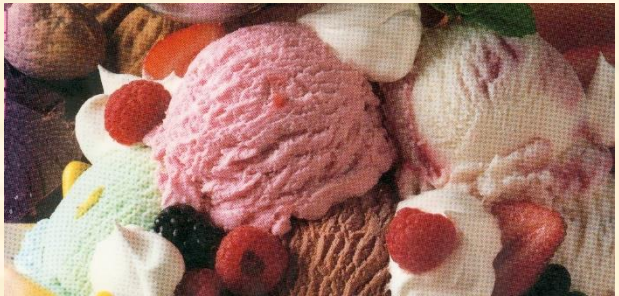
IDFA INTERNATIONAL DAIRY FOODS ASSOCIATION

ICE CREAM TECHNOLOGY CONFERENCE

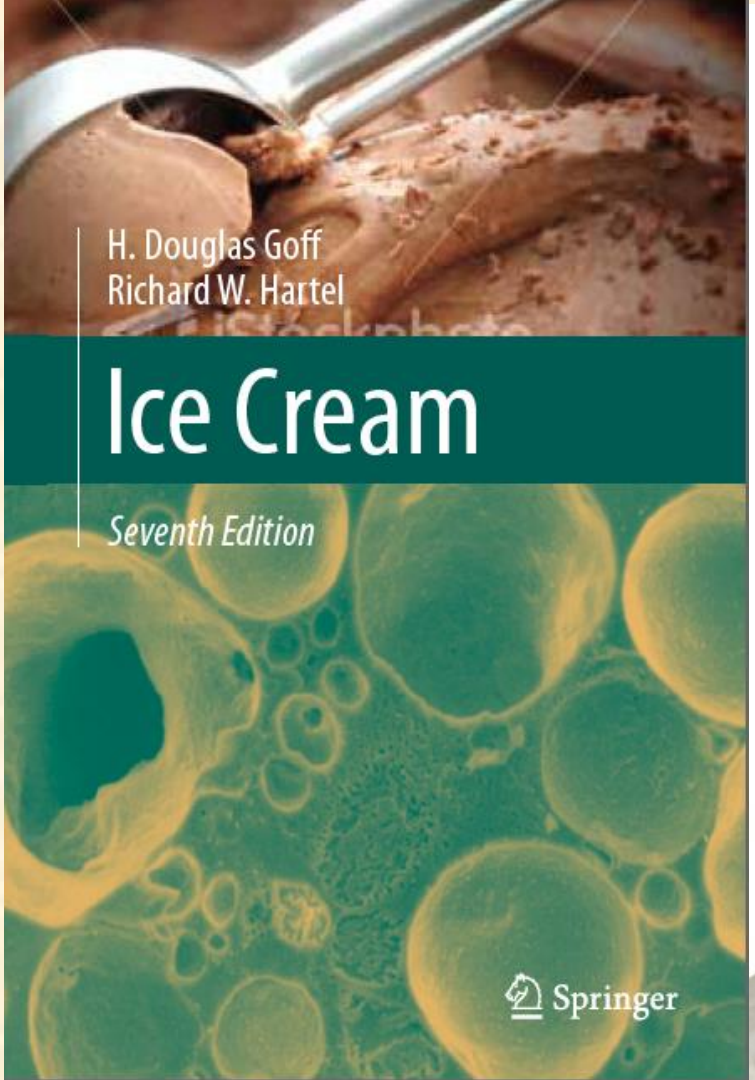
April 10 -11, 2018
Sanibel Harbour Marriott Resort
Fort Myers, FL

UNIVERSITY of GUELPH

Ice Cream Structure and its Practical Implications for Product Performance and Clean Label Formulations



Prof. H. Douglas Goff
University of Guelph


H. Douglas Goff
Richard W. Hartel
Ice Cream
Seventh Edition
Springer

Outline

- Formulations and Ingredients
- Structure
  - Colloidal structure and properties
  - Aqueous structure and properties
- Clean labelling implications
- Questions/Discussion…….

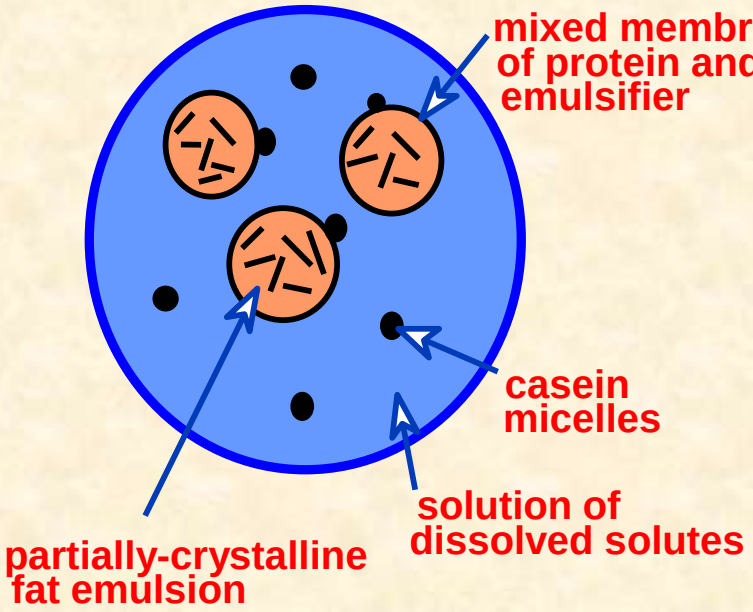
Ice Cream Mix Composition and Functionality

- **(Milk) Fat** (4 - 8) - >10 - 16%
  Structure; texture
- **Milk solids-not-fat** 9 - 12%
  Protein functionality (fat and air interfaces, water phase); Lactose functionality (solute)
- **Sweeteners** 14 - 16%
  Freezing point depression
- **Stabilizers** 0 - 0.25%
  Aqueous phase structuring
- **Emulsifiers** 0 - 0.25%
  Colloidal phase structuring
- **Water** 60 - 64%

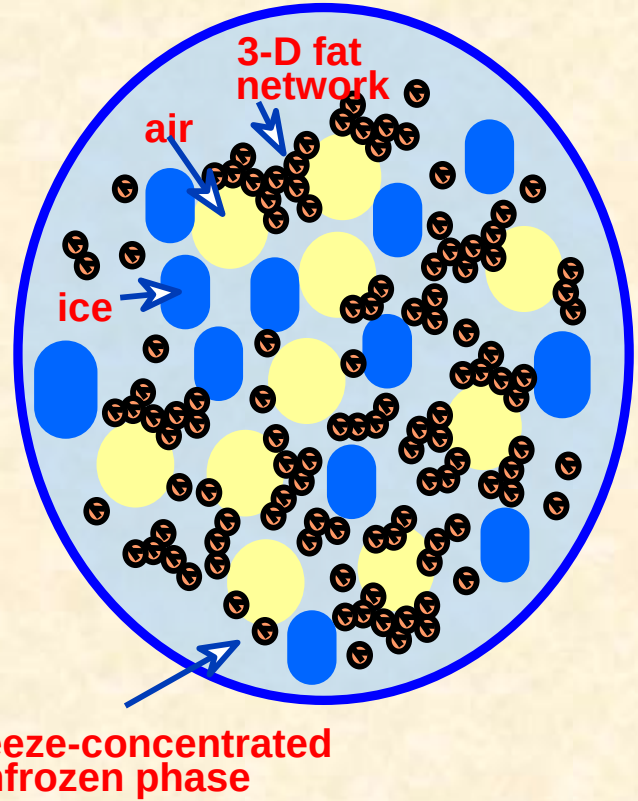
Formulations

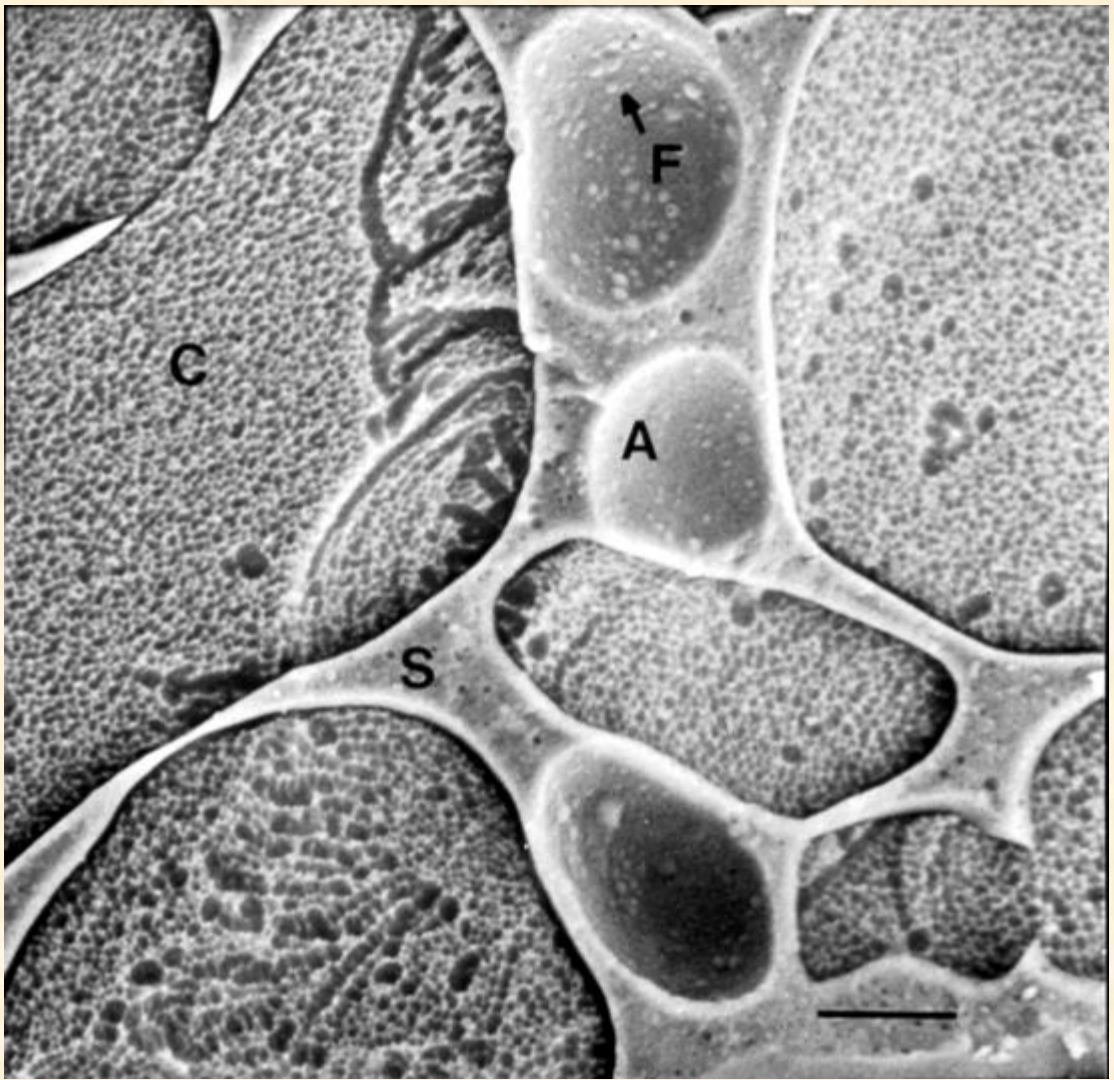
- Variations in composition, ingredients
- Price Spectrum (overrun)
- "Health-conscious"
  - Lowfat, Light, No Sugar Added, etc.
- Clean Label

Ice Cream Mix (x10,000)



Ice Cream (x1000)





