Using Computational Fluid-Dynamics (CFD) for the Evaluation of Tomato Puree Pasteurization: Effect of Orientation of Bottle

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Abstract

Introduction
In-package pasteurization is the most used method for tomato microbiological stabilization. The search for safer and better quality food has created a need to better understand the processes involved in producing it. However, little is known about the temperature and velocity profiles during the thermal processes of liquid foods in commercial packaging, which results in over-dimensioned processes to guarantee safety, decreasing the sensorial and nutritional characteristics of the product and increasing process costs. Determination of the temperature-time history may be derived by using direct measurements or by mathematical modelling. Because of the complex nature of heat transfer in natural convection heating, the determination of the slowest heating zone (SHZ), which is defined as the location in the can receiving minimum heating, is a difficult task. The placement of thermocouple probes to record temperature during heating at various positions in the container disturbs the flow patterns. This fact explains the interest in numerical simulations, which can predict the temperature evolution in the whole dominium of the can. For this purpose, computational fluid dynamics (CFD) offers a powerful tool for numerical predictions of the transient temperature and velocity profiles during natural convection heating of packed liquid foods. The objective of the present paper was to evaluate the effect of packaging orientation (conventional, inverted, and horizontal positions) in the pasteurization of tomato puree in a commercial glass bottle using CFD.

Use of COMSOL Multiphysics® software
In this work, natural convection heating of tomato puree was simulated by solving the governing equations of continuity, momentum and energy conservation, using the finite element method with COMSOL Multiphysics®. The analysis of the vertical bottle (conventional and inverted) was based on a 2D model (axial symmetry), while a 3D model must be considered for the horizontal orientation (symmetry in the longitudinal plane). The model was used to predict transient temperature and velocity distributions inside the product, as well as transient location of the SHZ during thermal process. A bacterial lethality kinetic (F-value) and another model to predict changes in quality factors (C-value) were coupled to heat transfer model in order to estimate time processing and final quality of tomato puree, respectively.

Results

The model developed allowed predict the effect of orientation of package on temperature distribution, flow pattern, position of SHZ, time processing and quality changes in tomato puree during pasteurization. It was observed that among the different orientations, the lowest processing time was obtained for the horizontal orientation, while no difference was found between the process times for the conventional and inverted orientations. Therefore, the lowest loss of quality, quantified by C-value, was achieved when the bottle was horizontally positioned.

Conclusion

The results obtained demonstrate the potential of using Computational Fluid-Dynamics (CFD) to evaluate thermal processes of liquids foods, such as tomato puree pasteurization. Moreover, the model developed can also be used to determine which set of operating conditions would enhance the quality and the safety of the final product, thus minimizing expensive and time-consuming pilot test-runs.