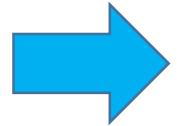


# Freezrowave



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



S. CURET<sup>a,b</sup>, M. HAVET<sup>a,b</sup>, V. JURY<sup>a,b</sup>, O. ROUAUD<sup>a,b</sup>, M. SADOT<sup>a,b</sup>, P. JHA<sup>a,b</sup>, E. XANTHAKIS<sup>c</sup>, S. ISAKSSON<sup>c</sup>, L. ARHNE<sup>c</sup>,  
M. SHRESTHA<sup>d</sup>, J. HUEN<sup>d</sup> & J-P BERNARD<sup>e</sup>

**Alain LE-BAIL**<sup>a,b</sup>,

**[alain.lebail@oniris-nantes.fr](mailto:alain.lebail@oniris-nantes.fr)**

<sup>a</sup> ONIRIS-UMR GEPEA CNRS 6144, Nantes, France / <sup>b</sup> UBL – Uni. Bretagne Loire /

<sup>c</sup> RISE, Research Institutes of Sweden – Agrifood and Bioscience, Gothenburg 41276, Sweden

<sup>d</sup> TTZ-BILB, Bremerhaven, Germany / <sup>e</sup> SAIREM, France



1

BACKGROUND

2

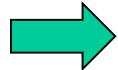
PROJECT

3

RESULTS

4

OUTLOOK



## STRATEGIES TO REDUCE FREEZE DAMAGE

ENHANCING THE FREEZING RATE : ↗ NUCLEATION RATE ↗ ENERGY

USE OF NUCLEATING AGENTS : ↗ NUCLEATION RATE

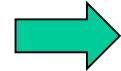
USE OF ALTERNATIVE PROCESS:

- PRESSURE SHIFT FREEZING
- ULTRASOUND NUCLEATION
- ELECTRIC and ELECTROMAGNETIC IRRADIATION



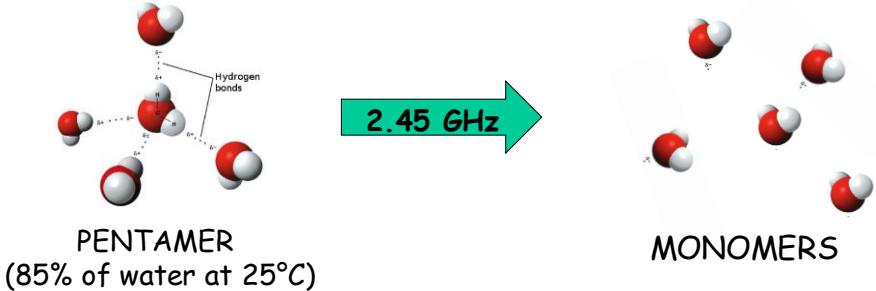
- STATIC ELECTRIC FIELD (SEF)
- STATIC MAGNETIC FIELD (SMF)
- OSCILLATING MAGNETIC FIELD → INDUCED ELECTRIC FIELD
- OSCILLATING ELECTRO-MAGNETIC FIELD
- EMF = MICROWAVE, RF WAVES...

-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 → ↗ SUPERCOOLING

HANYU et al (1992),


**B) PART TIME EMISSION OF ENERGY + REFRIGERATION**

ASSUMPTIONS: ICE CRYSTALS DISRUPTION + ↗ SECONDARY NUCLEATION

Anese, 2012, Xanthakis, 2015, Ben-Shmuel (2014), Patents US 2011/Dorward, Kim et al (2011-SAMSUNG), Lim et al (2006-LG)

Anese et al., 2012, Food Research International 46 (2012) 50-54

Ben-Shmuel Patent N0.: US 8,653,482 B2, Date of Patent: Feb. 18, 2014

Dorward, Patent US 2011/0229928 A1

Fowler, P. W., Quinn, C. M., Redmond, D. B. (1991) Decorated fullerenes and model structures for water clusters, The Journal of Chemical Physics, 95(10), p7678.

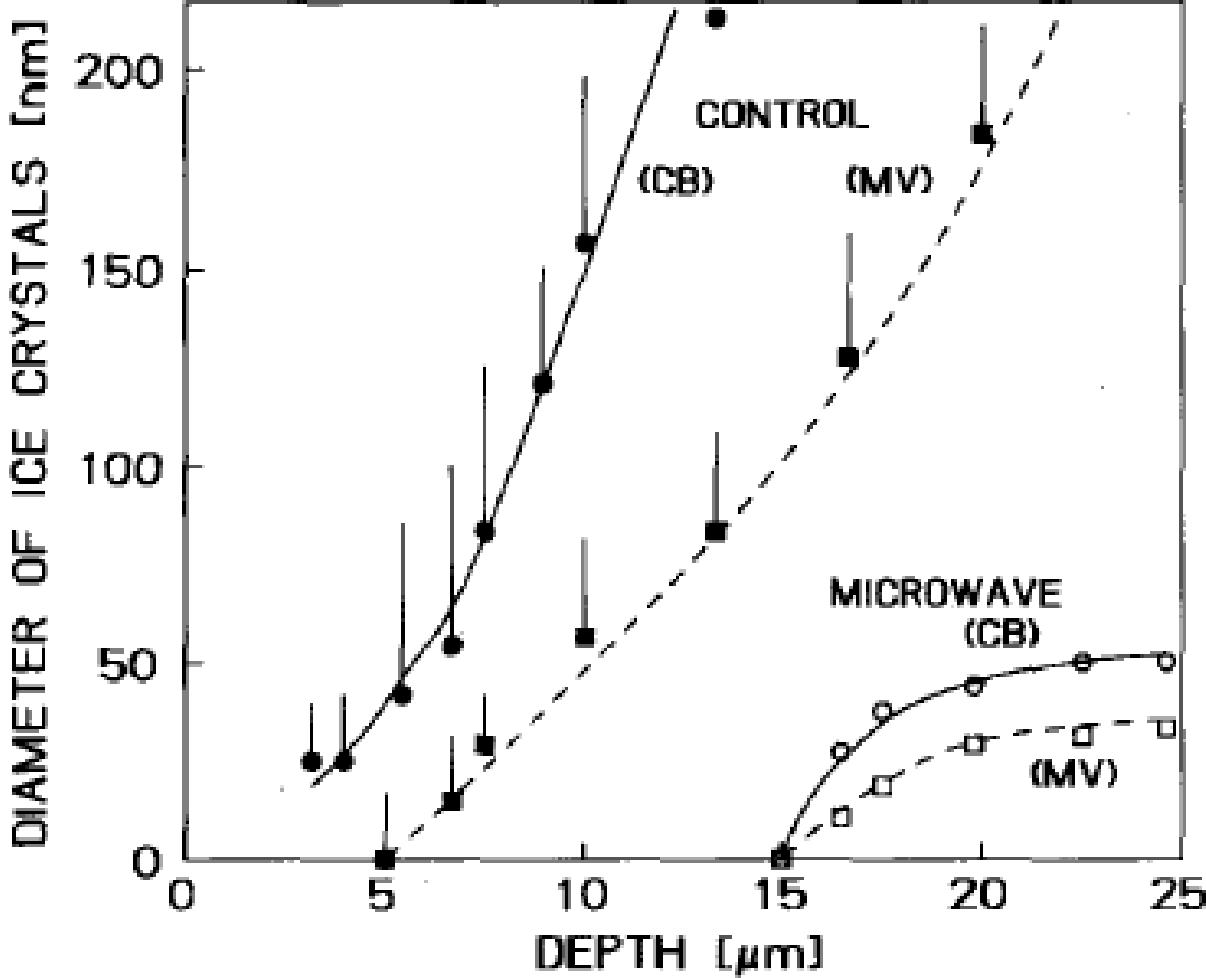
Ignatov, I., Mosin, O. V. (2013) Structural Mathematical Models Describing Water Clusters, Journal of Mathematical Theory and Modeling, Vol. 3, No 11, pp. 72-87.

