Freezewave

Oniris GEPEA

Microwave assisted freezing (MAF) of apple and potato

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Talble of Content

1 Introduction
2 Microwaves Assisted Freezing (MAF) & Freezewave Project
3 Results: MAF of Apple and Potato
4 Data analysis
5 Outlook

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How Freezing Process can be Affected??

Means to act on Freezing & Phase Change

- Foreign Agents Driven
  - ✓ Nucleators (e.g. ice nuleating bacteria)
  - ✓ Antifreezing proteins
  - ✓ Ice structuring proteins
- State Variable Driven
  - ✓ Temperature manipulation (Conventional method)
  - ✓ Pressure variation (e.g. Pressure shift freezing, Vacuum freezing)
  - ✓ Volumetric method (e.g. Ultrasound method)
- External Field Driven
  - ✓ Satic fields (Static electric and magnetic fields or SEF and SMF)
  - ✓ Oscillating fields (Oscillating electric and magnetic fields or OMF and OEF)
  - ✓ Eltromagnetic fields (EMF): Microwaves (MW) and Radio frequency (RF)

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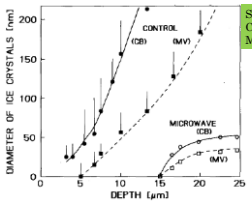
Freezing + Electromagnetic Field - Oscillating

Hanyu et al (1992) an improved cryofixation method. Cryoquenching of small tissue blocks during microwave irradiation



Squid retina
CB-Cell bodies
MV-Microvilli

Microwave:
2.45GHz, (50ms),
Power max: 500W

- 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

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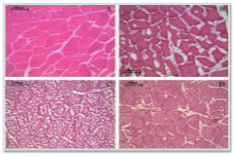
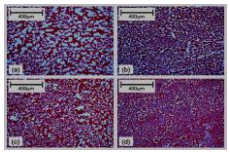
Freezing + Electromagnetic Field - Oscillating

Freezing Assisted by Radiofrequency
Anese et al. 2012



A: control (unfrozen meat); B: air freezing; C: cryo freezing; D: RF cryo freezing
RF frozen meat presented smaller ice crystals
Much less intercellular voids and cell disruption were observed

Freezing Assisted by Microwaves
Xanthakis et al. (2014)



A = control, B, C, D: increasing microwave power
62% decrease in the average ice crystal size vs. control
Degree of supercooling was decreased circa 92%

Freezewave

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

ERANET – SUSFOOD PROJECT (EUROPE – COLLABORATIVE)

www.freezewave.eu

Oniris (France)

Partners
ONIRIS (F)
RISE (S)
TTZ (G)
SAIREM-SME (F)

TTZ Bremerhaven (Germany)

RISE (Sweden)

Sairem (France)

FREEZEWAVE OBJECTIVES:
-Understanding and optimization of freezing with microwaves
-Develop protocols to evaluate freeze damage
-Batch process development
-Continuous process development
-Industry testing

Coord.: alain.lebail@oniris-nantes.fr

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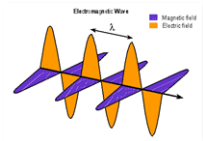
Microwave Assisted Freezing (MAF)

Our Approach



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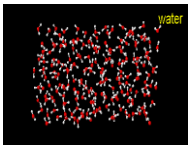

Low Power Microwave (2.45 GHz) | Freezing Process

➢Better quality product
➢Less energy intensive conditions

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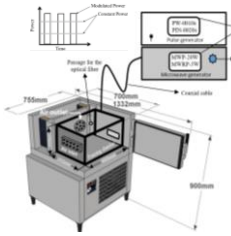
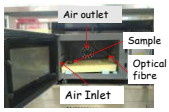
Microwave Assisted Freezing (MAF)

Prototype Multimode Microwaves Freezer





Inner view

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Microwave Assisted Freezing (MAF)

Experimental Design for MAF of Apple & Potato (Blanched)

Methodology

Sampling (Apple and Potato)

1.3 × 1.3 × 1 cm³ – L × H × W

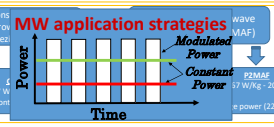
Temperature equilibration 6 ºC

Cooling

Control

No P (0 W)

