Microwave Assisted Freezing: Experiments and Modelling

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Microwaves assisted freezing. Experiments and modelling.

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Freezing is widely used in the food industry to preserve product quality thanks to the low storage temperature. It is well known that a faster freezing enhances frozen food quality while forming smaller ice crystals. Indeed large ice crystals damage cells membranes. However fast freezing processes are energy demanding. It is therefore a challenge to reduce process cost without increasing ice crystals size or to reduce ice crystal size without a dramatically increase of cost.

Some experimental studies have shown that it is possible to obtain smaller ice crystals by using electromagnetic waves assisted freezing [1–3]. The freezing process could thus be carried out with less intensive conditions. Nevertheless the optimisation of this new process requires that all involved phenomena responsible of improving ice nucleation are well understood. Two hypothesis are proposed to explain the lower crystals size: i) Water molecules rotations due to microwaves interfere with H-bond network, which could be a crystalline structure precursor [1]; ii) Microwaves heating induces a partial melting of ice crystals. The small temperature rise induced by microwaves pulses is followed by a rapid temperature decrease. The partial melting due to these temperature oscillations could induce a secondary nucleation [3].

This study aimed to model an innovative process of pulsed microwaves assisted freezing of a model gel (methylcellulose). The phase change model is based on spherical ice crystal growth and an original enthalpy formulation. The objective is to get a better understanding of thermal interactions between microwaves and product during freezing. The experimental device is characterized by a TE10 waveguide at 2.45 GHz (43 x 86 mm) in which gas nitrogen at -40°C is introduced. The sample of 9 g is placed at the centre of the waveguide crosssection where the electric field is the highest. Both nitrogen and microwaves reach the sample on the same surface. Other surfaces are insulated. Temperature is measured by optical fibres at several depths. Both microwave incident and reflected powers are measured. The 2D model was validated for both microwave heating and phase change independently first, then with the entire process. It allowed to observe spatial and temporal evolutions of the thermal and electromagnetic variables (temperature, electric field strength) and their effects, like resonance or development of hot spots.

[1] Y. Hanyu, M. Ichikawa, G. Matsumoto, An Improved Cryofixation Method - Cryoquenching Of Small Tissue Blocks During Microwave Irradiation, J. Microsc. 165 (1992) 255–271.
[2] M. Anese, L. Manzocco, A. Panozzo, P. Beraldo, M. Foschia, M.C. Nicoli, Effect of radiofrequency assisted freezing on meat microstructure and quality, Food Res. Int. 46 (2012) 50–54.
[3] E. Xanthakis, A. Le-Bail, H. Ramaswamy, Development of an innovative microwave assisted food freezing process, Innov. Food Sci. Emerg. Technol. 26 (2014) 176–181.