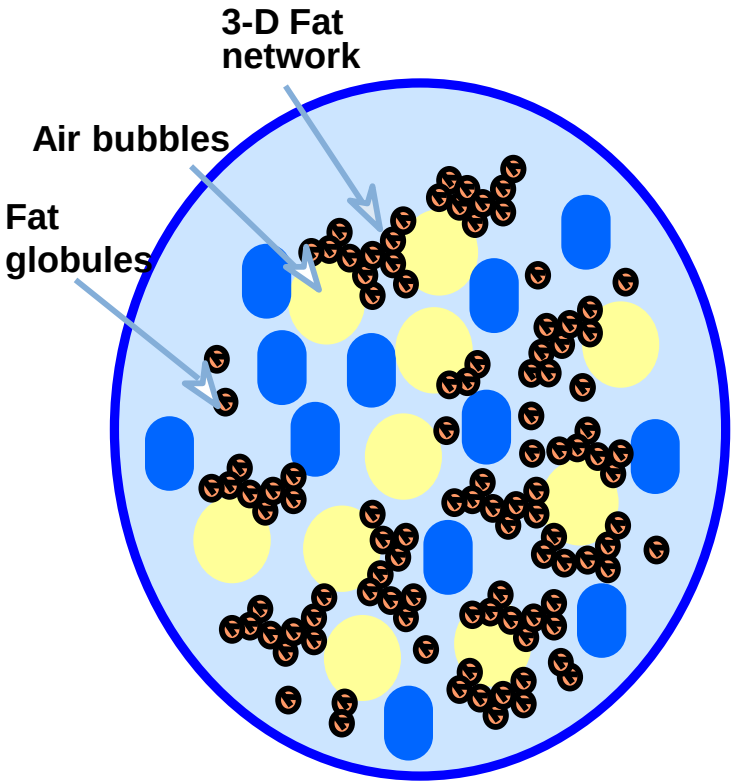
C=ice crystal

A=air bubble

F=fat globule

S=serum (unfrozen) phase

Colloidal Structure

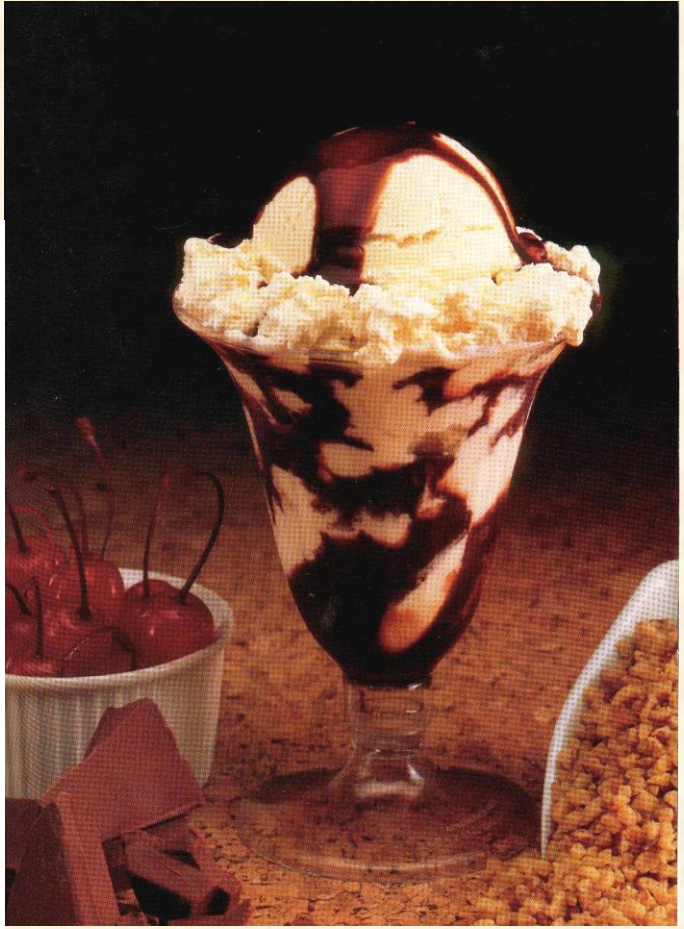


Performance Properties

- Dryness
- Shape retention
- Air stability/shrinkage
- Creamy → greasy texture

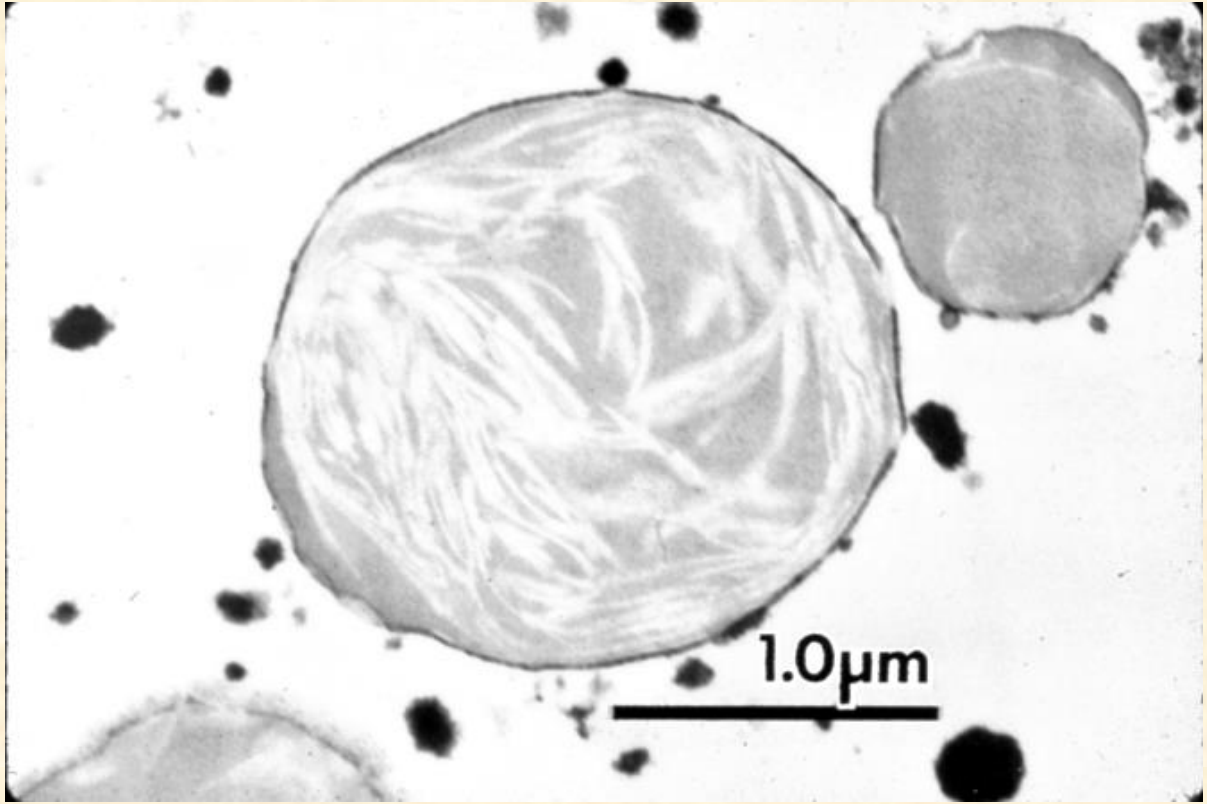
Dependent on:

- Fat content and source
- Proteins and emulsifiers
- Homogenization, ageing and whipping

