Novel Innovations in Food Freezing

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Freezing

- Change water to ice
- Low $a_w$ (water activity) stops bacterial growth
- Storage life many years
- Large quantity of heat to be removed to change water to ice
- Large change in thermal properties with temperature
Freezing curve

Temperature (°C)

Time

Initial cooling
Super-cooling
Phase change
Completion of freezing
Equalisation
Ice Content in -1° C to -5° C range

- Beef Riedel (1957) Calorimetry
- Cod Sussman & Chin (1966) NMR
- Model COSTHERM
Why does $-18^\circ C = \text{frozen}$

Simple answer:

$-18^\circ C \approx 0 F$

No safety issues below $-12^\circ C$ ($-5^\circ C$)

Provided there is good temperature control, many foods can be stored at $-12^\circ C$ with no loss of quality
Freezing rate - theory

Fast
- Small ice crystals
- Intracellular ice
- Less damage

Slow
- Large ice crystals
- Extracellular ice
- Damage to cell structure
Freezing rate - reality

Unaffected by variations in freezing rate
- products with a high content of dry matter, such as peas, meat products with a high fat content, and certain ready meals

Require a minimum freezing rate (0.5 to 1°C/min), but are relatively unaffected by higher freezing rates
- fish, lean meat, and many starch and flour thickened ready meals

Quality improves when freezing rates are increased (3 to 6°C/min)
- many fruits, egg products and flour thickened sauces

“products that are sensitive to too high freezing rates and tend to crack”
- Soft fruits, raspberries, tomatoes
Current methods

Air blast
- Batch, continuous – spiral / tunnel, fluidised bed, (cryogenic)

Immersion/Spray
- Batch, continuous, (cryogenic)
- Combination – air/spray (cryogenic)

Contact
- Plate, belt
- Combination – air/plate/belt
New innovations

- Twelve technologies/approaches identified
- Three general approaches
  1. **Improvements** of existing methods
  2. Adjuncts to existing methods that *assist* in controlling ice formation
  3. Treatments that *change* the properties of the food thus changing how ice is formed
Novel/innovative approaches

**Improvements**
- Impingement
- Hydro-fluidisation

**Assistance**
- High-pressure
- Pressure-shift
- Ultrasonic
- Magnetic resonance (CAS)
- Electrostatic
- Microwave
- Radio Frequency

**Change**
- Dehydrofreezing
- Antifreeze proteins
- Ice nucleation proteins
Improvements

Impingement and Hydro-fluidisation
• Essentially improvements of air blast and immersion, respectively
  • Higher surface heat transfer rates increase rate of freezing
  • Rapid freezing = smaller ice crystals
• Advantages depend on the size of the product
  • Poor thermal conductivity limits the rate of cooling in large objects, rather than the heat transfer between the cooling medium and the product
Assistance

High pressure, pressure shift, ultrasound, magnetic resonance, electrostatic, microwave, radio frequency

• Adjuncts to existing freeing systems
• Aim to control/change the way that ice is formed within the food during freezing
• Similar claimed advantages
• Differences in proposed principles
Assistance - principles

High pressure / pressure-shift
- Depresses freezing point
- Promotes supercooling
  - Promotes more even ice nucleation throughout the product

Ultrasound
- Cavitation
  - Promotes nucleation
  - Fragments large ice crystals
- Promotes more even ice nucleation throughout the product

Magnetic resonance, electrostatic, microwave, radio frequency
- Dipolar rotation of water molecules?
- Fragments large ice crystals
- Prevents clustering of water molecules
- Promotes more even ice nucleation throughout the product
Change

Dehydrofreezing, antifreeze and ice-nucleation proteins

- Change the properties of the food
- Differences in proposed principles
Change - principles

**Dehydrofreezing**
- Reduces the water content
- Lowers the freezing point
- Reduces the amount of ice
- Reduces the heat load

**Antifreeze proteins**
- Lower the freezing point
- Suppresses the growth of ice crystals
- Inhibit ice formation
- Alter ice crystal growth
- Retard ice re-crystallisation during storage

**Ice nucleation proteins**
- Raise the freezing point
- Shorten the freezing time
- Aid more even ice nucleation throughout the product

FRPERC: Food Refrigeration and Process Engineering Research Centre
Current state

Developed
- Impingement
- Dehydrofreezing
- Antifreeze proteins

Pilot scale
- Hydro-fluidisation
- High pressure
- Ultrasound

Proof of principle stage
- Magnetic resonance
- Electrostatic
- Microwave
- Radio frequency
- Ice nucleation proteins
Other alternatives: Super-cooling

- Freezing from a super-cooled state
- Super-cooling
  - The process of reducing the temperature of a liquid below its freezing point without nucleation
  - When a liquid freezes to a solid, it forms a crystalline matrix, but that matrix needs a seed to start growing
  - In the absence of a seed, the liquid becomes super-cooled
- Potential: Rapid nucleation of ice throughout product on freezing = smaller ice crystals, no ice front?
Super-, Sub-cooling garlic cloves

![Graph showing temperature vs time for garlic cooling at -5°C and -15°C](image)

- **Garlic (-5°C)**
- **Garlic (-15°C)**
Unpeeled garlic bulbs 1 week: left, super-cooled (-6°C); right, frozen (-30°C)
If you’d like to know more

• Current advances in food freezing (2014) New Food (www.newfoodmagazine.com)


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