Kim et al., 2011 (LG), US 2010/02295711 A1, Sept. 16, 2010

Lim et al. Patent EP 1 980 809 A2

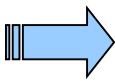
Xanthakis, E et al. Development of an innovative microwave assisted food freezing process, (2014), Innovative Food Science and Emerging Technologies 26, 176-181

Ralf Ludwig (2001). "Water: From Clusters to the Bulk". Angew. Chem. Int. Ed. 40 (10): 1808-1827.



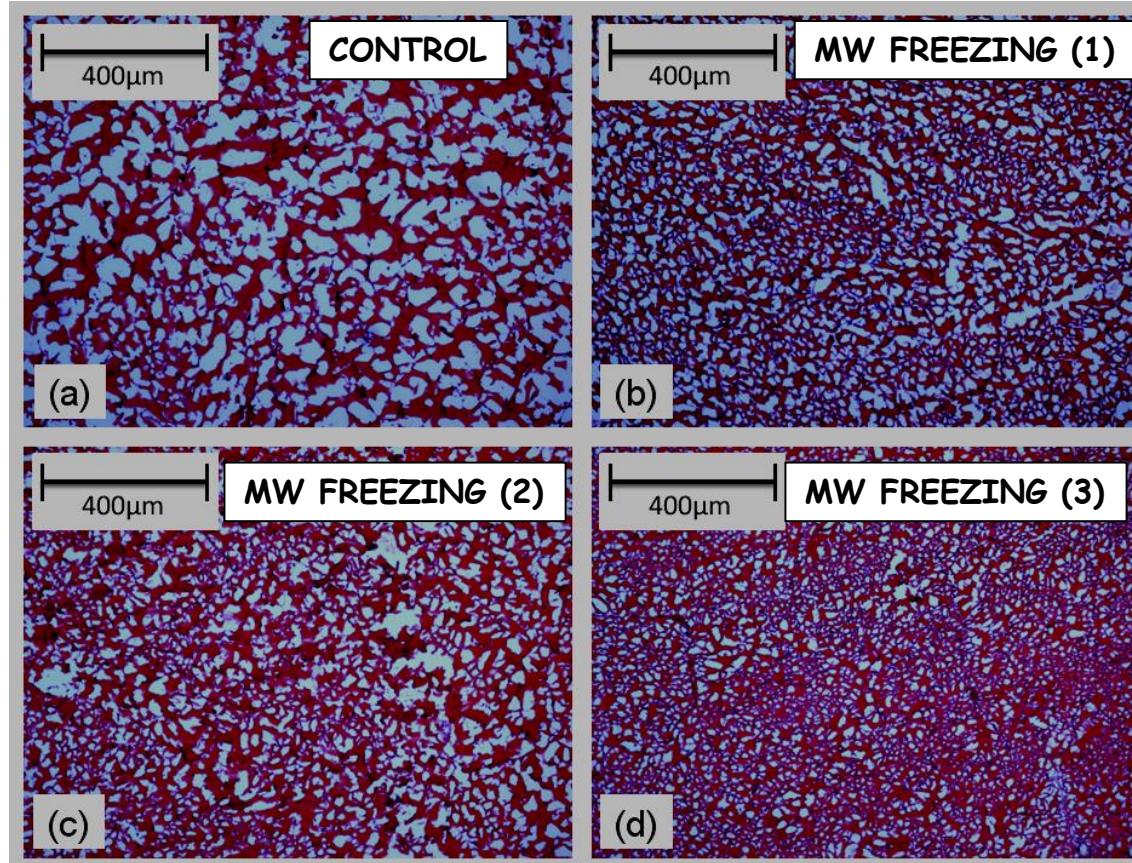
- FREEZING WITH MICROWAVES  
 → SMALLER ICE CRYSTALS  
 → MORE UNIFORM DISTRIBUTION

ALSO: JACKSON et al (1997)  
 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)



Development of an innovative microwave assisted food freezing process, E. XANTHAKIS, A. LE-BAIL & H. RAMASWAMY - IFSET - Accepted April 2014; INFOO\_IFSET-D-14-00057

1

BACKGROUND

2

PROJECT

3

RESULTS

4

OUTLOOK



# Freezewave FREEZE WAVE PROJECT (2015 - 2018)

## FREEZE WAVE CONCEPT:

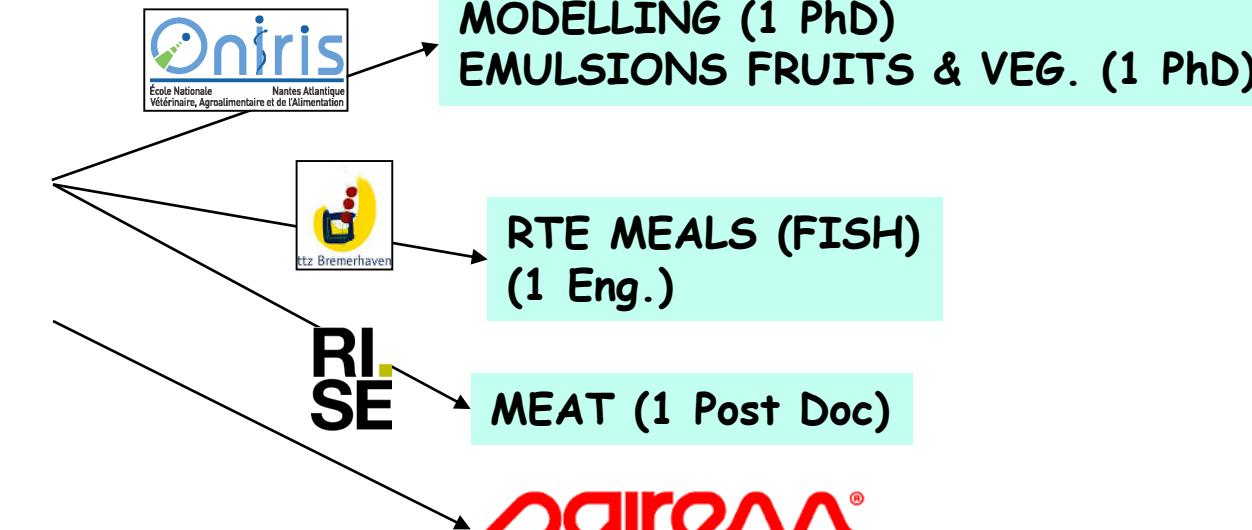
- APPLICATION OF LOW ENERGY MICROWAVES DURING FREEZING
  - REFINEMENT OF ICE CRYSTALS
  - HIGHER QUALITY FROZEN FOODS

