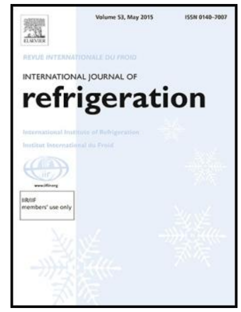

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Numerical Modelling of an Innovative Microwave Assisted Freezing Process

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Highlights

- An innovative pulsed microwave assisted freezing process was modelled
- Phase change was modelled using enthalpy formulation including ice crystal growth
- Thermophysical and dielectric properties were linked to the ice fraction
- Influence of microwave pulses on temperature oscillation amplitude was highlighted
- Freezing front location and reflection influence hot-spot displacement

Abstract

This study aimed to model an innovative process of pulsed microwave assisted freezing (MAF), which was expected to improve frozen product quality. The phase change model was based on spherical ice crystal growth and an original enthalpy formulation. The objective was to understand better the thermal interactions between microwaves and a product being frozen in a TE10 waveguide in which nitrogen gas and microwaves reach the product on the top surface. The 2D model was validated against the literature data and used to perform numerical simulations. The freezing front location and the reflection at air-product interfaces have a large impact on microwave behaviour in the product, especially on hot-spot displacement. As in some experimental works, temperature oscillations were observed. It is shown that their amplitude is related to the pulse duration. These results will help in designing experimental procedures to study the interest of using low energy pulsed microwaves during freezing.

Keywords:

Freezing; Pulsed Microwaves; Modelling; Crystallisation; Ice Fraction

Nomenclature

a	constant K
Cp	specific heat capacity $J.kg^{-1}.K^{-1}$
E	local electric field $V.m^{-1}$
h	specific enthalpy $J.kg^{-1}$
k	thermal conductivity $W.m^{-1}.K^{-1}$
L	solidification latent heat $J.kg^{-1}$
N	number of crystals
Q	heat source term $W.m^{-3}$
r	crystal radius m
T	temperature K
t	time s
V	volume m^3
x	mass fraction

Greek symbols

ε_0	vacuum permittivity $F.m^{-1}$
ε'	relative dielectric constant
ε''	relative dielectric loss factor
λ	wavelength m
ρ	density $kg.m^{-3}$