INNOVATIVE AND LOW ENERGY MICROWAVE ASSISTED FREEZING PROCESS FOR HIGH QUALITY FOODS

Alain LE-BAIL\textsuperscript{a,b}, S. CURET\textsuperscript{a,b}, M. HAVET\textsuperscript{a,b}, V. JURY\textsuperscript{a,b}, O. ROUAUD\textsuperscript{a,b}, M. SADOT\textsuperscript{a,b}, P. JHA\textsuperscript{a,b}, E. XANTHAKIS\textsuperscript{c}, S. ISAKSSON\textsuperscript{c}, L. ARHNE\textsuperscript{c}, M. SHRESTHA\textsuperscript{d}, J. HUEN\textsuperscript{d} & J-P BERNARD\textsuperscript{e}

\textsuperscript{a} ONIRIS-UMR GEPEA CNRS 6144, Nantes, France / \textsuperscript{b}UBL – Uni. Bretagne Loire / \textsuperscript{c}RISE, Research Institutes of Sweden – Agrifood and Bioscience, Gothenburg 41276, Sweden / \textsuperscript{d}TTZ-BILB, Bremerhaven, Germany / \textsuperscript{e}SAIREM, France

alain.lebail@oniris-nantes.fr
STRATEGIES TO REDUCE FREEZE DAMAGE

ENHANCING THE FREEZING RATE: ⚫ NUCLEATION RATE ⚫ ENERGY

USE OF NUCLEATING AGENTS: ⚫ NUCLEATION RATE

USE OF ALTERNATIVE PROCESS:
✔ PRESSURE SHIFT FREEZING
✔ ULTRASOUND NUCLEATION
✔ ELECTRIC and ELECTROMAGNETIC IRRADIATION

- STATIC ELECTRIC FIELD (SEF)
- STATIC MAGNETIC FIELD (SMF)
- OSCILLATING MAGNETIC FIELD ➔ INDUCED ELECTRIC FIELD
- OSCILLATING ELECTRO-MAGNETIC FIELD
- EMF = MICROWAVE, RF WAVES...

-A review on effect of dc voltage on crystallization process in food systems; Jha & al. IFSET 2017
-An overview on magnetic field and electric field interactions with ice crystallisation; application in the case of frozen food, Jha et al. Crystals 2017, 7(10),
2 STRATEGIES IN THE LITERATURE (& PATENTS)

A) CONSTANT ENERGY + REFRIGERATION
DISSOCIATION OF PENTAMERS $\rightarrow$ SUPERCOOLING

HANYU et al (1992),

B) PART TIME EMISSION OF ENERGY + REFRIGERATION
ASSUMPTIONS: ICE CRYSTALS DISRUPTION + $\rightarrow$ SECONDARY NUCLEATION


Anese et al., 2012, Food Research International 46 (2012) 50-54
Kim et al., 2011 (LG), US 2010/02295711 A1, Sept. 16, 2010
Lim et al. Patent EP 1 980 809 A2
Xanthakis, E et al. Development of an innovative microwave assisted food freezing process, (2014), Innovative Food Science and Emerging Technologies 26, 176-181

![Diagram showing the comparison between control and microwave-treated samples.](image)

- FREEZING WITH MICROWAVES
  « SMALLER ICE CRYSTALS
  « MORE UNIFORM DISTRIBUTION

Novel microwave technology for cryopreservation of biomaterials by suppression of apparent ice formation
Xanthakis et al. (2014): Microwave during freezing

- Degree of supercooling circa 92% (triggering of ice nucleation)
- 62% average ice crystal size vs. control. (Meat microstructure)
FREEZE WAVE (2015-2018)

1. BACKGROUND
2. PROJECT
3. RESULTS
4. OUTLOOK
FREEZE WAVE PROJECT (2015 - 2018)

FREEZE WAVE OBJECTIVES:
- UNDERSTANDING FREEZING WITH µWAVES
- BATCH PROCESS DEVELOPMENT
- CONTINUOUS PROCESS DEVELOPMENT
- INDUSTRY CONCEPTS & TESTINGS

FREEZE WAVE CONCEPT:
- APPLICATION OF LOW ENERGY MICROWAVES DURING FREEZING
  → REFINEMENT OF ICE CRYSTALS
  → HIGHER QUALITY FROZEN FOODS

FREEZE WAVE CHALLENGES:
- OPTIMIZING QUALITY vs ENERGY...