## FREEZE WAVE CHALLENGES:

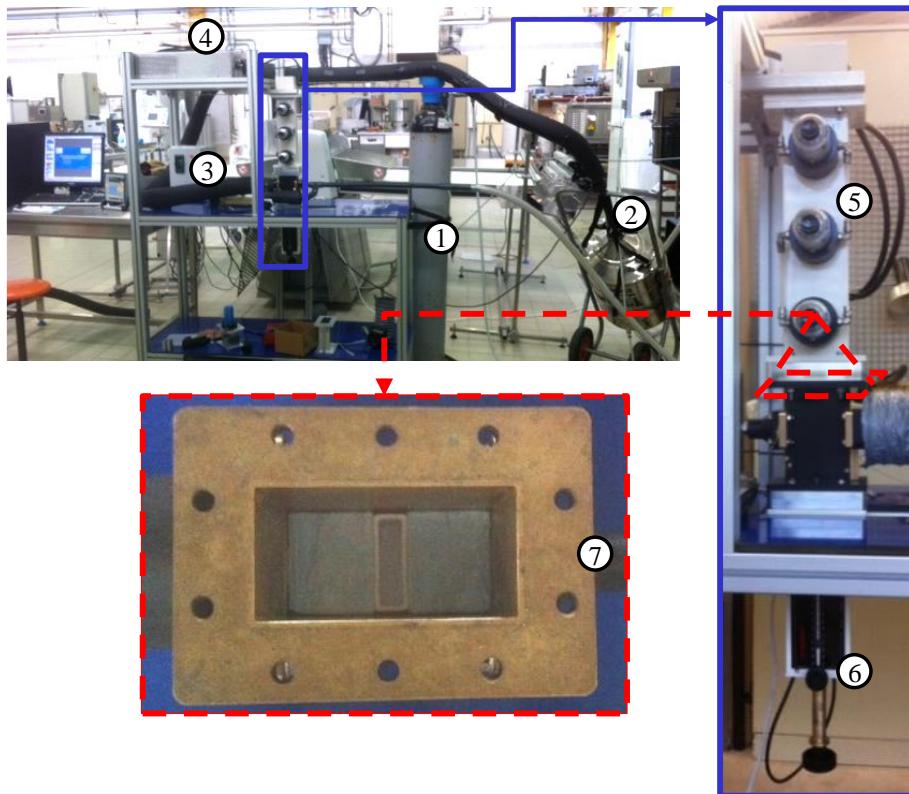
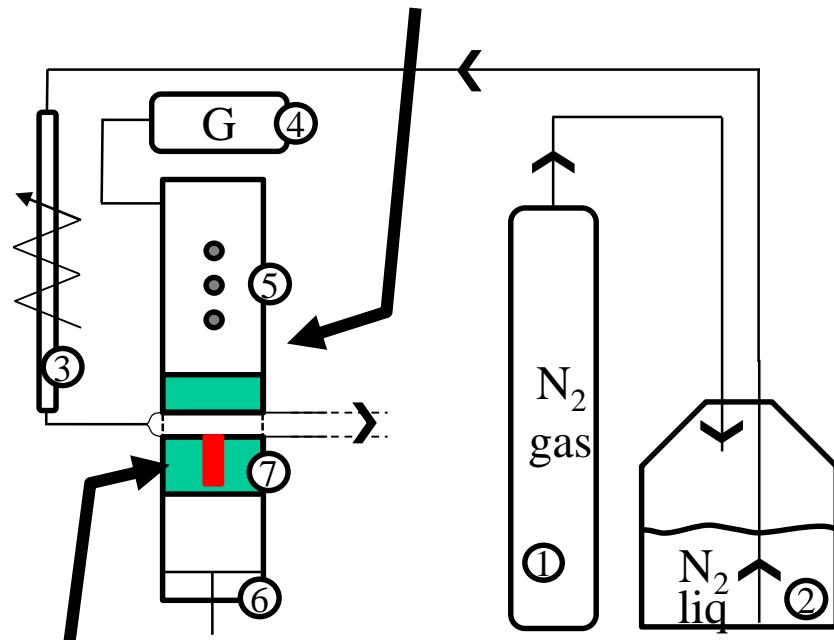
- OPTIMIZING QUALITY vs ENERGY...

## FREEZE WAVE OBJECTIVES:

- UNDERSTANDING FREEZING WITH  $\mu$ WAVES
- BATCH PROCESS DEVELOPMENT
- CONTINUOUS PROCESS DEVELOPMENT
- INDUSTRY CONCEPTS & TESTINGS