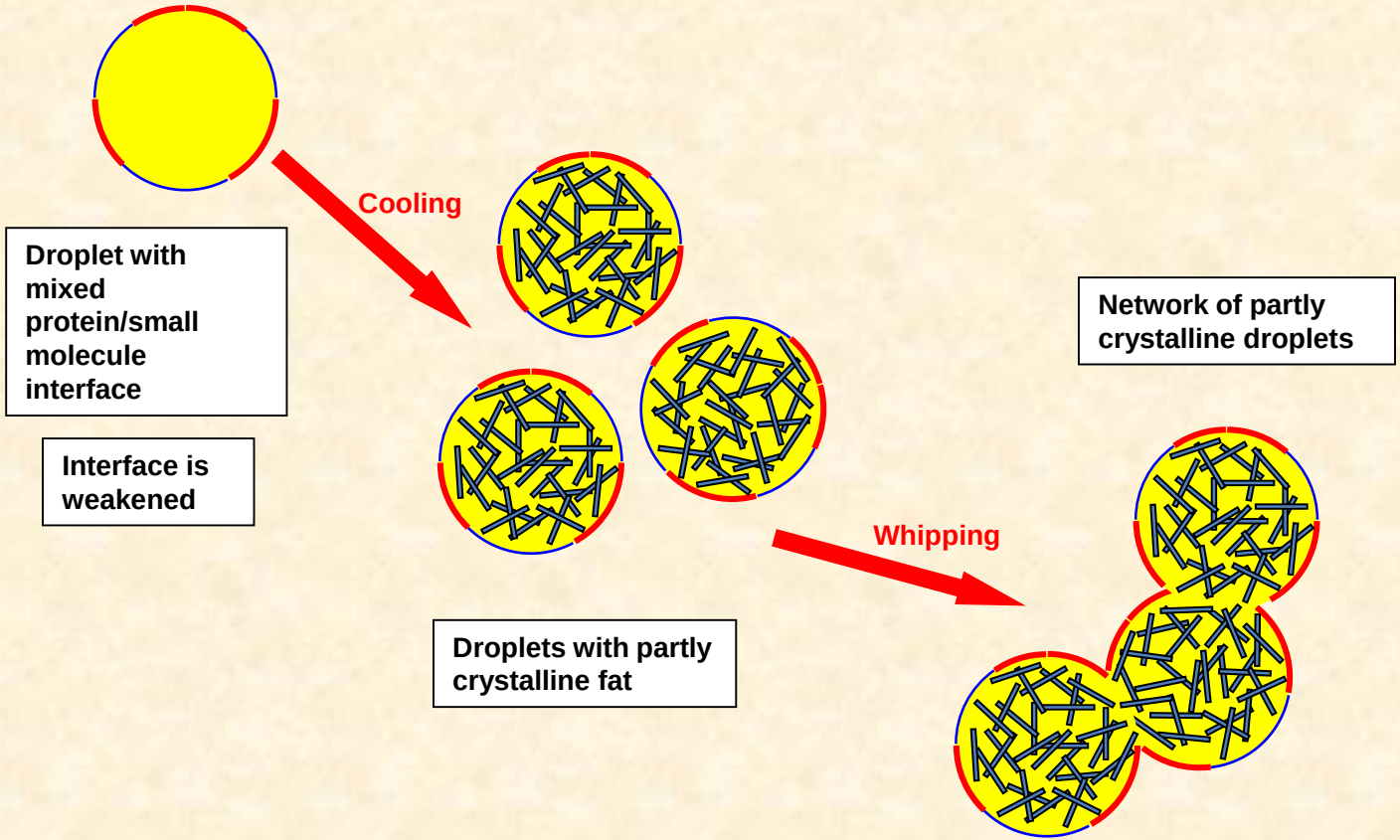


Homogenization: creates small stable fat globules

Ageing: crystallization of some fat

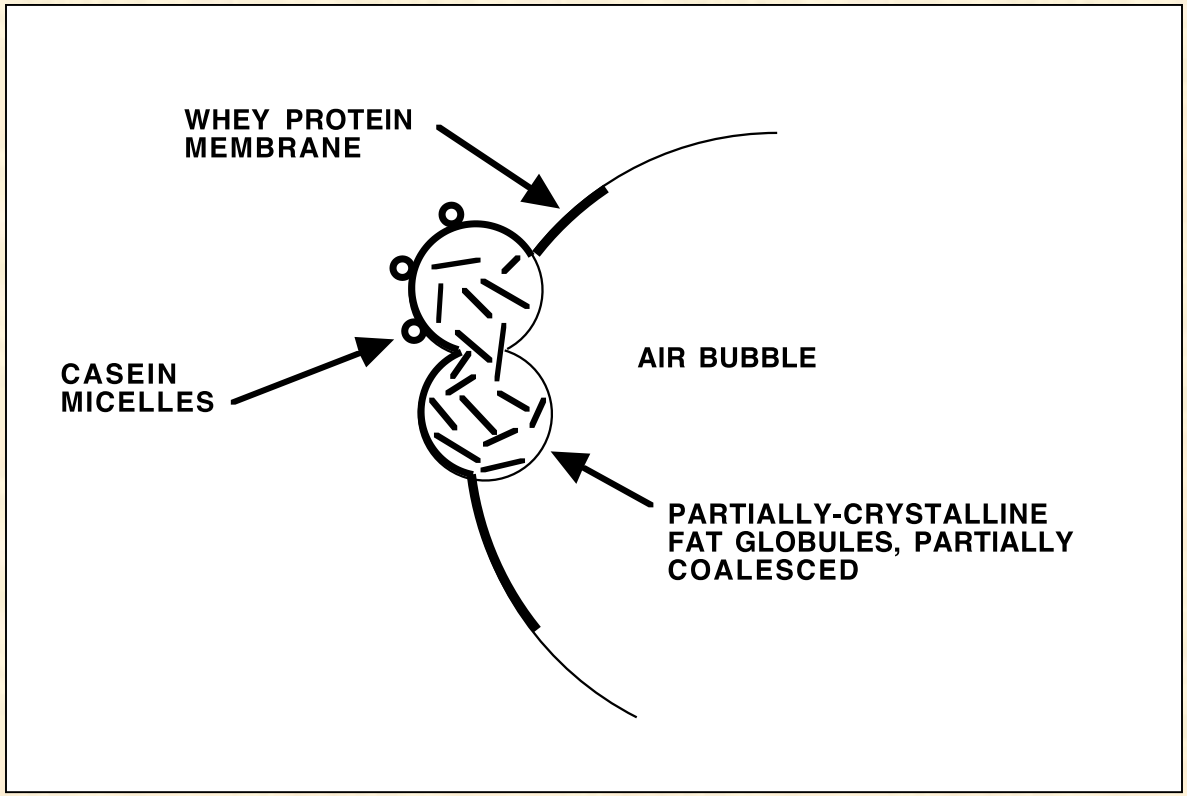


Partial coalescence of droplets containing semi-crystalline fat

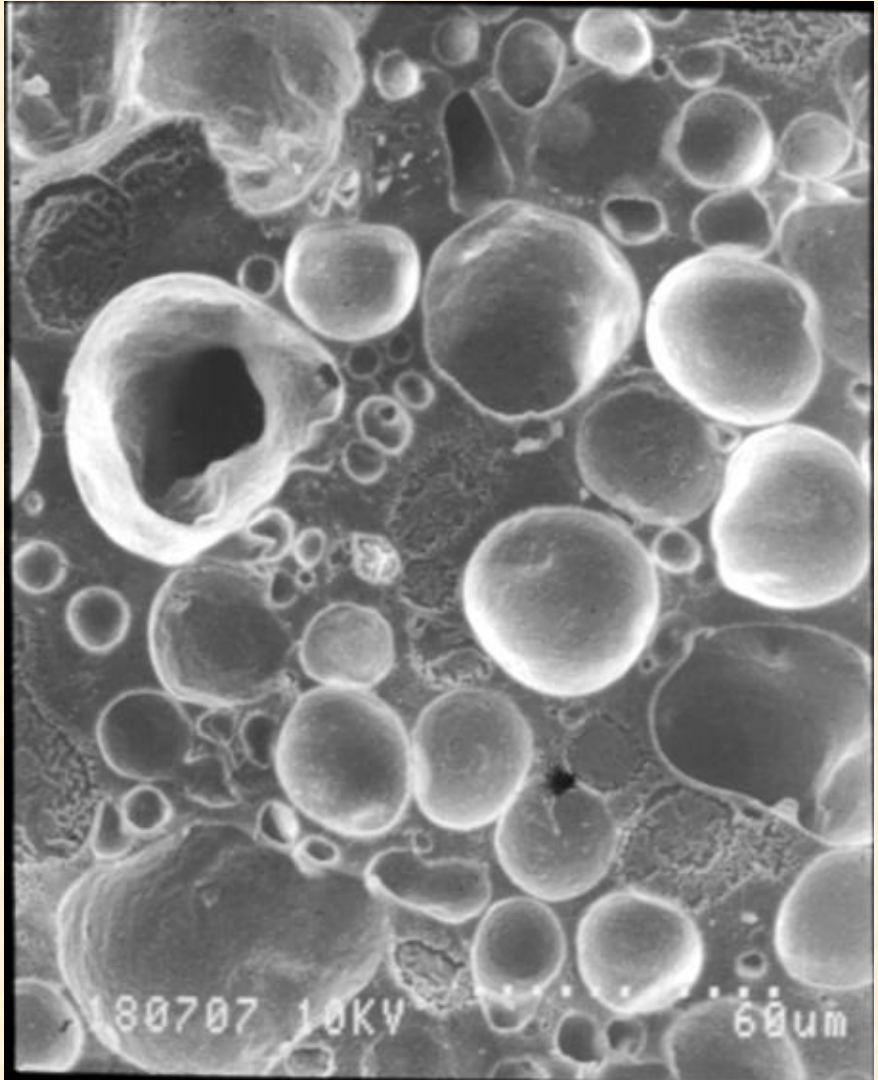


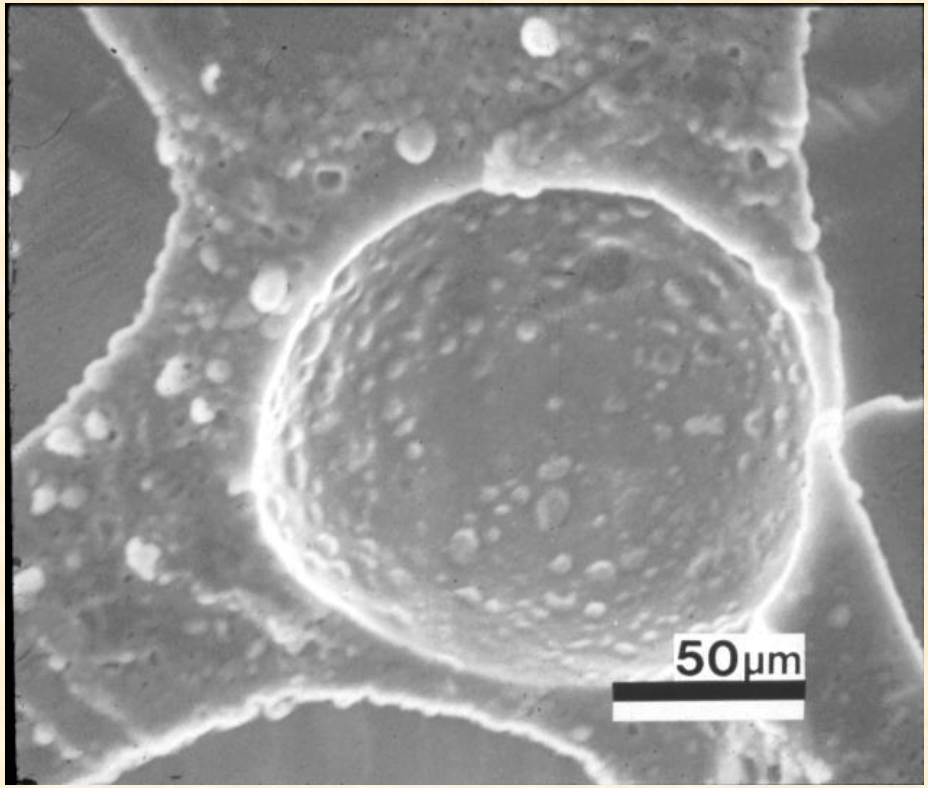
Courtesy M. Kalab

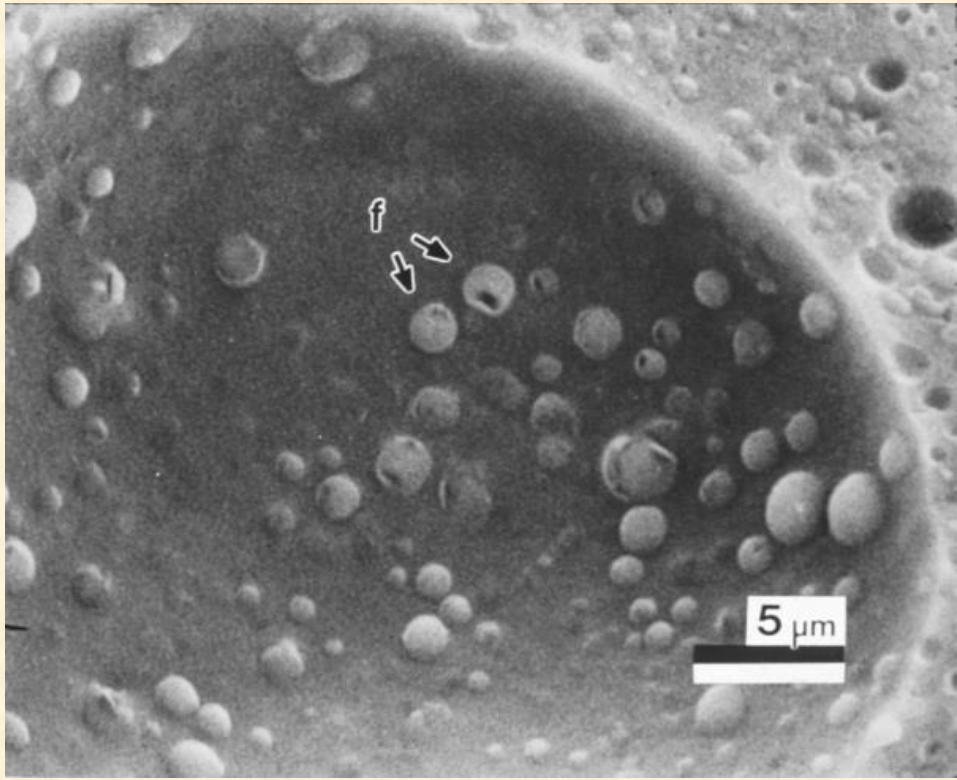
Aerated emulsions: fat globules and clusters accumulate at air interfaces



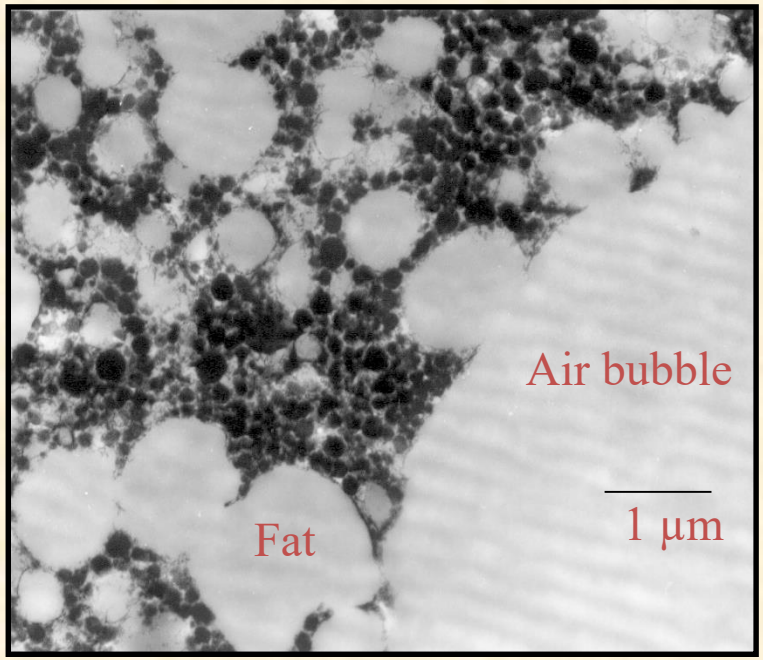
Air bubbles in freshly-drawn ice cream

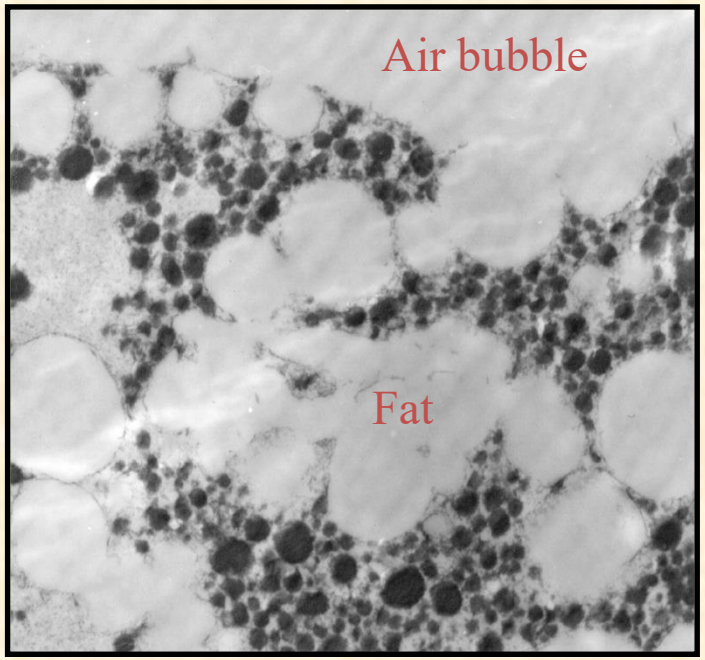



50µm

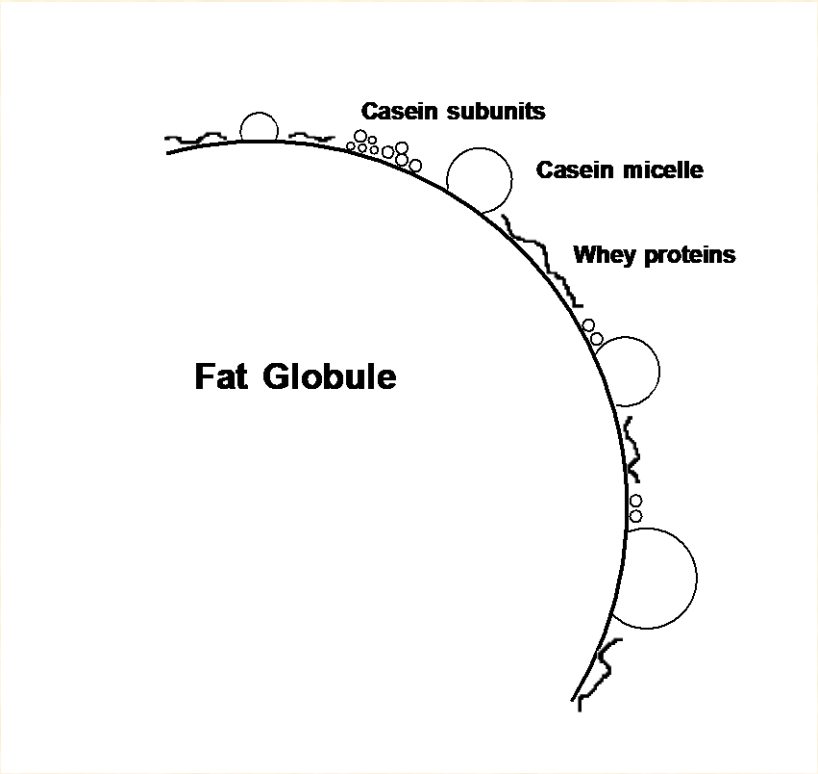

f
5 µm

Partially-coalesced fat globule networks in ice cream

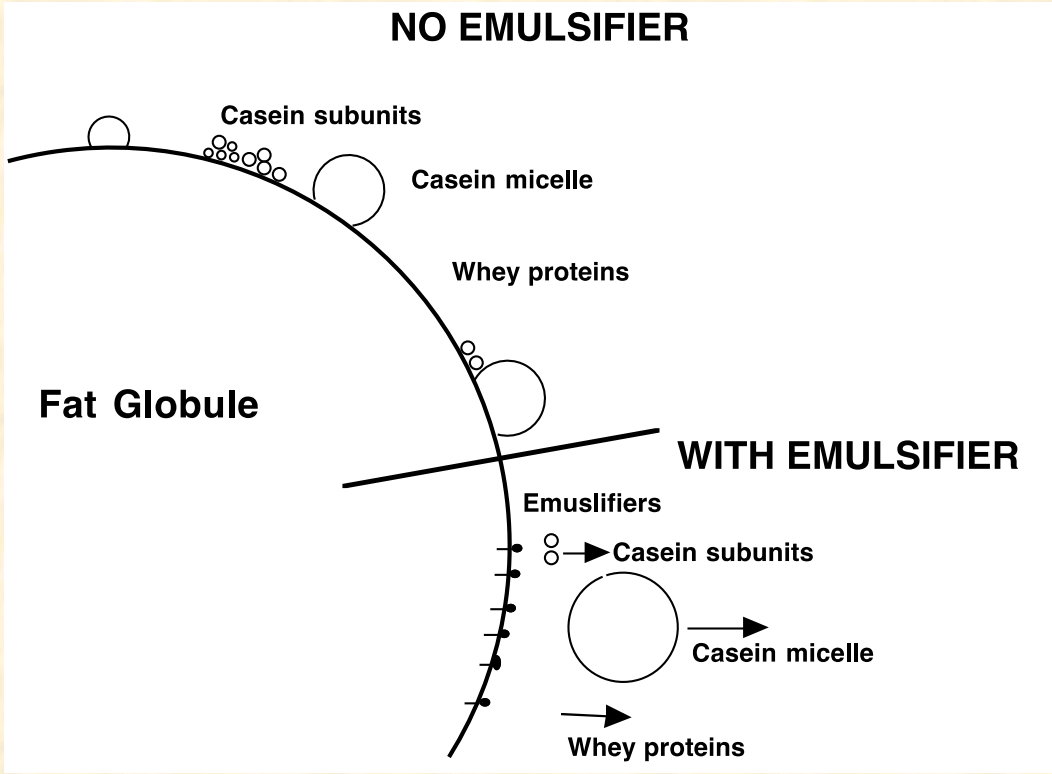




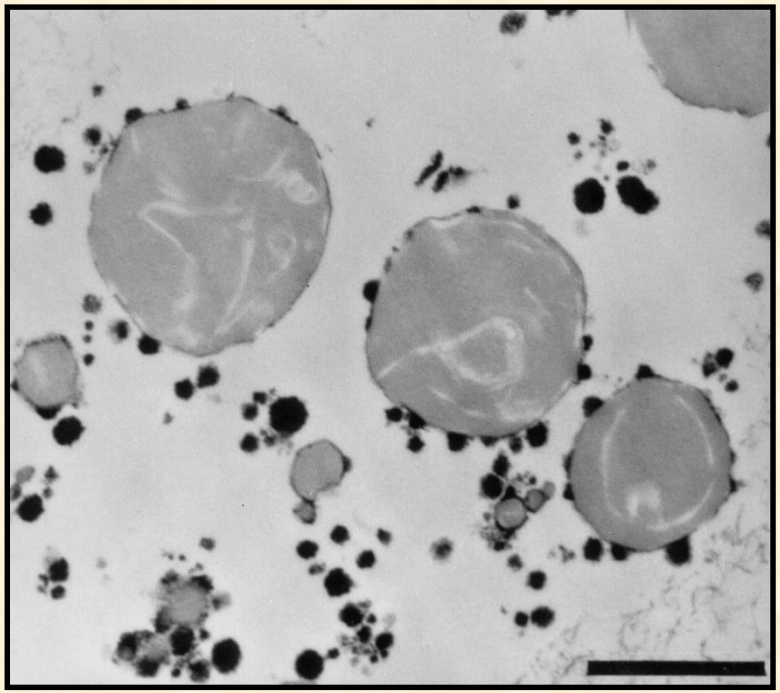
Fat globules stabilized by proteins after homogenization



Emulsifiers: Protein displacement at homogenization and during ageing



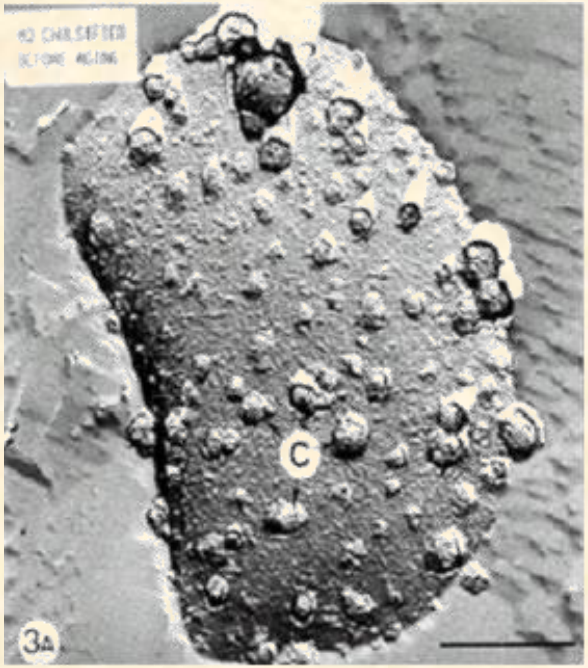
Homogenized Fat Globules and the Role of Emulsifiers



No emulsifier, adsorbed casein

With polysorbate 80

Homogenized Fat Globules and the Role of Emulsifiers and Ageing

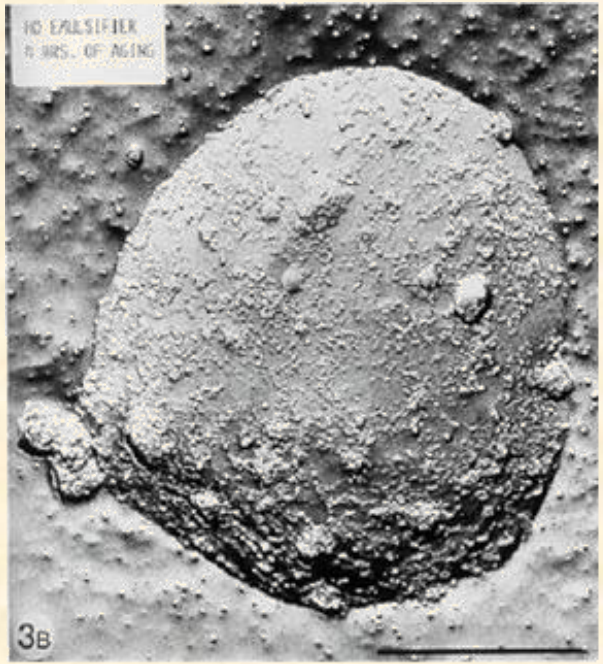


No emulsifier before ageing

With emulsifier before ageing

Courtesy W. Buchheim

Homogenized Fat Globules and the Role of Emulsifiers and Ageing

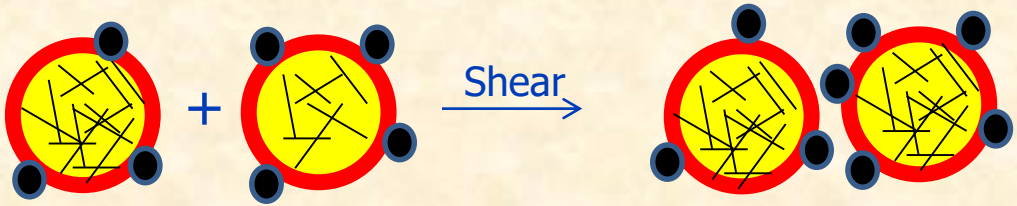


No emulsifier 4 hrs. of ageing

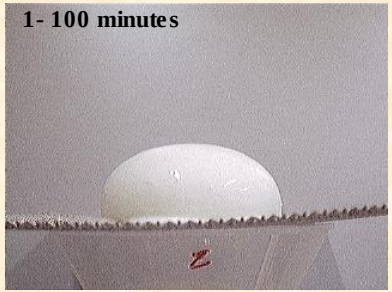
With emulsifier 4 hrs. of ageing

Courtesy W. Buchheim

With "thin" fat interface (emulsifiers) and partially crystalline fat (cold ageing)