MW application strategies



Freezing @ -30°C

Microstructure evaluation, drip loss, texture, etc……

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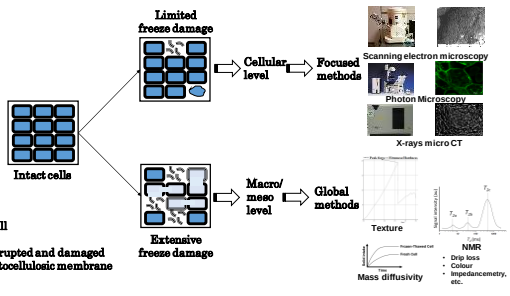
Freeze Damage & Assessment Methods

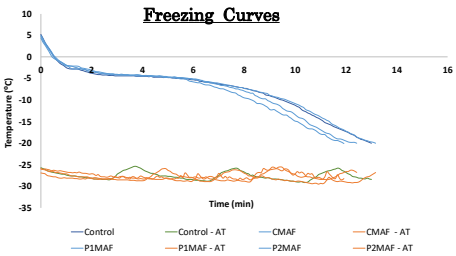


MAF Results

MAF of Apple

Freezewave

Freezing Curves



AT = Ambience temperature

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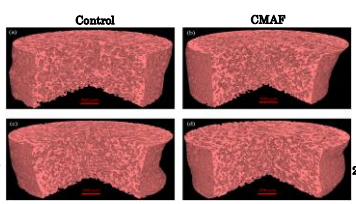
MAF of Apple

Microstructure: X-rays Tomography of Frozen-Freeze Dried Apples

MAF Results



- MAF conditions had small size pore size distribution than control

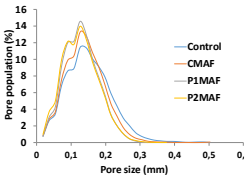
Figure: Microstructure of apple after freezing under different conditions: (a) Control, (b) CMAF condition (167 W/Kg), (c) and (D) PMAF conditions (500 W/kg and 667 and with 10 s pulse width and 20 s pulse interval). The lighter regions in the figure correspond to the cellular matrix, while darker regions correspond to the ghost of ice microcrystal that sublimed during freeze drying.

Results

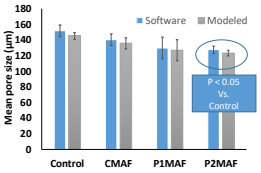
MAF of Apple

Freezewave

Microstructure: X-rays Tomography – 3D Analysis



Frequency curve for apple sample treated under various conditions. CMAF = constant microwave condition, PMAF = Pulsed microwave conditions.



Mean pore size obtained with the software and the normal distribution fitting for apples frozen by different freezing protocols.

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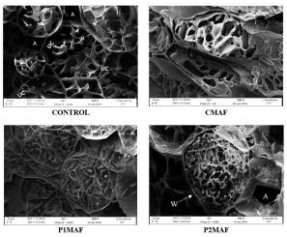
Results

MAF of Apple

Microstructure: Cryo-SEM images of apple



- ✓ More LICs under control conditions
- ✓ P2MAF condition best among all conditions

Figure: Cryo-SEM images of apple after freezing under different conditions. Abbreviations used in the above picture: A = air space, W = cell wall and membrane structure, LIC = large ice crystals size.

Results

MAF of Apple

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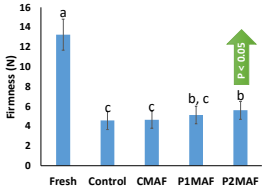
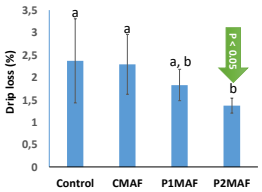
Texture & Drip loss





- ✓ Better quality preservation (lower firmness & drip loss) was obtained under PMAF conditions, especially under P2MAF conditions

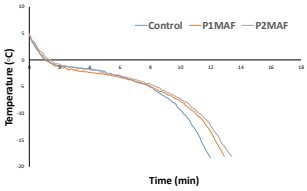
Results

MAF of Potato

Freezewave

Note : Based on results obtained for MAF of apples only PMAF conditions were used for freezing of potato and was compared with the control sample

Freezing Curves



13/01/2019

Results

MAF of Potato

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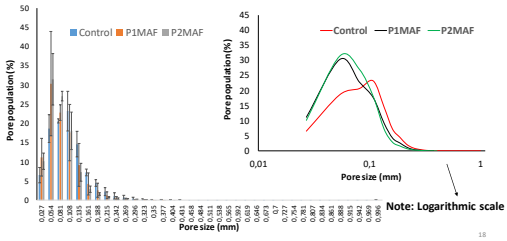
Microstructure: X-rays Tomography of Frozen-Freeze Dried Potatoes