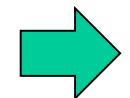
**WAVE GUIDE  
SINGLE MODE**



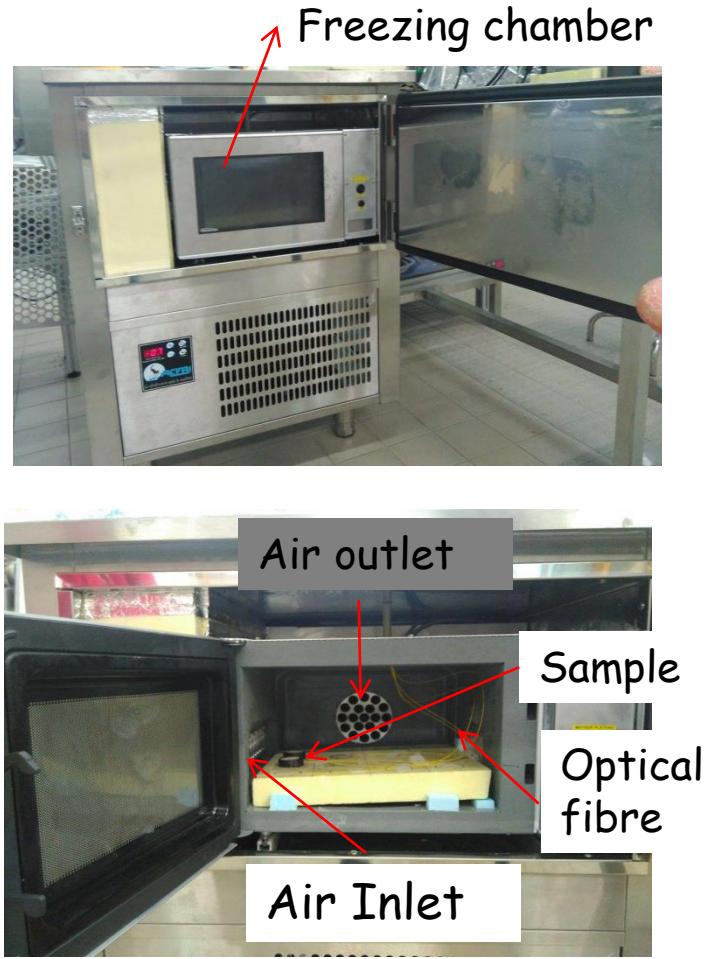
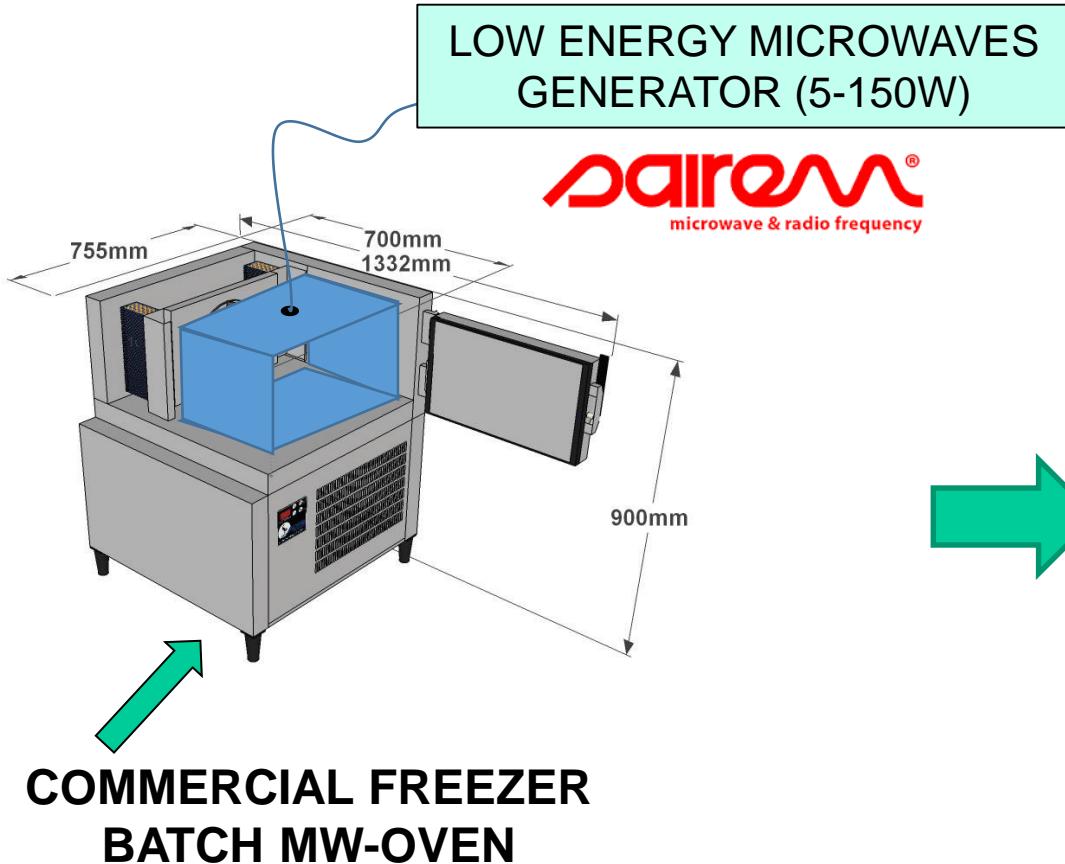
**PROTOTYPE SYSTEM**

**SAMPLE:**  
METHYLCELLULOSE GEL  
5 cm x 5 cm x 1 cm





## PROTOTYPE MULTIMODE MICROWAVES FREEZER



1

BACKGROUND

2

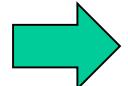
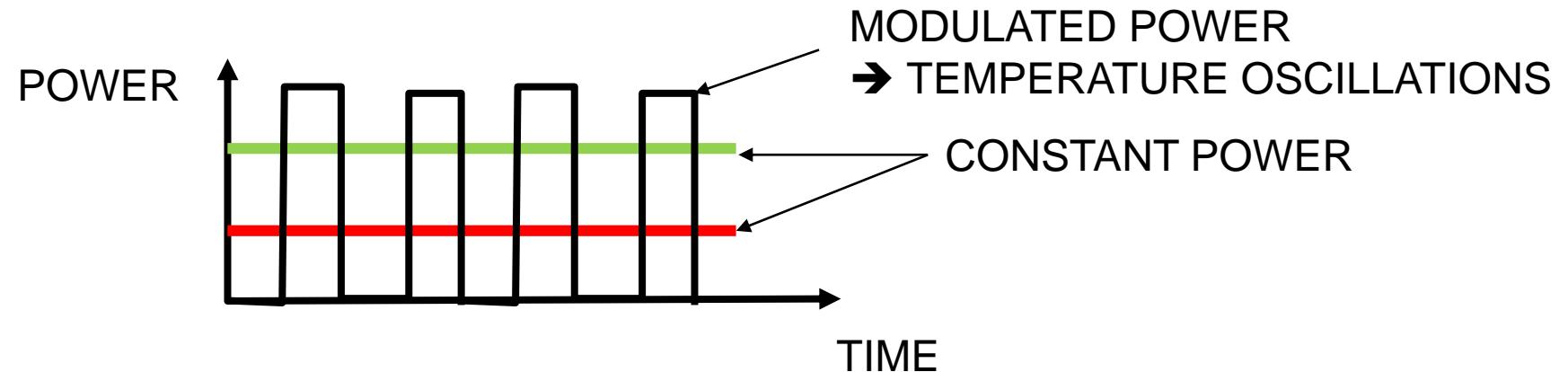
PROJECT