With "thick" fat interface (proteins) and partially crystalline fat

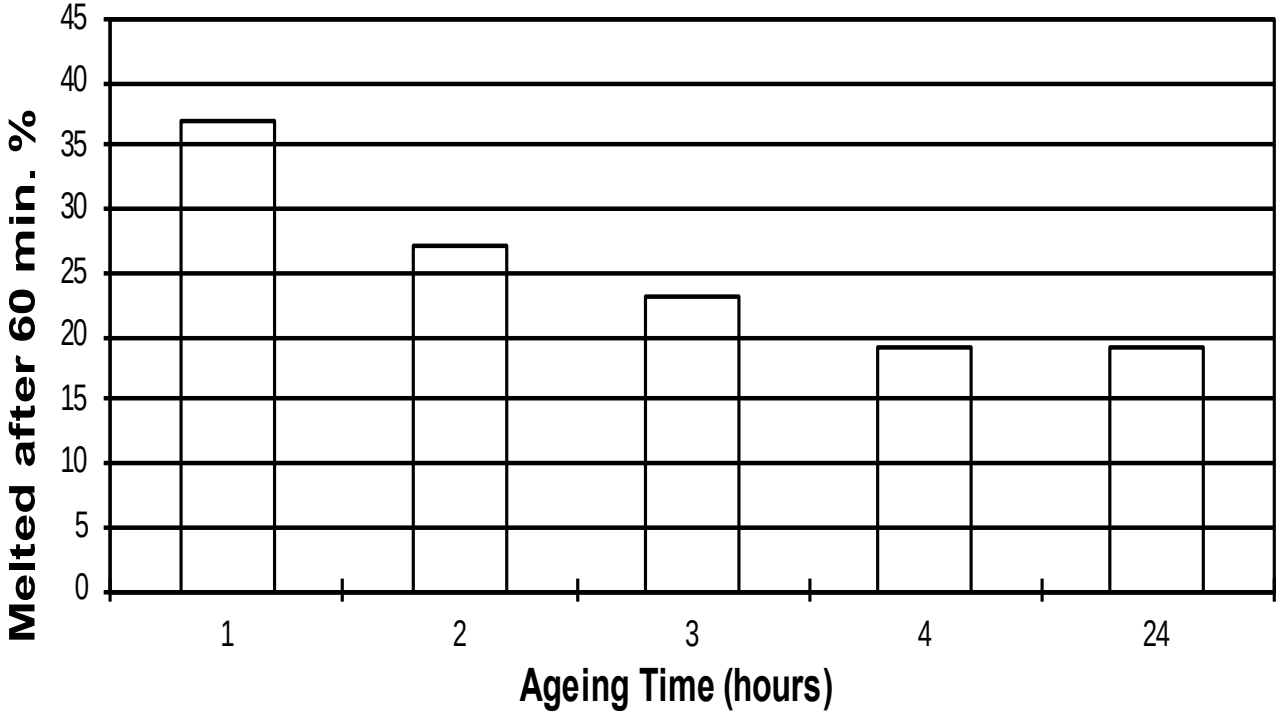


No emulsifier

0.15% mdg
+ 0.02% ps 80

0.15% mdg
+ 0.06% ps 80

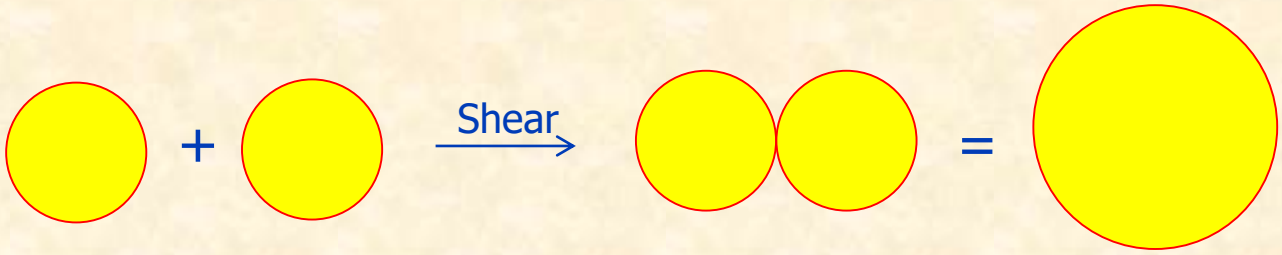
Melting Resistance as Function of Ageing Time



Non-dairy fat Frozen Desserts

Modified milk ingredients, sugar, milk ingredients, glucose, ***coconut oil***, mono- and diglycerides, propylene glycol monostearate, cellulose gum, carob bean gum, carrageenan, artificial flavour, colour.

MODIFIED MILK INGREDIENTS, SUGAR, WATER, GLUCOSE, **COCONUT OIL**, NATURAL VANILLA FLAVOUR, MONO AND DIGLYCERIDES, VEGETABLE GUMS (GUAR, CAROB BEAN), CARRAGEENAN, NATURAL COLOUR.



Liquid oil : Coalescence

Solid fat : Stability

Effect of Solid Fat Content on Structure in Ice Creams Containing Palm Kernel Oil and High-Oleic Sunflower Oil

KRISTINE K. SUNG AND H. DOUGLAS GOFF

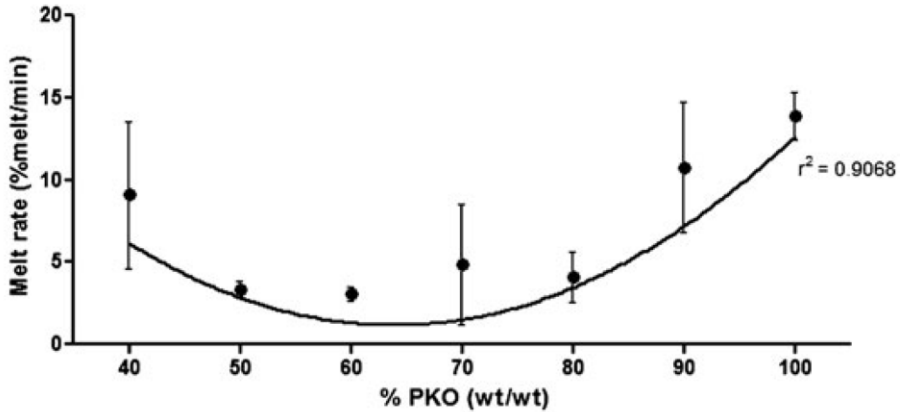
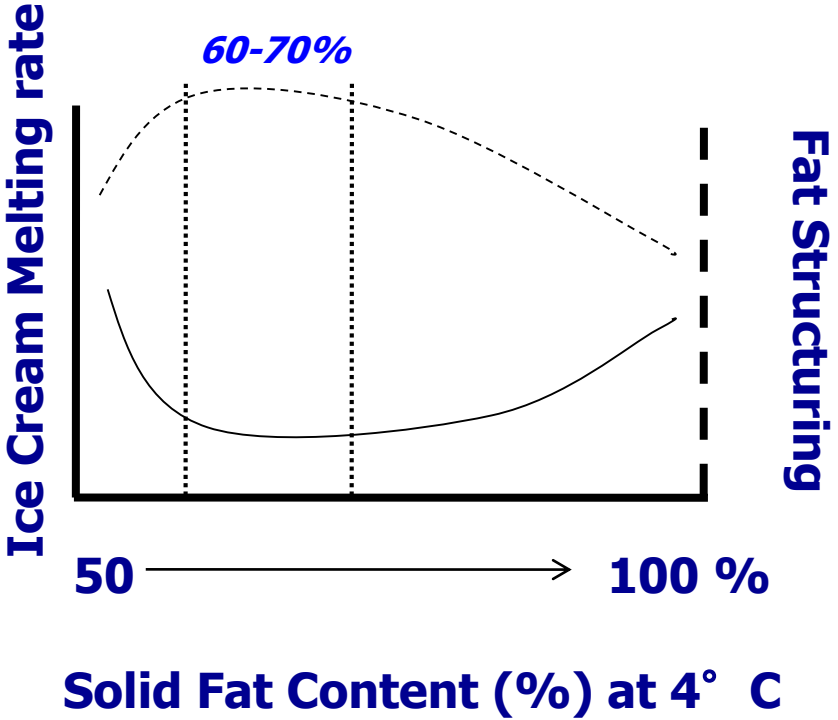
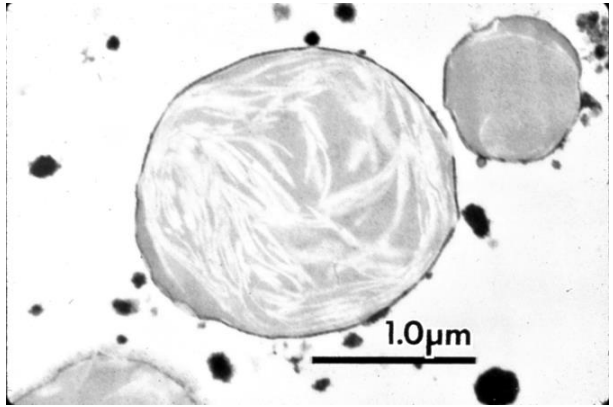


Figure 5—Melt rate of ice cream as a function of increasing palm kernel oil (PKO) concentration in a fat blend of PKO and high-oleic sunflower oil.





Guttierez, Sung and Goff, 2009

Low Fat Destabilization, Full Collapse and Drip-Through

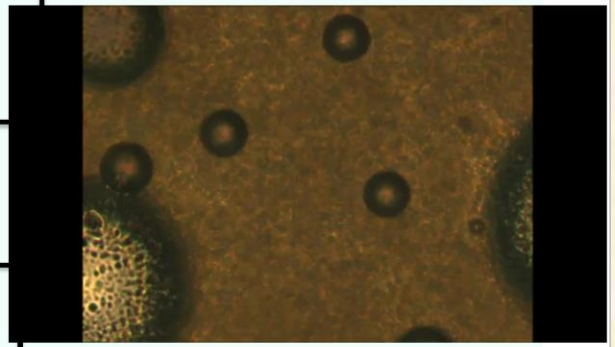
1 - Ice crystals

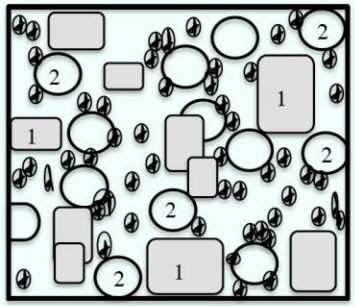
- Fat/destabilized fat

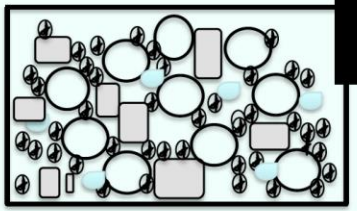
-Free water

-Serum phase

2 - Air cells



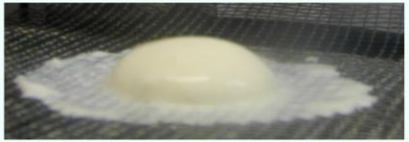


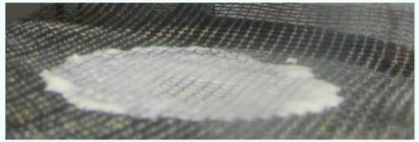


t = 0 minutes

t = 60 minutes

t = 70 minutes





Courtesy R. Hartel

High Fat Destabilization, Minimal Collapse

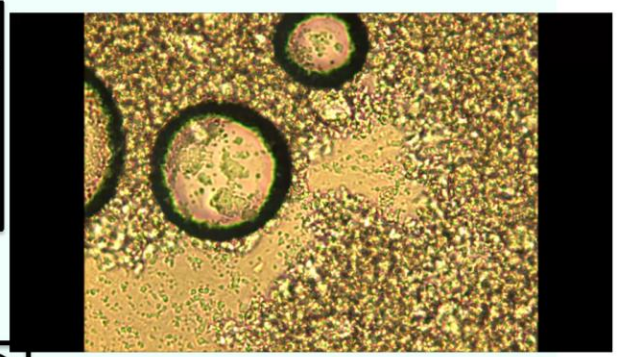
1 - Ice crystals

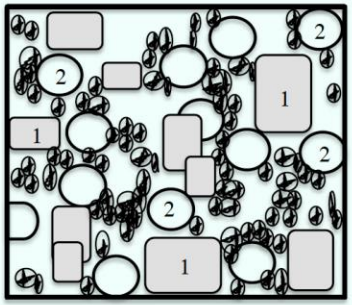
- Fat/destabilized fat

-Free water

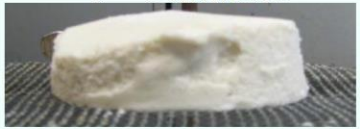
-Serum phase

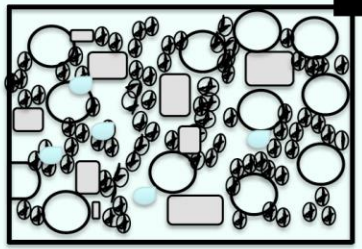
2 - Air cells



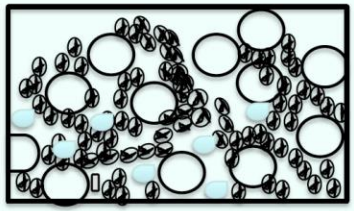


t = 0 minutes





t = 60 minutes



t = 120 minutes

Courtesy R. Hartel

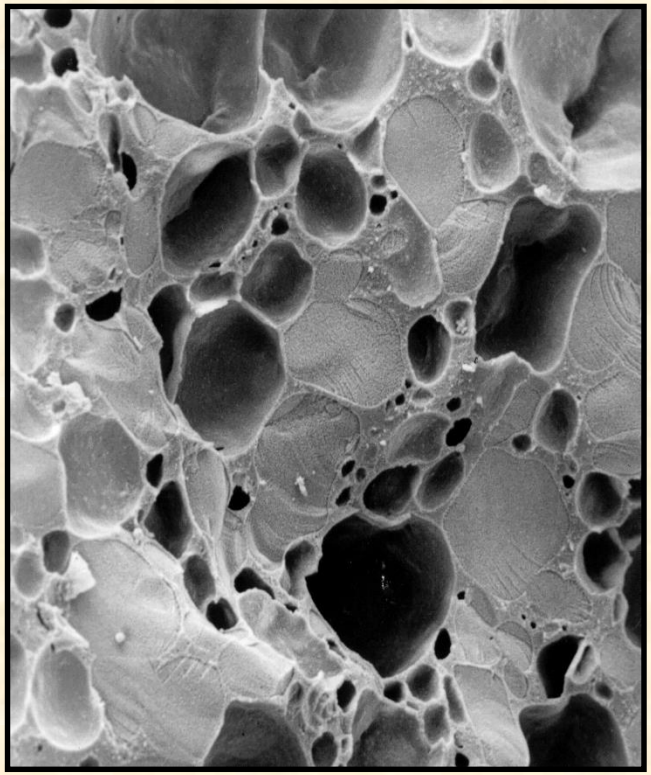
Here's Why Those Creepy Walmart Ice Cream Sandwiches Don't Melt

Summer is here—have some guar gum!