MODELLING (1 PhD)
EMULSIONS FRUITS & VEG. (1 PhD)
RTE MEALS (FISH) (1 Eng.)
MEAT (1 Post Doc)
PROTOTYPE SINGLE MODE MICROWAVES FREEZER

PROTOTYPE SYSTEM

SAMPLE:
METHYLCELLULOSE GEL
5 cm x 5 cm x 1 cm
PROTOTYPE MULTIMODE MICROWAVES FREEZER

LOW ENERGY MICROWAVES GENERATOR (5-150W)

COMMERCIAL FREEZER BATCH MW-OVEN

Freezing chamber
Air outlet
Sample
Optical fibre
Air Inlet
Inner view
FREEZE WAVE (2015-2018)

BACKGROUND

CHALLENGES OF FREEZE WAVE:
- OPTIMISATION OF MW POWER
- OPTIMISATION OF MODE OF EMISSION

RESULTS

![Diagram showing power over time with constant and modulated power]

MODULATED POWER ➔ TEMPERATURE OSCILLATIONS

CONSTANT POWER

TIME

➡️ FROZEN FOOD QUALITY?
QUALITY OF FROZEN FOODS

- TEXTURE
- DRIP LOSSES
- COLOR
- MICROSTRUCTURE
- SENSORY ANALYSIS
  - CRYOMEB
  - MICRO TOMOGRAPHY
  - CARNOY FIXATION
  - CELL DAMAGE vs MASS DIFFUSIVITY

(ttz Bremerhaven)
ICE CRYSTALS: X-ray MICROTOMOGRAPHY

MORE INFO; WEDNESDAY 12h15 ([O15.4]) and 12h45 (O15.6)
MW ASSISTED FREEZING: POTATO

Mean ice crystal size (mm)

Control @ -30°C
PMW-5W @ -30°C

Mean equivalent diameter of pore (mm)

Pore size distribution (%)

Control @ -30°C
PMW-5W @ -30°C

Cumulative pore size distribution (%)

Mean equivalent diameter of pore (mm)

-8.25 %
FREEZE DAMAGE vs DIFFUSIVITY TESTS

- Sugar solution (20 % sucrose in distilled water (wt / wt))
- TSS = 16.30 ° Brix
- Salt solution (3-4 % NaCl solution (30 or 40 g/L of distilled water)

- Time duration - 6 hours
- Sample geometry - Cylindrical shape (diameter (Ø) = 28 mm & length (L) = 12 mm)
- Frozen sample was thawed for 10 hours at 5 °C prior to diffusivity test
- Temperature of the solution was maintained at 20 °C through out the test
- Solute gain at the end process will determined (Apple - dry matter content & Potato - Osmolality measurement)

Sugar uptake during diffusivity test for apple
- Static freezing @ -20 °C
PROCESS OPTIMISATION WITH CFD MODELLING

- PhD M SADOT – ONIRIS
- INTERACTIONS RISE-ONIRIS
OUTLOOK

DESIGN OF A CONTINUOUS PROCESS

HEAT EXCHANGER

INSULATION

1.5 m

0.2 m
OUTLOOK

4

WEBSITE:
• FAQ,
• E-LETTER

WWW.FREEZEWAVE.EU

FINAL FREEZEWAVE CONGRESS 5th Nov. 2018
PRE-EFFOST CONFERENCE EVENT
Nantes – France

32nd EFFoST
International Conference
6-8 November 2018
Nantes, France

Save the date!