of exposure time due to flow distribution and light irradiance gradient due to UV light attenuation in a medium with high absorptive properties such as food liquids including fresh juices, liquid sugars and marinades. Consequently, the variation in UV doses that any given microorganism will be exposed to during the inactivation process can significantly alter the required performance standard of the reactor. The determination of dose distribution, minimum and maximum UV doses is of high importance in the design of continuous UV process. Based on earlier calculations, it was demonstrated that survivors in a portion of insufficiently irradiated liquid dominate the final result of inactivation, while partial over-irradiated portions with no survivor cannot be compensated. In absorptive liquids portions of the solution that have the radial position further from UV–source and minimum path length due to insufficient mixing would receive a minimal UV dose and thus represent the insufficiently irradiated portions. That means that UV process calculated based on the maximum dose will deliver a safe process.

Different designs of UV reactors including turbulent and laminar flow dynamics currently being validated for use in food processing in order to overcome the interference of high UV absorptivity and turbidity associated with food liquids. While there is currently no practical method available for measuring the dose distribution, dose delivery can be assessed using modified bioassay method employing the injection of target bacteria as a tracer. This approach can be also used to provide separate information of the UV dose distribution in juices when the UV lamps are ON and mean residence time and RTD when the lamps are OFF. The use of this approach can help in interpretation of biodosimetry results of actual performance of the reactor and to improve the efficiency of the process.

Computing the UV inactivation was another challenge to evaluate performance of UV processing reactors. In the current study, mathematical modeling was used as a tool to evaluate the inactivation performance of UV reactors with the different hydraulics design based on calculation of the UV fluence rate in a treated medium. UV fluence rate (irradiance) distribution was calculated using Multiple Point Source Summation Method. Laminar flow in annulus is defined by Poiseuille's Law and radial variation of residence time of the liquid can be computed. In addition, modern software is capable of predicting particles and fluid velocities, particle mixing, and residence times. Assuming first order reaction kinetics, the change in bacterial count can be computed in radial direction of the tube.

In order to do the calculations, the reaction kinetic rate constant of specific target bacteria must be known as well as absorptive and rheological properties of the treated foods. The bench-scale collimated beam device has evolved as a standard method for determination of dose-response relationships in a treated medium. This method has significant drawbacks for food liquids that have low UV light transmittance due to attenuation of UV light on the surface of the liquid in the petri dishes or in thin cuvettes and thus results in significant gradient of UV irradiance in the sample. In addition, very limited kinetic data for human pathogens are available for fresh juices and other food liquids. The objective of the study was to generate kinetic parameters of UV inactivation of E. coli K12 using annular single lamp UV reactors. These data are to be used to predict microbial lethality and UV dose distribution in multiple lamp UV reactors.

The testing was conducted in the range of flow rates using caramel buffer model to mimic absorptive properties of some food liquids. To conduct the bioassay of UV dose distribution in the single and multiple lamp UV reactors, we used Eschericia coli K12 in a manner analogous to that for a salt tracer injection study. Bacteria were injected into the flow stream of model solution at the entrance to the tube after steady-state condition was achieved. The outflow fractions were collected as function of time after

injection. The distribution of unirradiated bacteria reflected the RTD within the UV reactor and was use to estimate mean residence time in the reactor. The distribution of surviving UV irradiated bacteria reflected the combined effects that flow distribution (RTD) and light irradiance distribution (LID) can have on UV radiance exposure of bacteria. More studies are planned to conduct to investigate the flow and UV fluence distribution in the reactors using biological tracers and to validate the modeling approach.