Shrinkage

Shrinkage

Discrete and stable air bubbles vs. large and channeled air bubbles



Prevention:

-Protein functionality

-Lower overrun

-Low temperature storage

Colloidal Structure and Texture

Perception of iciness decreases with increasing fat destabilization when there is no difference in ice crystal size

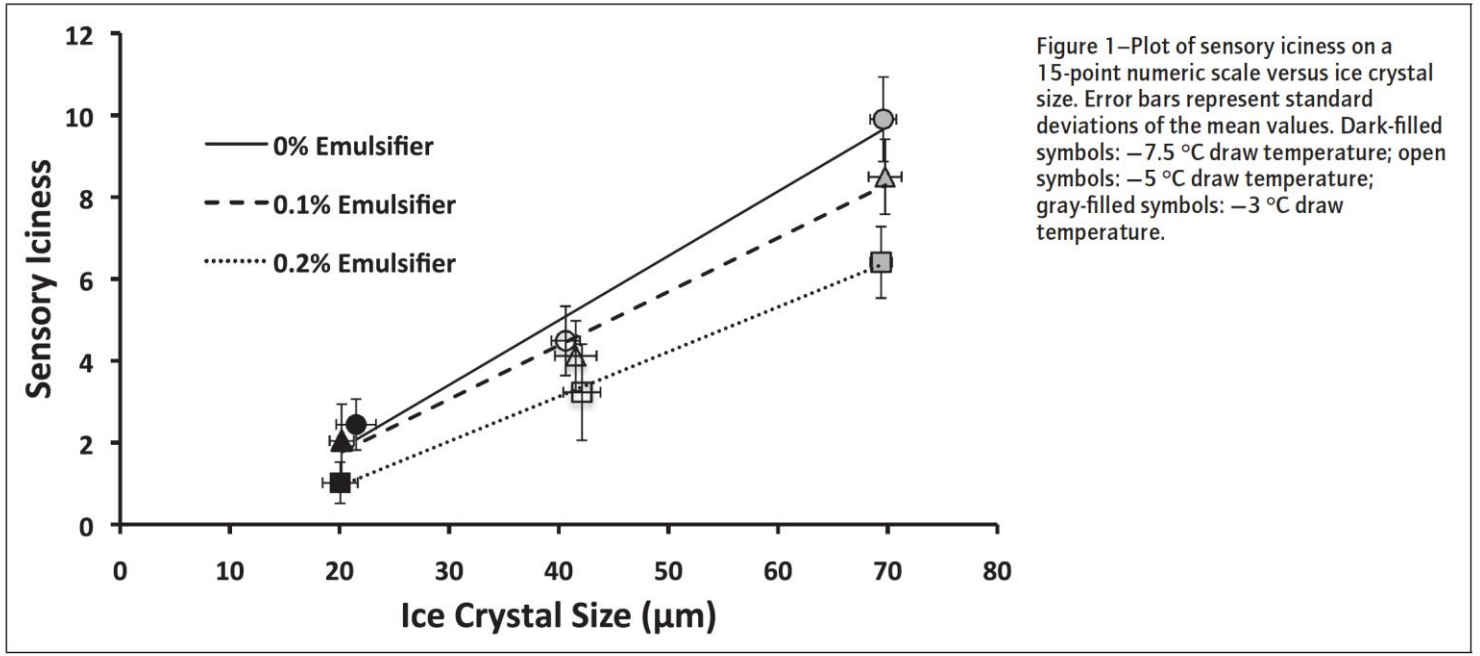


Figure 1–Plot of sensory iciness on a 15-point numeric scale versus ice crystal size. Error bars represent standard deviations of the mean values. Dark-filled symbols: –7.5 °C draw temperature; open symbols: –5 °C draw temperature; gray-filled symbols: –3 °C draw temperature.

Amador, Hartel and Rankin, 2017

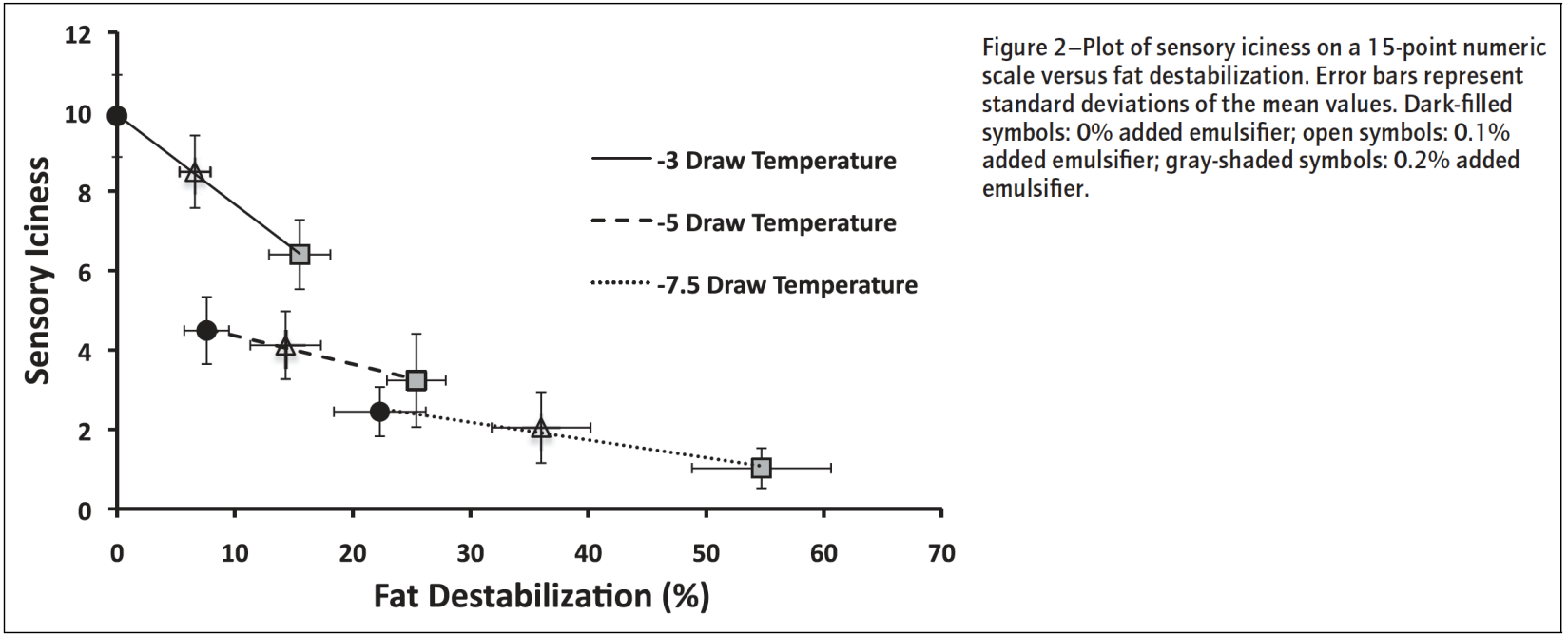


Figure 2–Plot of sensory iciness on a 15-point numeric scale versus fat destabilization. Error bars represent standard deviations of the mean values. Dark-filled symbols: 0% added emulsifier; open symbols: 0.1% added emulsifier; gray-shaded symbols: 0.2% added emulsifier.

Amador, Hartel and Rankin, 2017

But, perception of greasiness can also increase with increasing fat destabilization

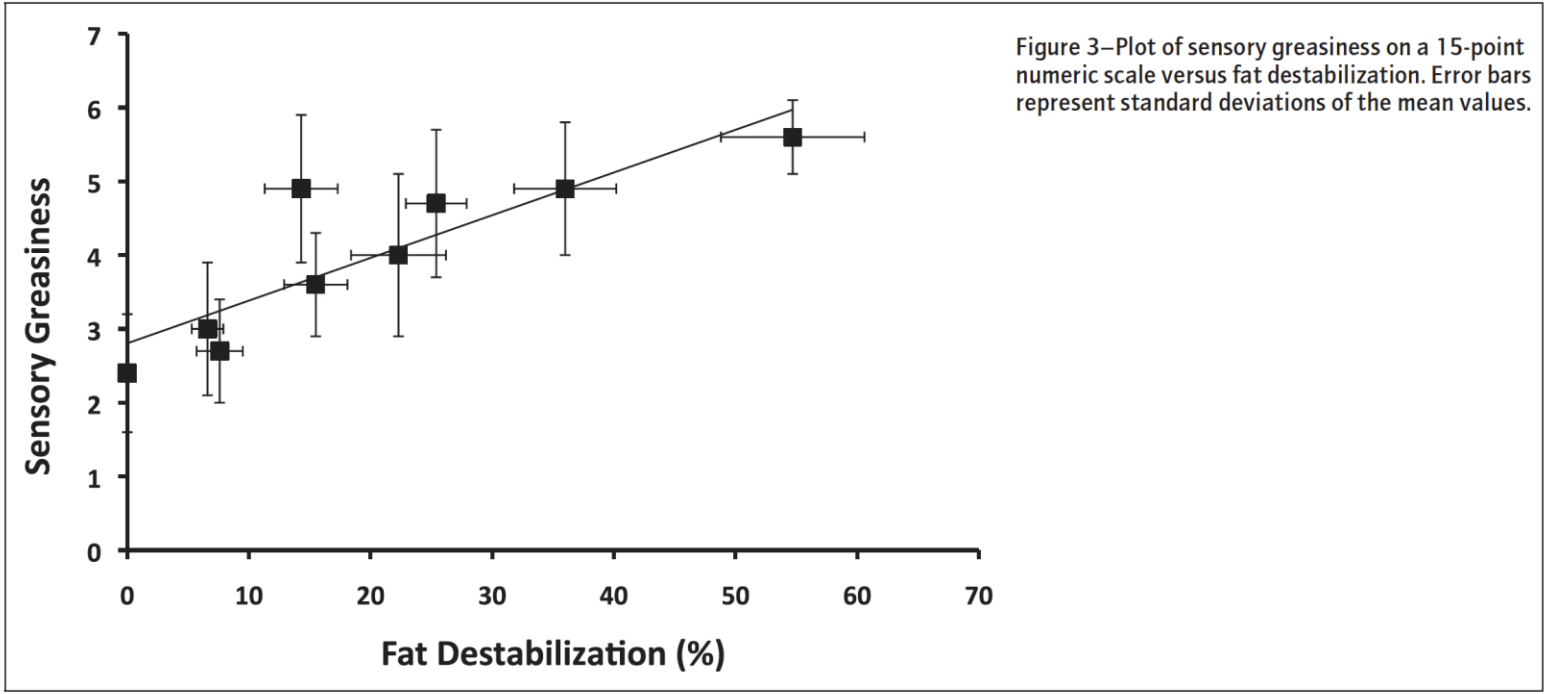
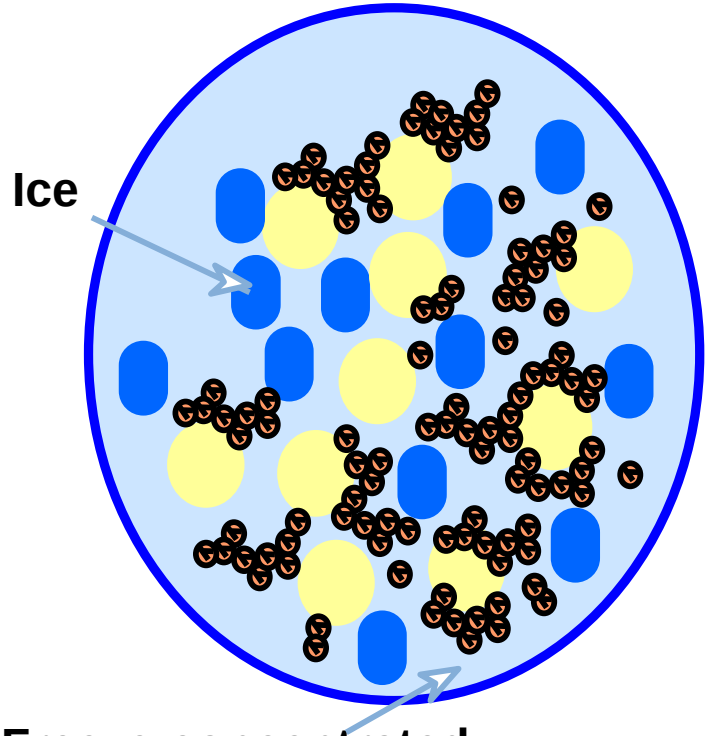
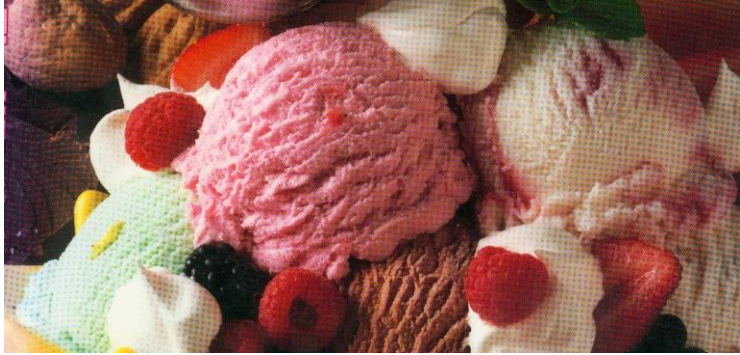


Figure 3–Plot of sensory greasiness on a 15-point numeric scale versus fat destabilization. Error bars represent standard deviations of the mean values.