18

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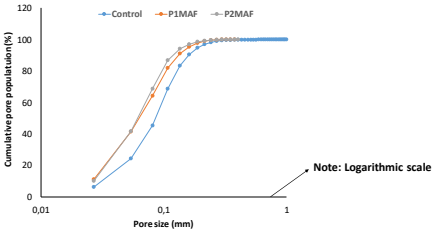
MAF of Potato

Microstructure: X-rays Tomography – 3D Analysis



Results

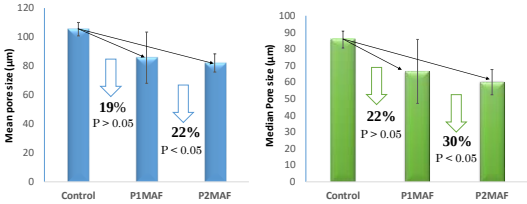
MAF

Results

MAF of Potato

Freezewave

Microstructure: X-rays Tomography – 3D Analysis



Blanched Potato

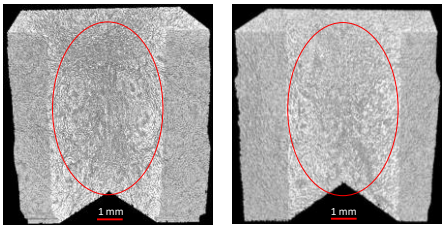
MAF

Results

MAF of Potato

Freezewave

Microstructure: X-rays Tomography-3D Analysis



➢ Control ➢ P2MAF

Blanched Potato

MAF

Results

MAF of Potato

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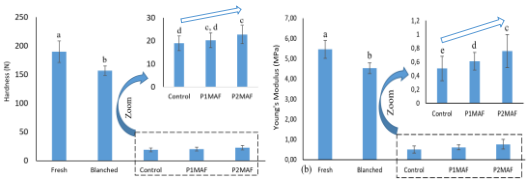
Texture Loss



✓ Better texture under PMAF conditions, however significant difference could be achieved only under P2MAF condition

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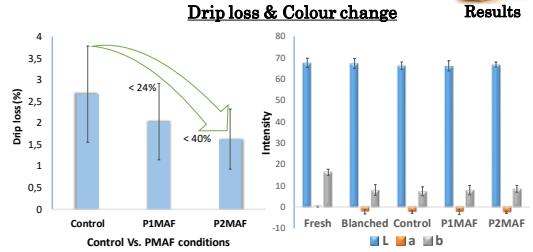
MAF of Potato

Drip loss & Colour change

MAF

Results



✓ MAF samples had higher water holding capacity

No effect on colour

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Outlook

Conclusion

✓MAF produced a more homogenous microstructure.
✓Reduced drip and texture loss.
✓No effect on colour.

Future perspectives

✓Explore freezing by using other frequencies of electromagnetic radiations.

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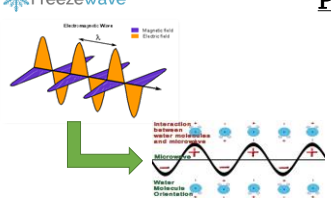
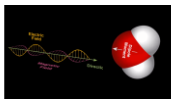
Possible Mechanism



Outcomes

➢ ↗ number of isomeric configurations
➢ ↘ probability for water molecules to integrate to a crystal lattice
➢ ↘ growth rate of crystals



Microwave freezing → Additional mechanism

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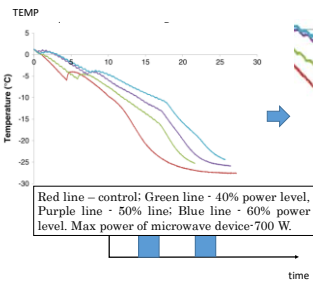
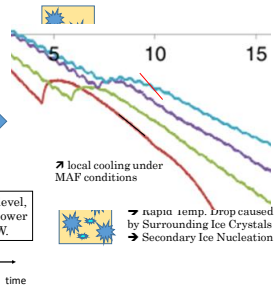
Possible Mechanism



Red line – control; Green line - 40% power level, Purple line - 50% line; Blue line - 60% power level. Max power of microwave device-700 W.



↗ local cooling under MAF conditions

→ Rapid Temp. Drop caused by Surrounding Ice Crystals
→ Secondary Ice Nucleation