Microwave Inactivation of Bacteria Under Dynamic Heating Conditions in Solid Media

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Abstract

In food industry, pasteurization of food products remains of great interest in order to ensure the microbiological quality for consumers. Among recent innovative technologies, the microwave heating process has been successfully applied to inactivate pathogen organisms [1,2]. Nevertheless, the development of this technology needs to be improved, especially with a better knowledge concerning the interaction of bacteria with the electromagnetic field. In such a microwave process where heat is generated by dielectric losses, it is necessary to predict accurately the temperature distribution associated to the microbial inactivation of bacteria. In this study, COMSOL Multiphysics 4.2a is used to model a microwave heating process in a TE10 rectangular waveguide (3D geometry). The sample consists of a small cylindrical Ca-alginate gel (D=8 mm, H=10 mm) inoculated with bacteria Escherichia Coli K12. The sample is placed along the microwave propagation direction into the waveguide. Maxwell's equations and heat transfer are coupled to a microbial inactivation model [3] under dynamic heating conditions (RF Module, Heat Transfer Module and two ODEs). The microwave inactivation of bacteria from 20 to 64 °C is compared to a conventional inactivation by conduction with the same heating ramp of 9 °C/min during 4 min and 30 s. The 3D numerical model enables to predict the temperature associated to the local microbial inactivation within the sample as a function of time. The classical inactivation parameters (D and z values) are identified from experimental results issued from water bath inactivation. Numerical results describe quantitatively the temperature pattern where hot and cold spots are distributed within the sample during microwave heating (Figure 1). Due to the non-homogeneous thermal treatment, the global inactivation of bacteria does not exceed 1 log at the end of processing with an incident microwave power of 130 W. COMSOL's simulations are validated with experimental measurements of global inactivation during microwave and water bath heating (Figure 2). The study clearly demonstrates that the microwave heating of small cylindrical sample is not homogeneous under dynamic heating conditions. Due to the strong temperature heterogeneities, the local microbial inactivation is lower compared to a water bath inactivation by thermal conduction. The numerical simulation also indicates that the bacteria destruction during microwave heating is mainly due to a thermal effect. Further developments of the microwave pasteurization process should include a time-temperature control loop or a pulsed microwave heating in order to ensure a better thermal homogeneity within the processed sample.

Reference

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2. R. Giuliani, A. Bevilacqua, MR. Corbo, C. Severini, Use of microwave processing to reduce the initial contamination by Alicyclobacillus acidoterrestris in a cream of asparagus and effect of the treatment on the lipid fraction, Innovative Food Science & Emerging Technologies, 11(2), 328-334 (2010).
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Figures used in the abstract

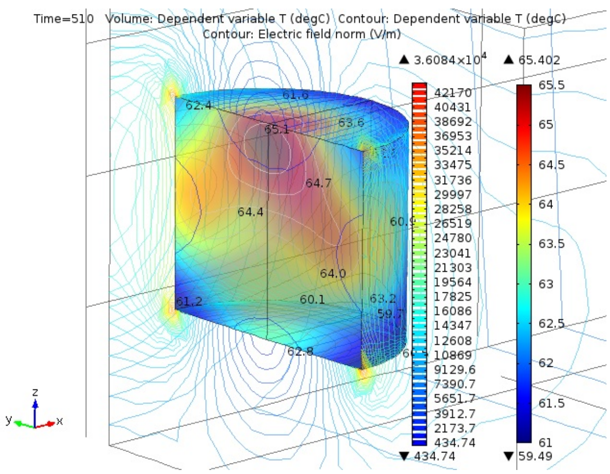

Figure 1: Temperature patterns and electric field distribution at the end of microwave processing.

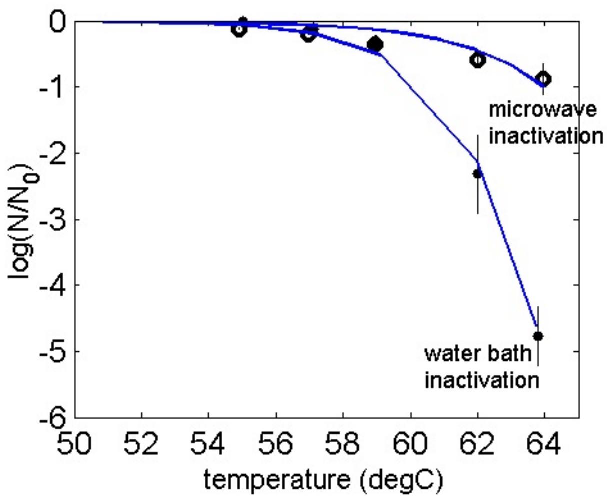

Figure 2: Comparison between microwave and water bath inactivation, (.) experimental measurements with standard deviation, (-) numerical model.