3

RESULTS

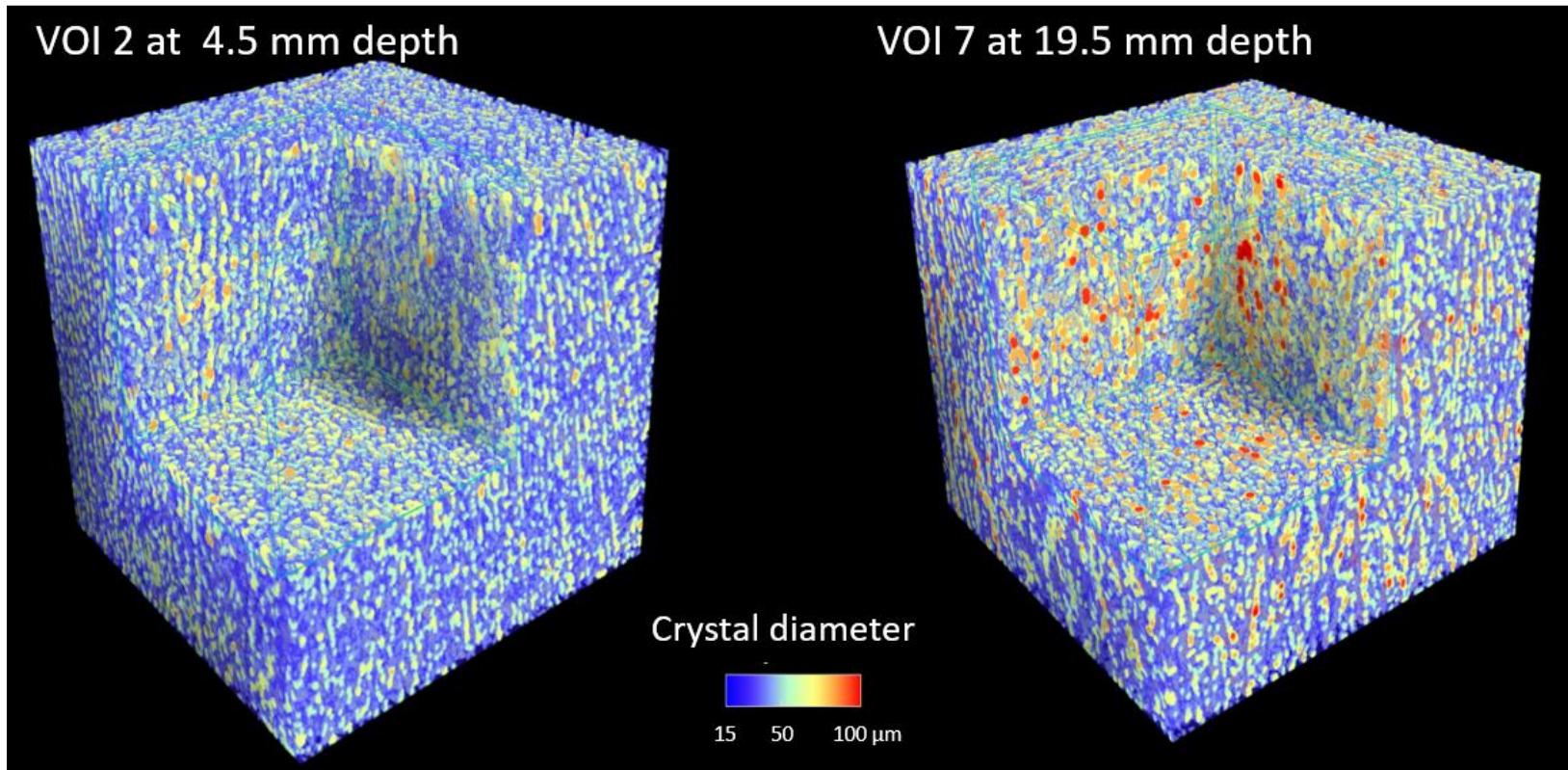
**CHALLENGES OF FREEZEWAVE:**

- OPTIMISATION OF MW POWER
- OPTIMISATION OF MODE OF EMISSION

  FROZEN FOOD QUALITY ?

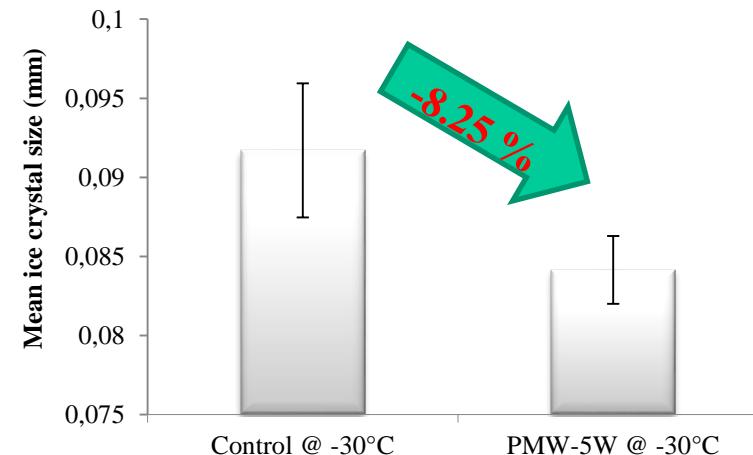
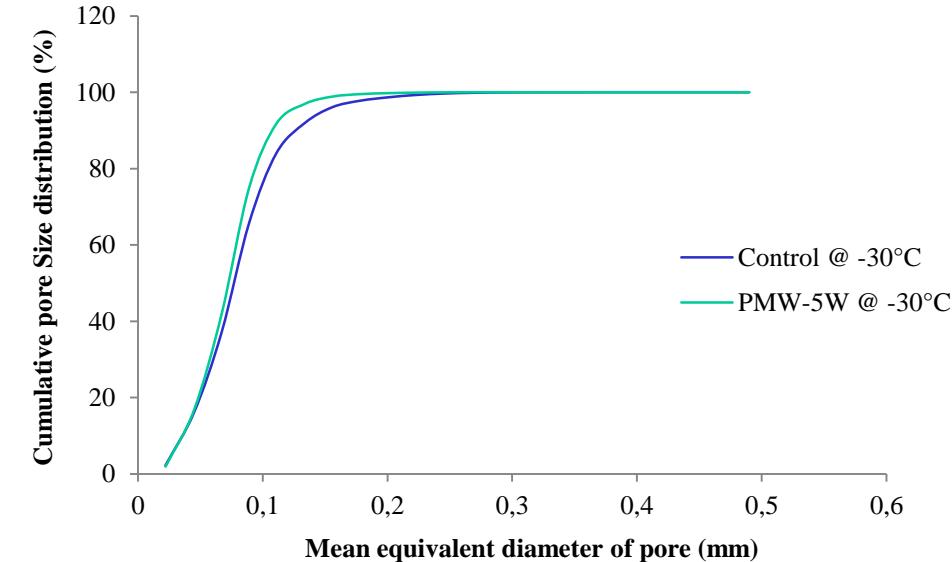
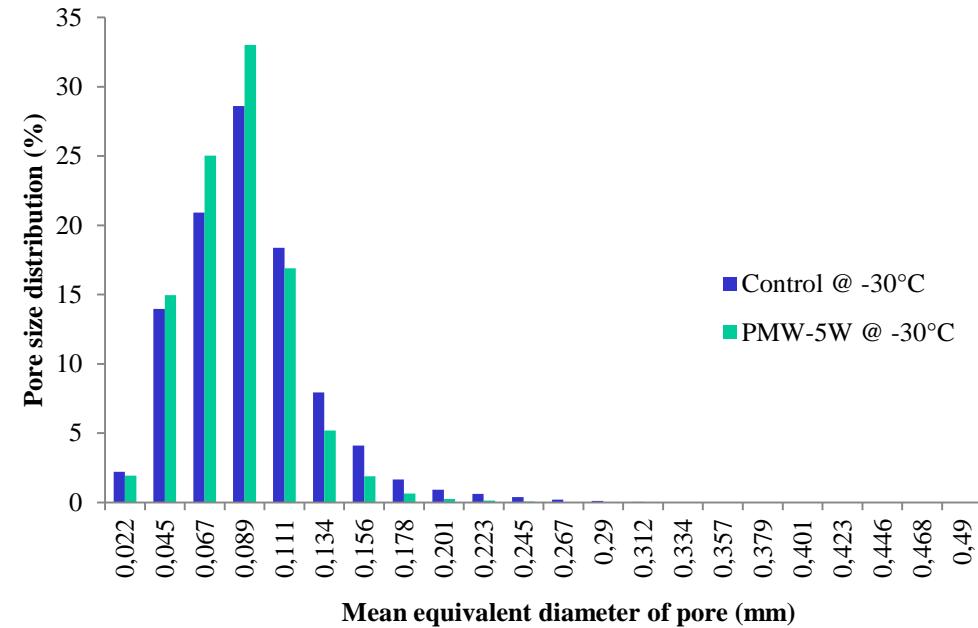
- TEXTURE
  - DRIP LOSSES
  - COLOR
  - MICROSTRUCTURE
  - SENSORY ANALYSIS
- CRYOMEB
  - MICRO TOMOGRAPHY
  - CARNOY FIXATION
  - CELL DAMAGE vs MASS DIFFUSIVITY