Amador, Hartel and Rankin, 2017

Aqueous Structure





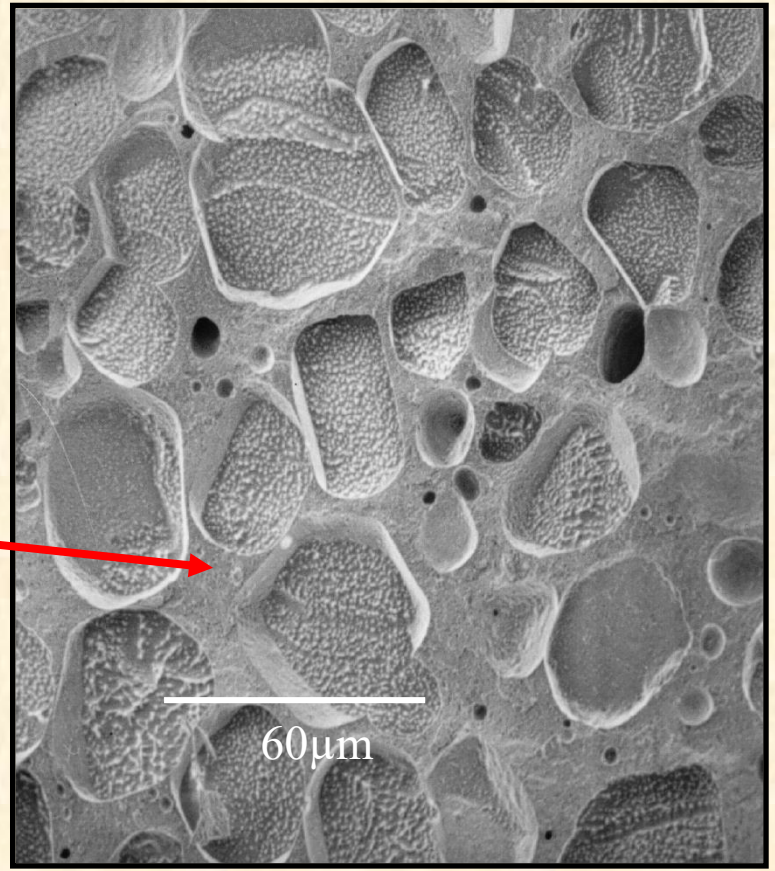
Performance Properties:

- Softness/scoopability
- Smooth→icy texture
- Shelf-life

Dependent on:

- Sugar content and source
- Proteins and stabilizers
- Freezing and hardening
- Cold-chain

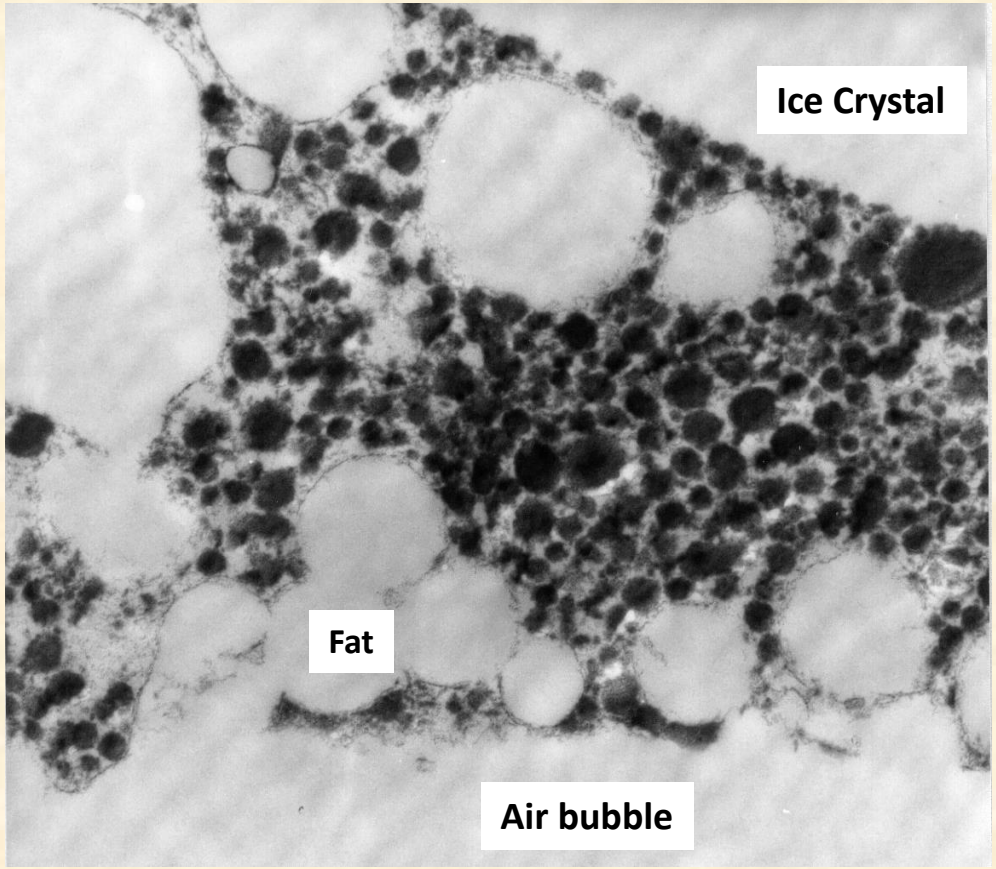
Ice crystals in freshly hardened ice cream



Freeze-concentrated Unfrozen phase

- Solution of sugars, salts and soluble proteins
- Dispersion of casein micelles and stabilizers
- Expands and shrinks with temperature
- Can undergo glass transition at low temperature

Casein micelles in the unfrozen phase of ice cream



Food Freezing: conversion of water to ice

- **Nucleation/seeding/growth - controls initial ice crystal size distribution (*fast freezing and hardening*)**
  - **Small crystals: smooth texture**

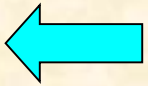
Freezing and hardening equipment

- **Solute freeze-concentration - controls ice phase volume**

Sugars, lactose and salts

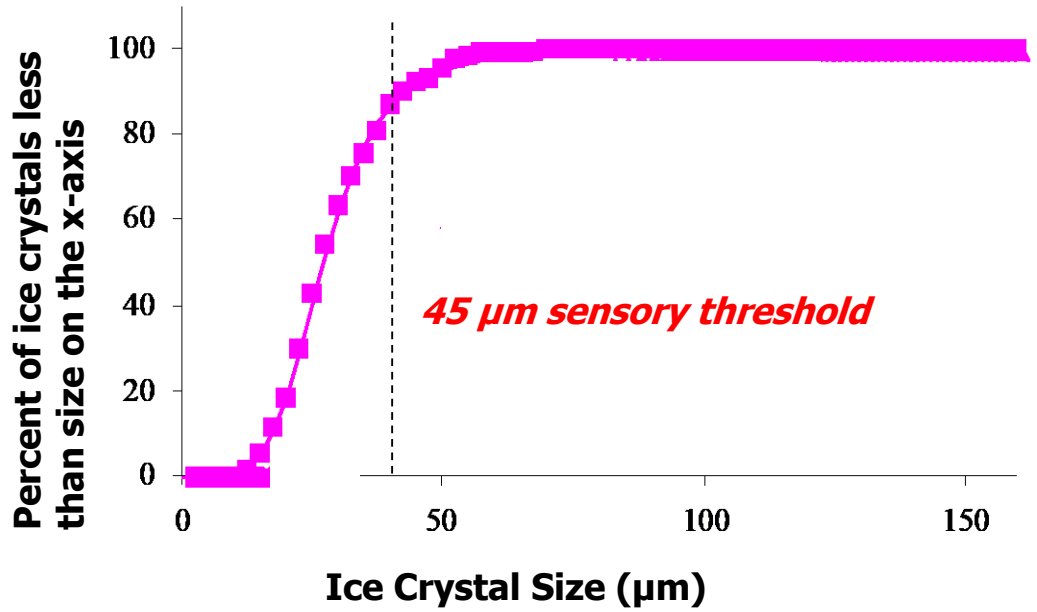
- **Glass transition of the unfrozen phase**
  - **Low temperature, long term stability**

- **Ice Recrystallization and Heat shock**
  - **minimize water redistribution**

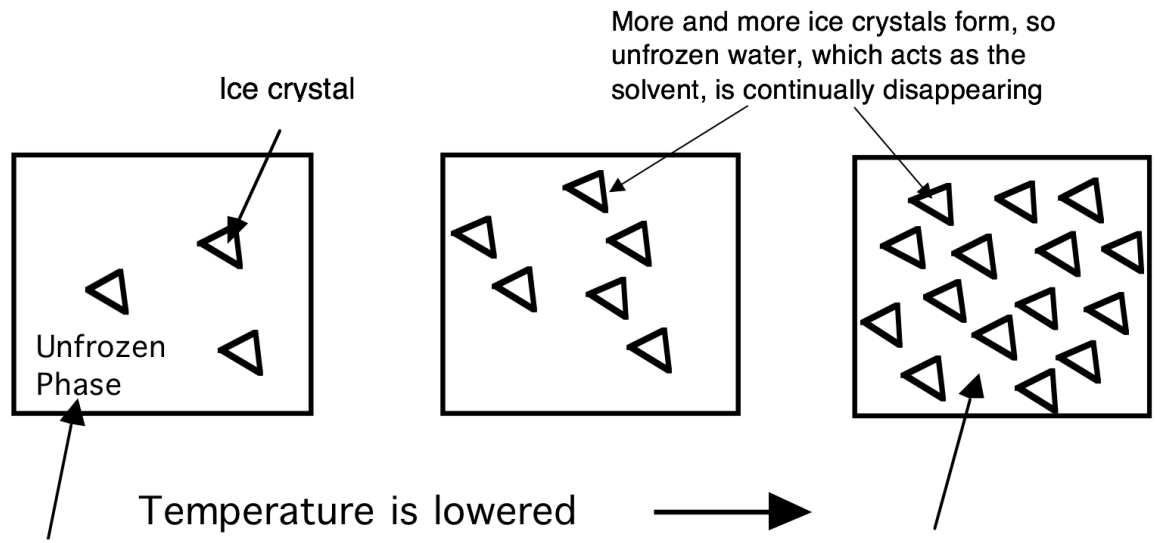


stabilizers

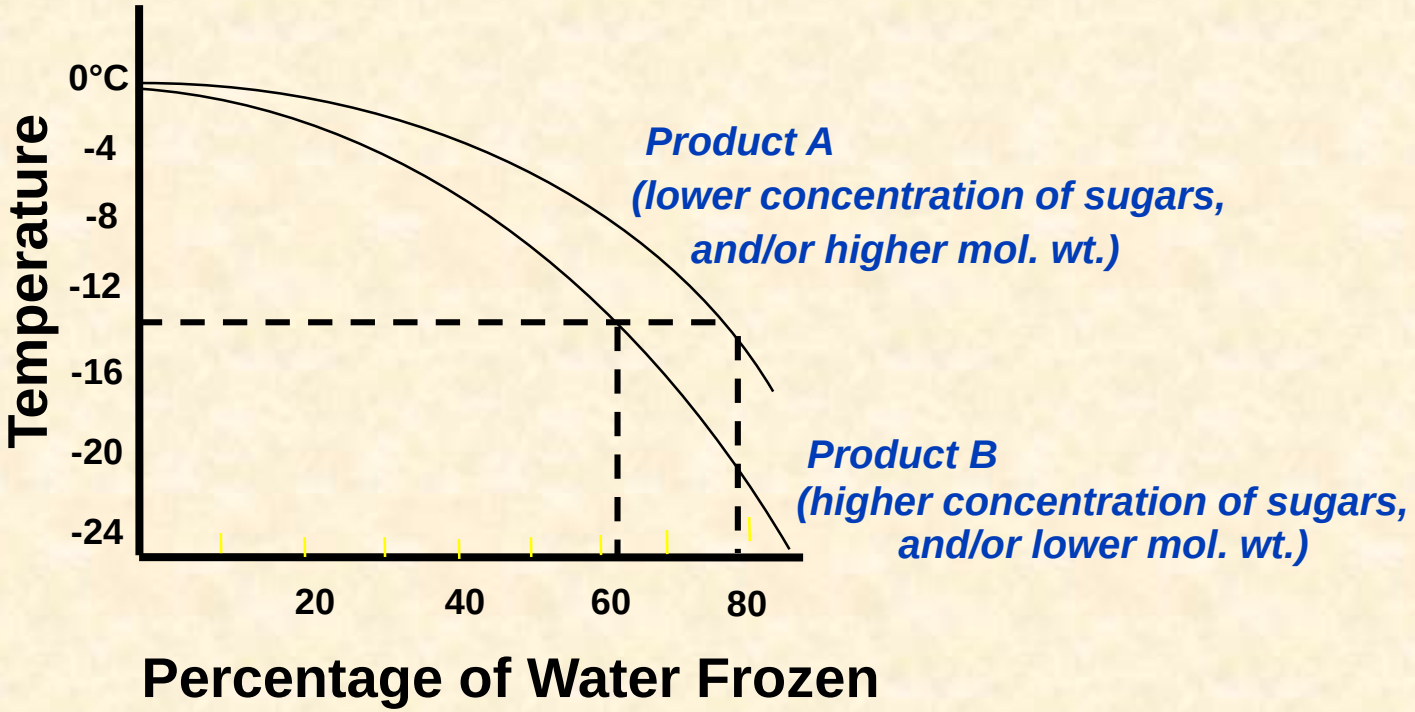
Ice crystal size cumulative distribution in fresh ice cream



