Smiling face of mathematical modeling –
Romancing with Computational Fluid Dynamics (CFD)

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Modeling in food processing is an interdisciplinary approach involving engineering approaches for transport phenomena driving the process with chemistry, reaction kinetics and predictive microbiology. Essential aspects of a mathematical model are to define physical, chemical or biological changes during a process, develop mathematical basis of this process with appropriate assumptions, solve the problem with required mathematical background and validate the model for various processing conditions. Therefore, mathematical models to simulate food processing operations must be physics-based describing the transport phenomena (formulation of continuity, energy and momentum equations with initial and boundary conditions) occurring during the process. With this background, they can be applied in design and optimization of food processing systems.

Calculations for a mathematical modeling study involve the solution of sets of equations analytically or computationally. While the first one has limitations, an efficient analysis tool that is widely used for the latter case is CFD. CFD is based on numerical methods predicting governing transport mechanisms over a multi-dimensional domain of interest. Since its first computer implementation in 1950s, it became a main tool to quantify complex problems in various industries including food processing. It was used to carry out comprehensive analysis and design efficient systems. Some fascinating subjects in food processing included thermal sterilization, pasteurization, baking, mixing, refrigeration, freeze-spray drying and cold storage.

CFD solutions start with forming computational geometry and meshing and continue with solving partial differential equations with suitable numerical techniques. Without having a pre-knowledge on these issues lead to use of various CFD programs as black-box with limited control on results. However, having a certain knowledge on numerical modeling and maintaining a high level of accuracy through post-processing are required for effective use of CFD for design and optimization purposes. In this presentation, CFD methodologies bringing new innovative approaches into mathematical modeling will be described briefly with various examples in food processing, experimental model validation approaches and food processing design and optimization.