MORE INFO; WEDNESDAY 12h15 ([O15.4]) and 12h45 (O15.6)]

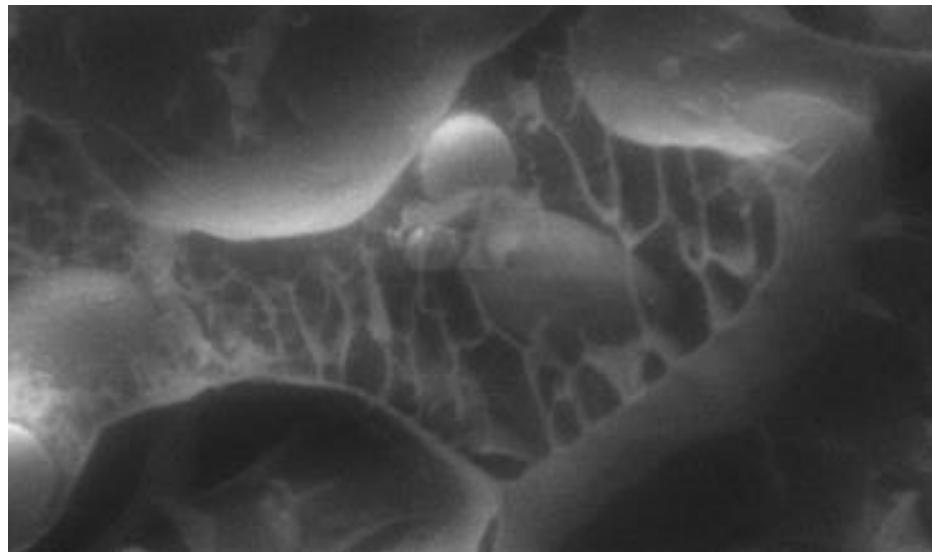
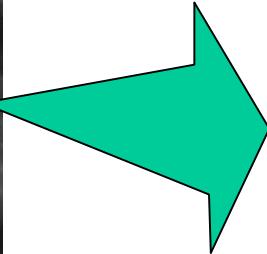
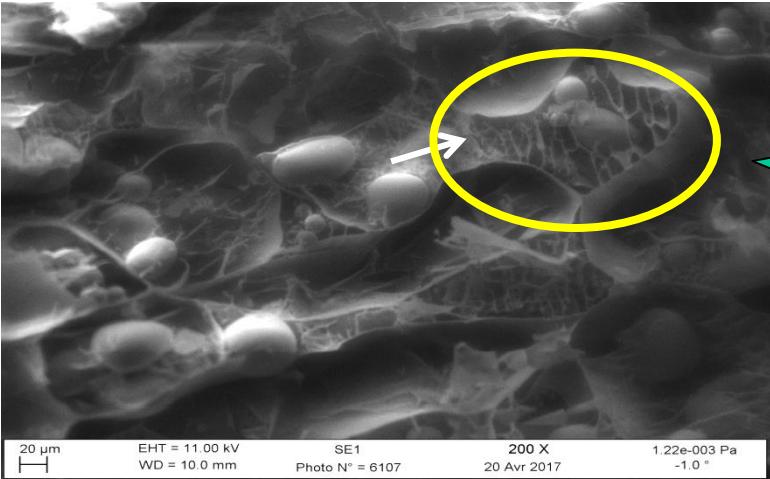
# MW ASSISTED FREEZING: POTATO