Freeze-concentration: the influence of sugars

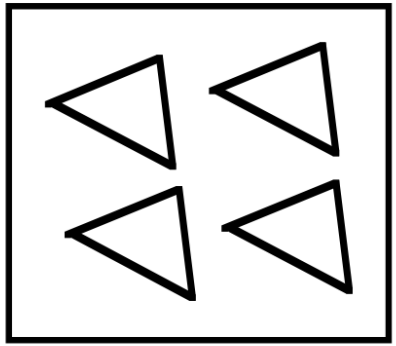


The Freezing Curve

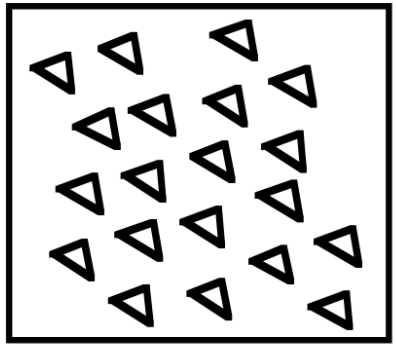


Recrystallization

50% of the water frozen in each case



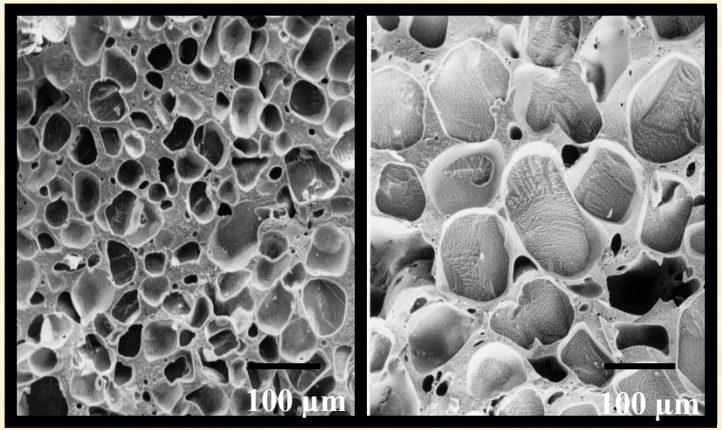
Small number of large crystals



Large number of small crystals

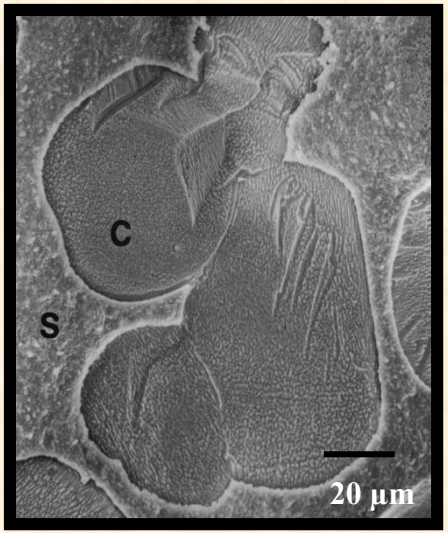
Heat shock

Ice cream: the effects of heat shock



Before *After*

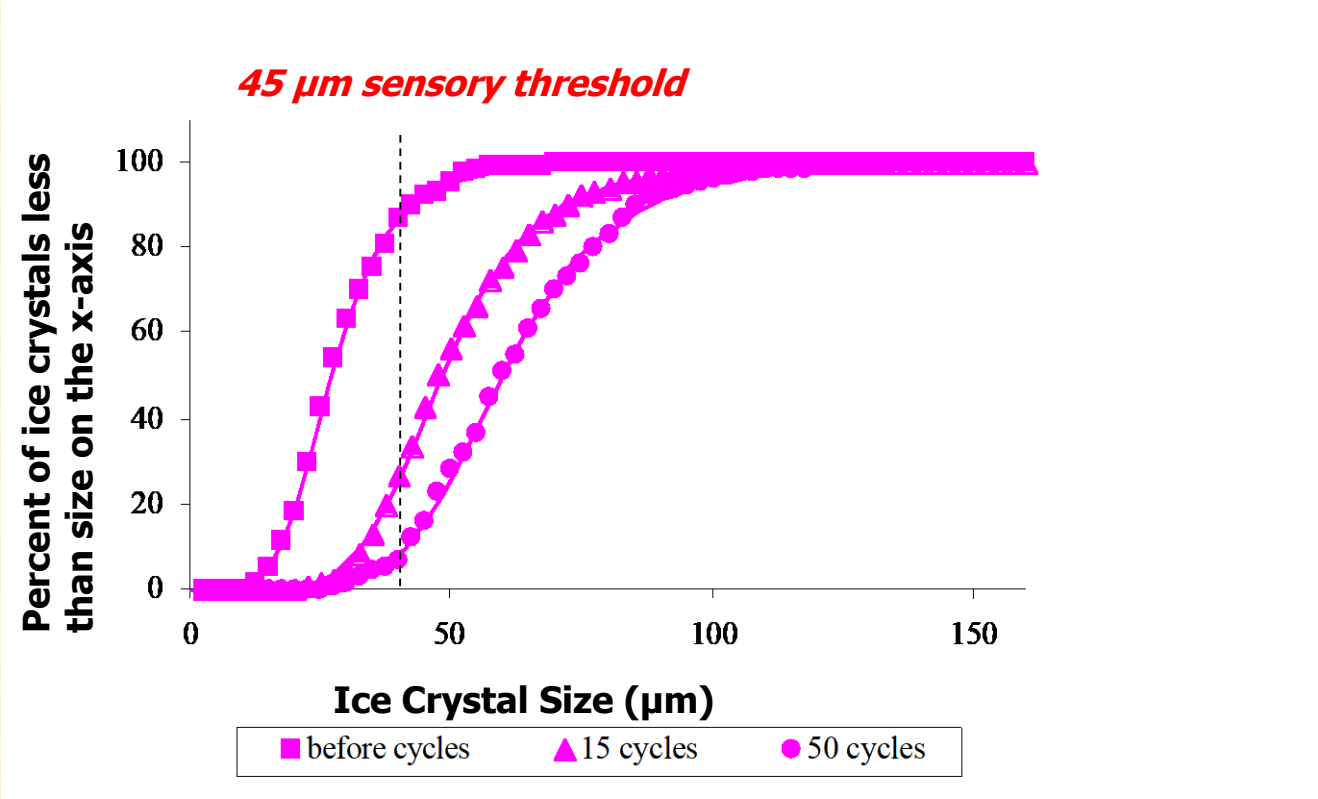
Recrystallization



Accretion

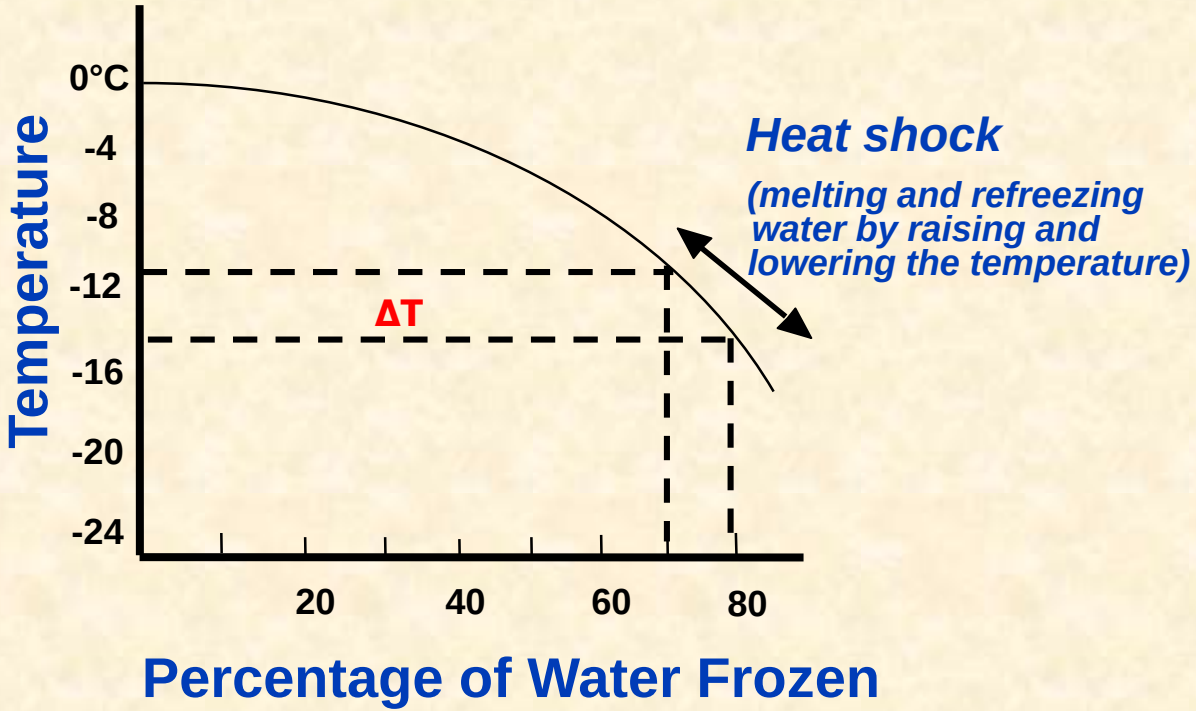
Caldwell and Goff, 1992

Ice crystal size cumulative distribution in fresh and stored ice cream

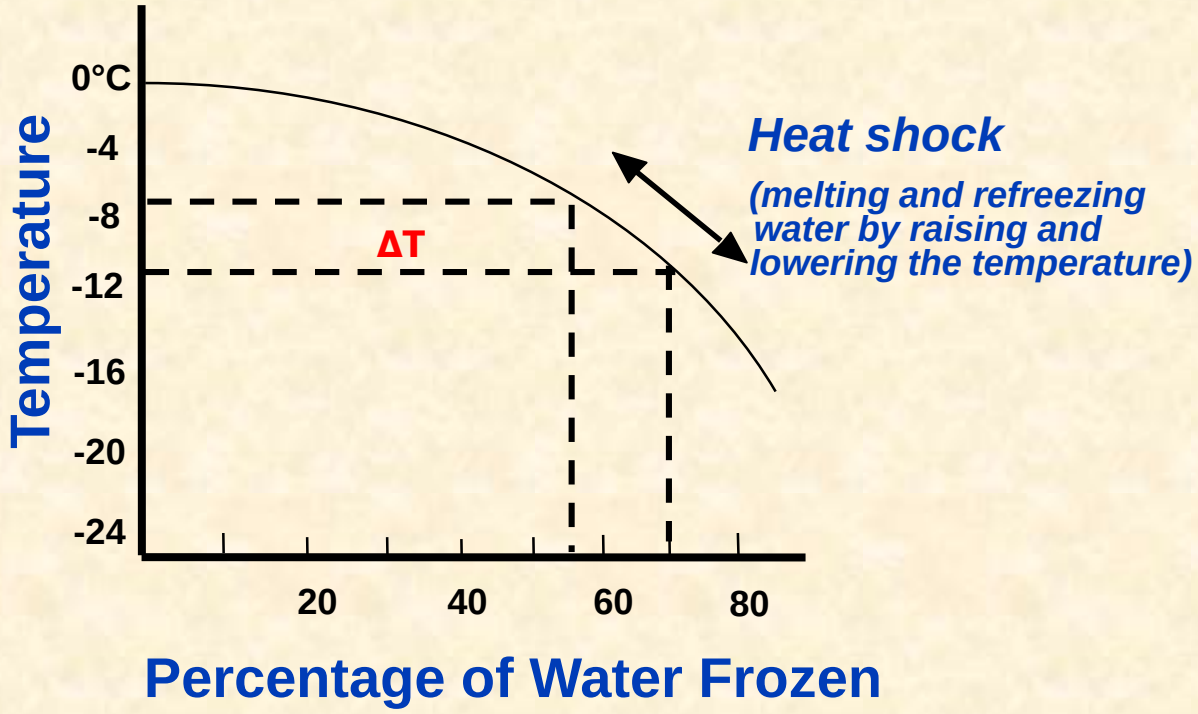


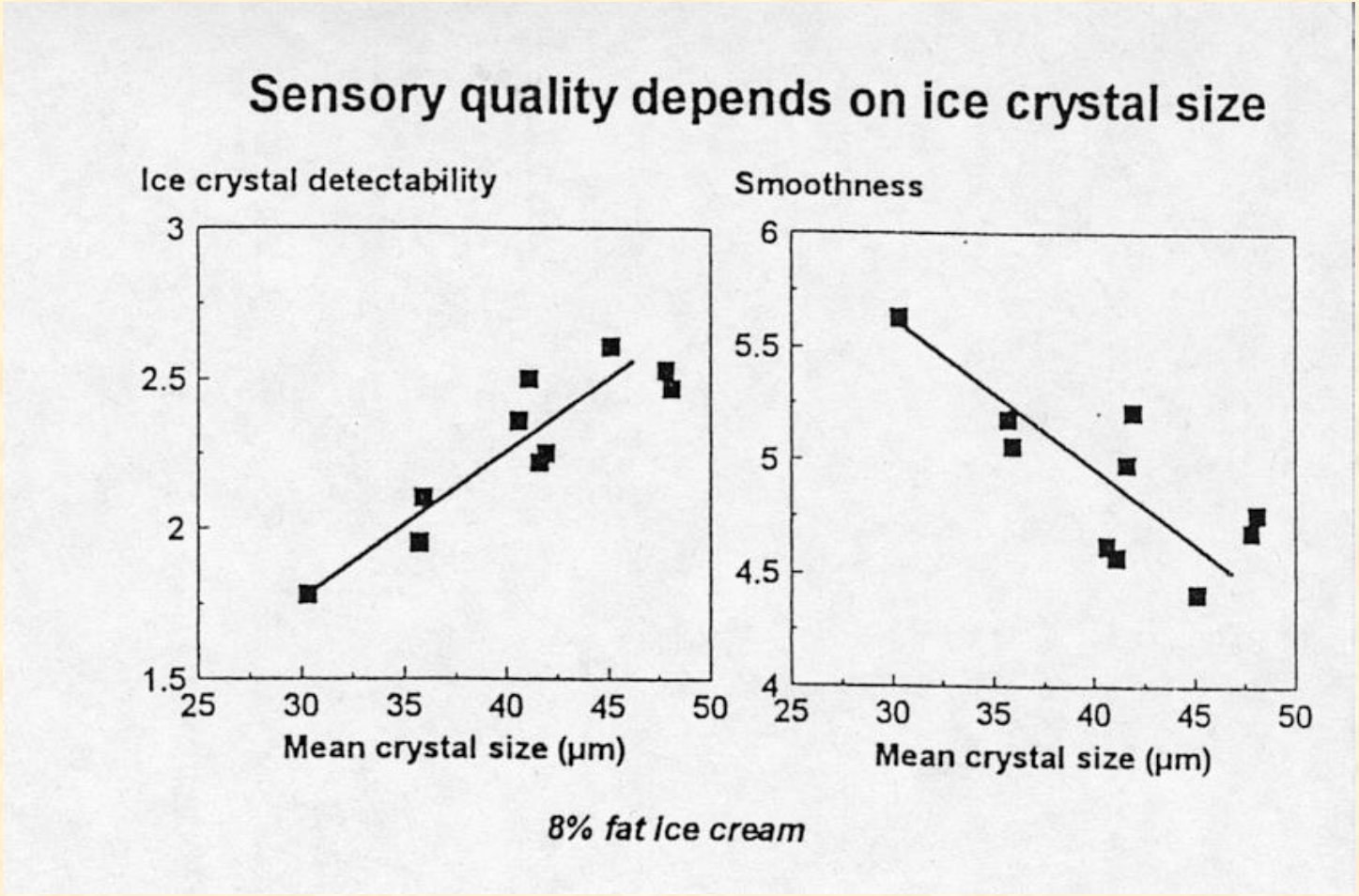
-10° C/12 hrs; -20° C, 12 hrs

The Freezing Curve



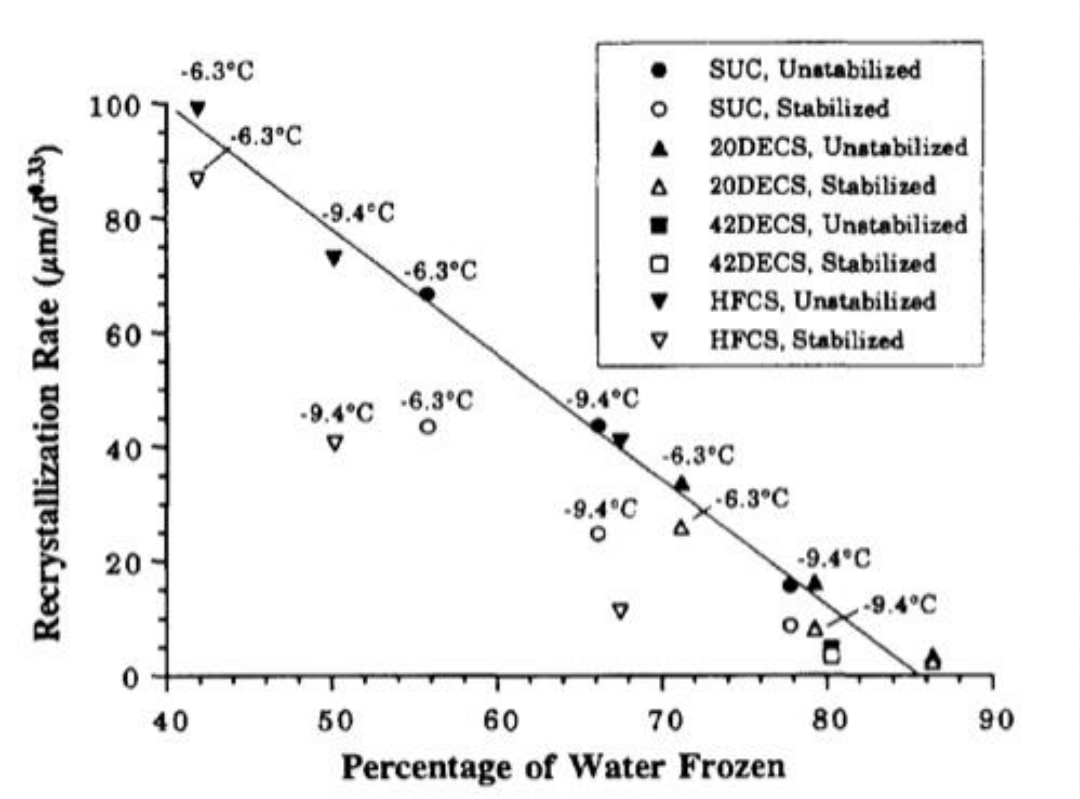
The Freezing Curve





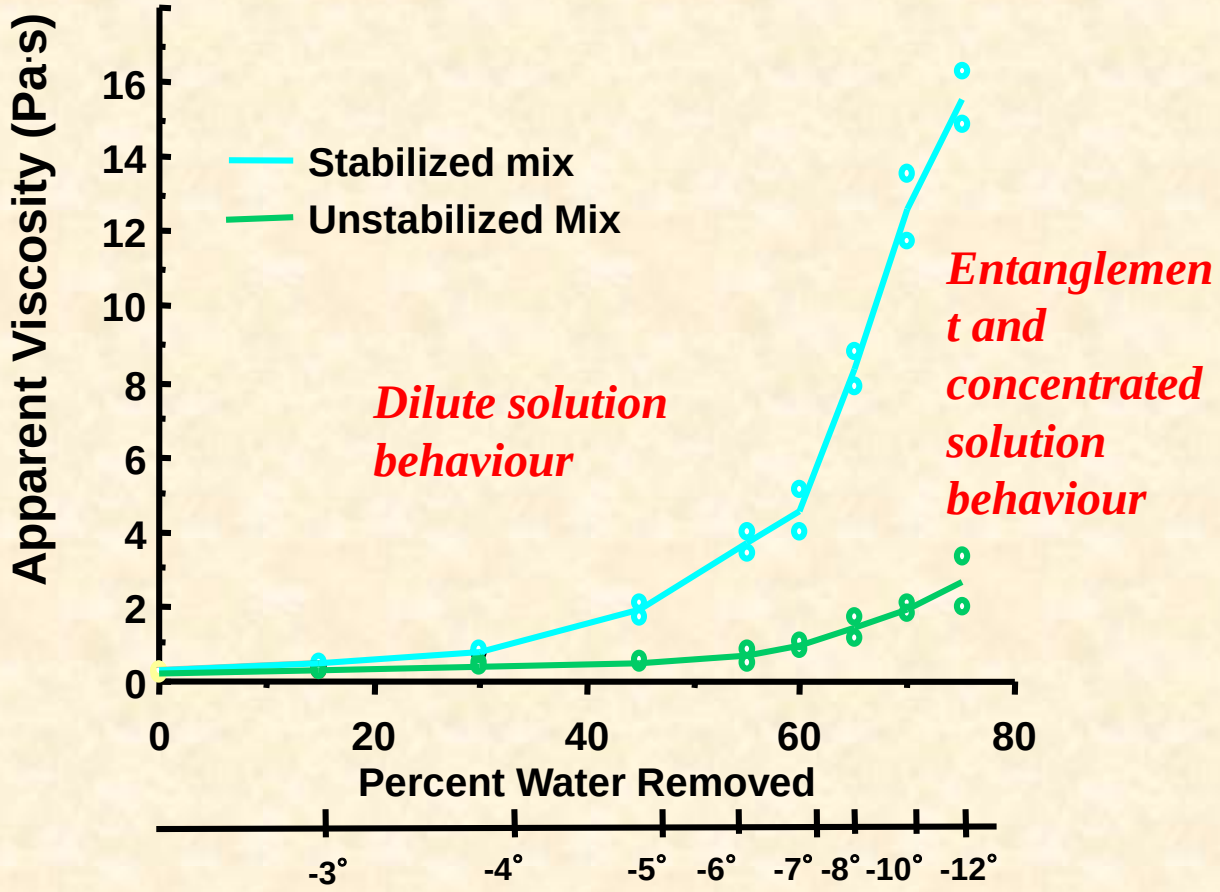
Russell et al., J. Food Eng., 39: 179-191 (1999).

Recrystallization rate depends on storage temperature, freeze-concentration and stabilizers!



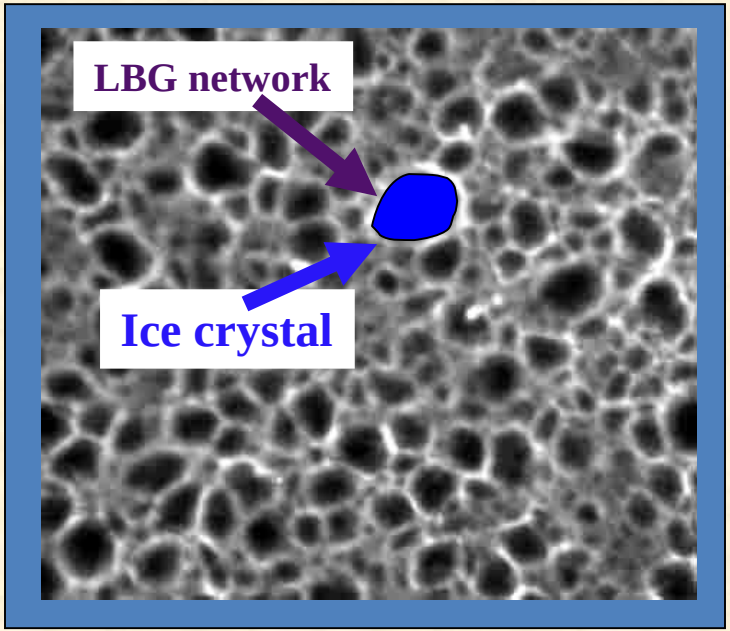