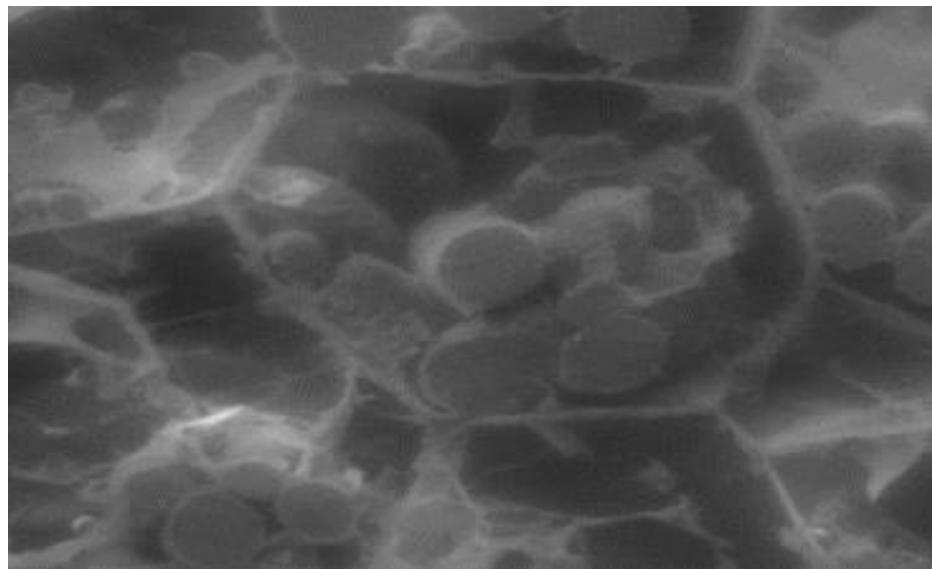
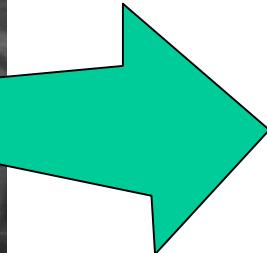
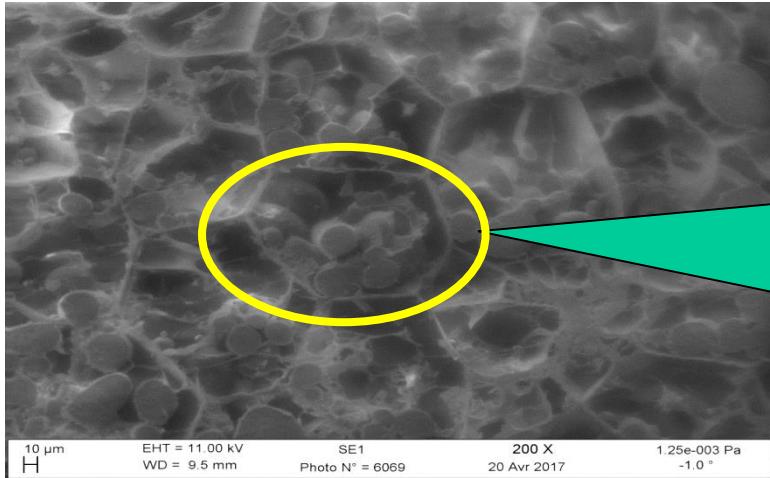


# Freezewave MW ASSISTED FREEZING: POTATO CRYO SEM

Control @ -30°C



PMW-5W @ -30°C



# FREEZE DAMAGE vs DIFFUSIVITY TESTS



- Sugar solution (20 % sucrose in distilled water (wt / wt))
- TSS = 16.30 ° Brix



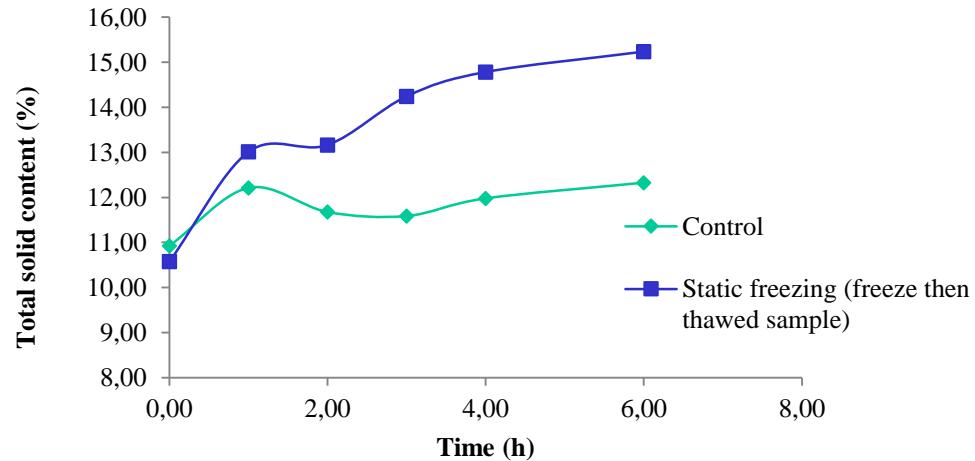
- Salt solution (3-4 % NaCl solution (30 or 40 g/L of distilled water))

- Time duration - 6 hours
- Sample geometry - Cylindrical shape(diameter ( $\emptyset$ ) = 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)



## Diffusivity Set-Up

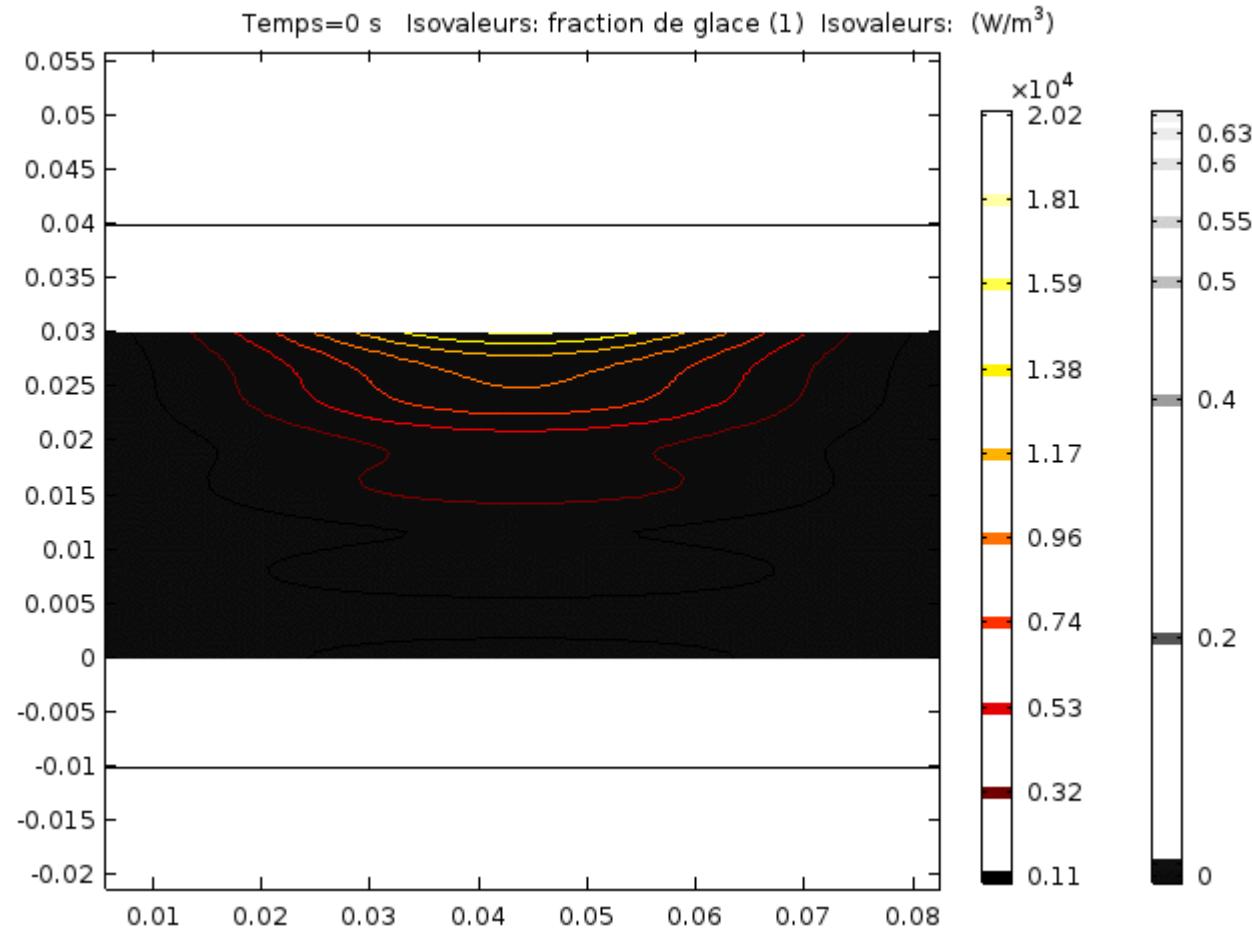
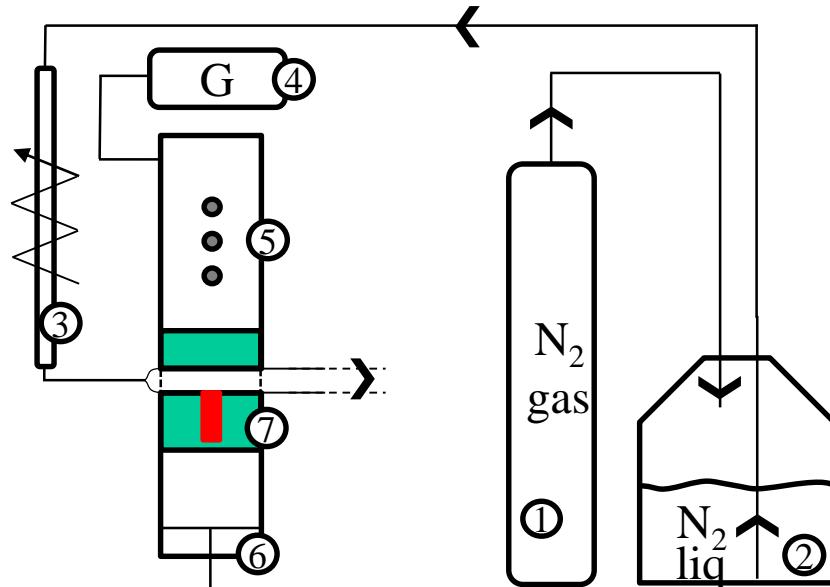
In future the experimental data will be fitted to the diffusion model and the mass diffusivity will be determined



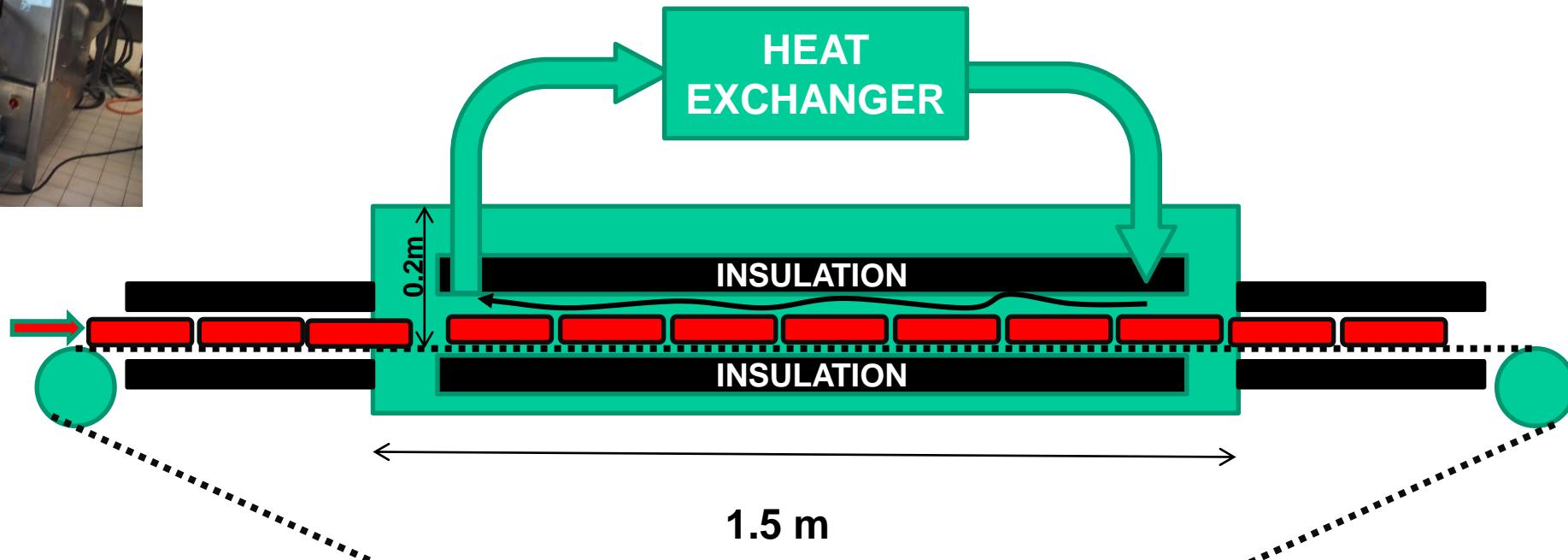
Sugar uptake during diffusivity test for apple  
 ✓ Static freezing @ -20 °C

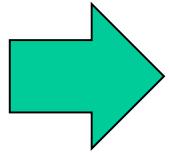
## PROCESS OPTIMISATION WITH CFD MODELING

- PhD M SADOT – ONIRIS
- INTERACTIONS RISE-ONIRIS



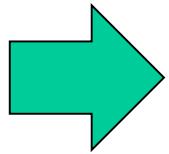
## DESIGN OF A CONTINUOUS PROCESS



**WEBSITE:**

- FAQ,
- E-LETTER

[WWW.FREEZEWAVE.EU](http://WWW.FREEZEWAVE.EU)



**FINAL FREEZEWAVE CONGRESS** 5<sup>th</sup> Nov. 2018  
**PRE-EFFOST CONFERENCE EVENT**  
**Nantes – France**