Hagiwara and Hartel, 1996

Viscosity enhancement during freeze-concentration



Goff et al., J. Texture Studies, 26:517, 1995

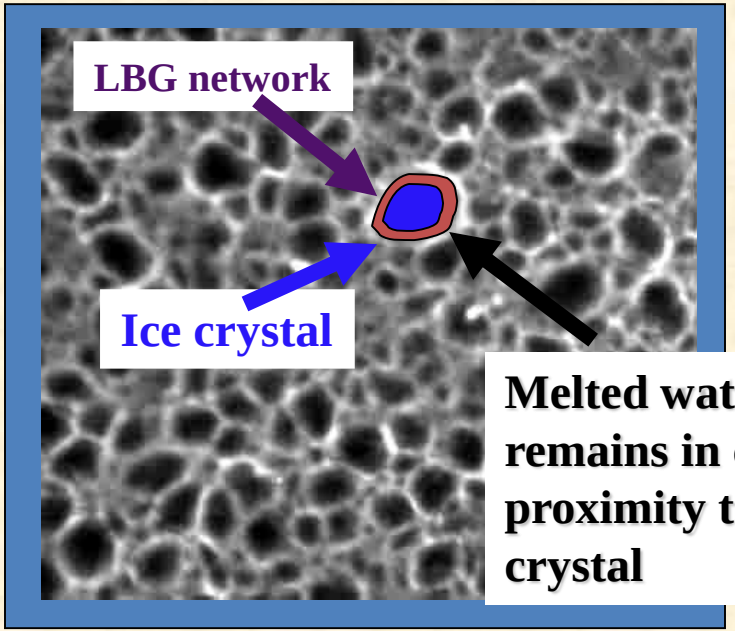
Stabilizer Functionality at Retarding Ice Recrystallization



Increase temperature

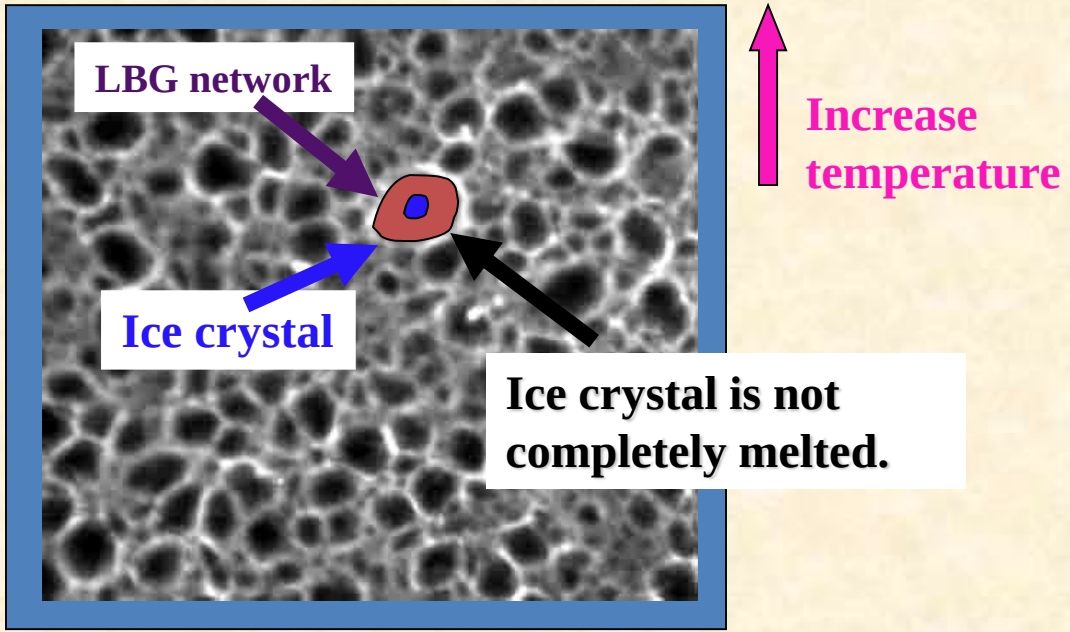
Goff et al., 1999

Stabilizer Functionality at Retarding Ice Recrystallization



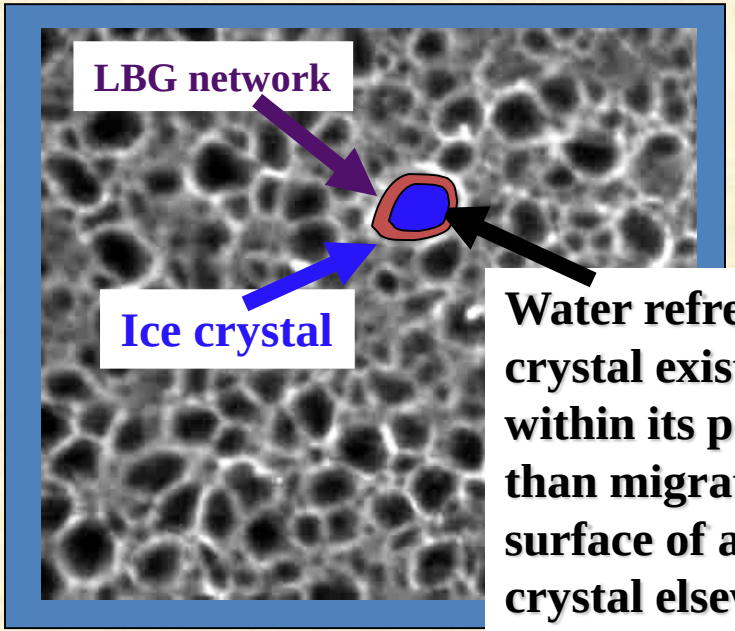
Goff et al., 1999

Stabilizer Functionality at Retarding Ice Recrystallization



Goff et al., 1999

Stabilizer Functionality at Retarding Ice Recrystallization

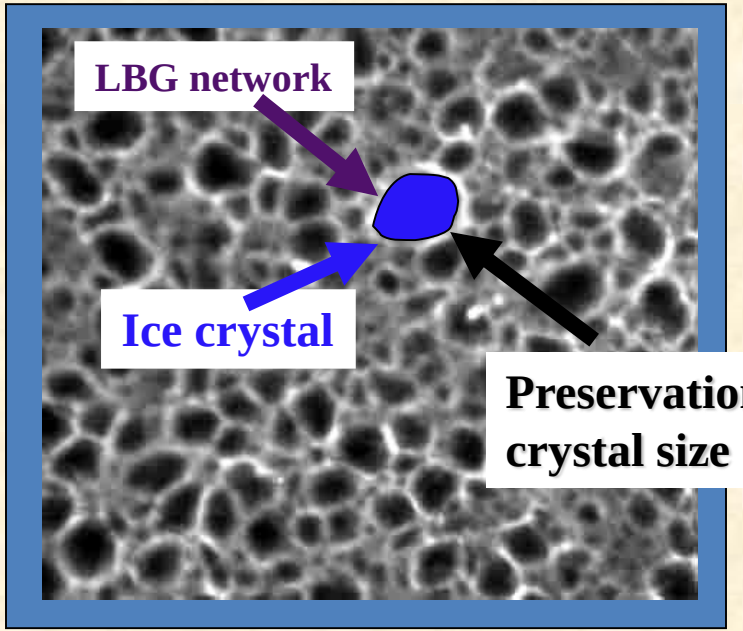


Decrease temperature

Water refreezes onto crystal existing within its pore rather than migrating to the surface of a larger crystal elsewhere

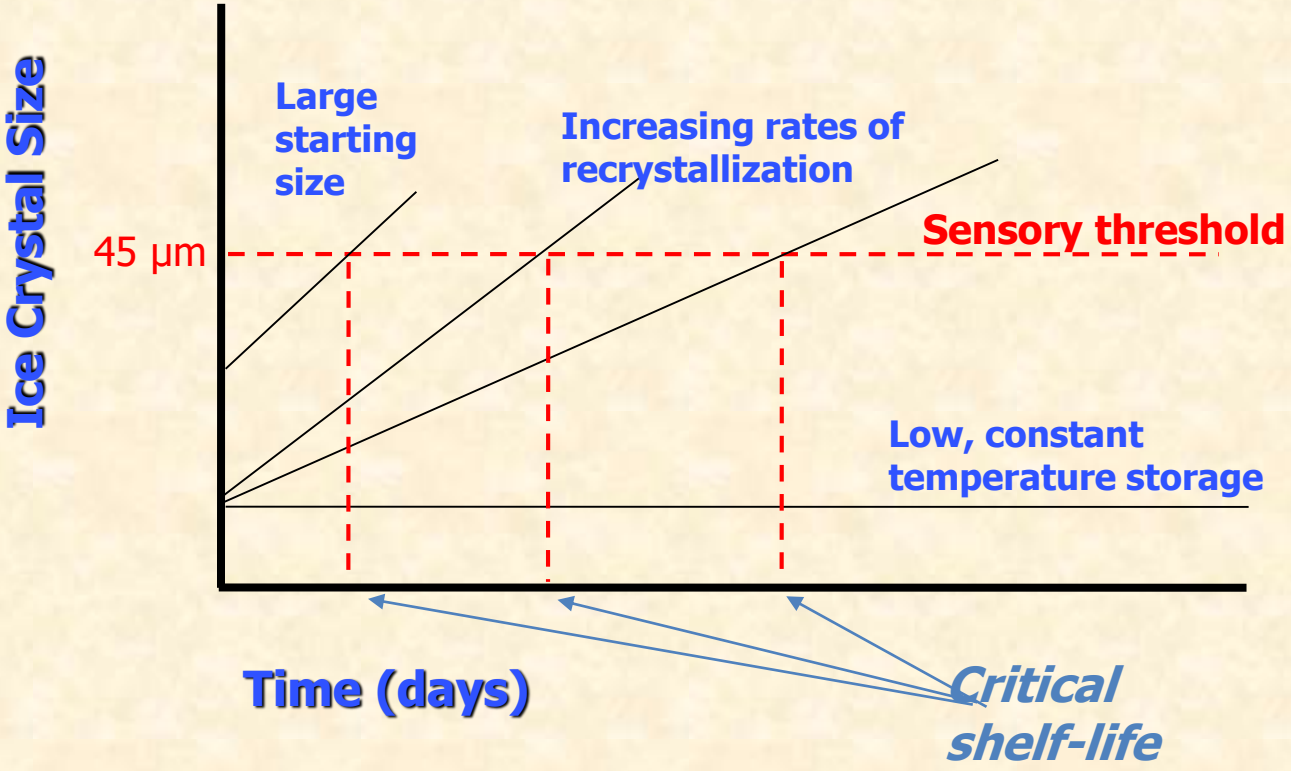
Goff et al., 1999

Stabilizer Functionality at Retarding Ice Recrystallization



Goff et al., 1999

Ice Cream Shelf-Life



Stabilizers and Texture

Perception of iciness decreases with increasing stabilizer level when there is no difference in ice crystal size

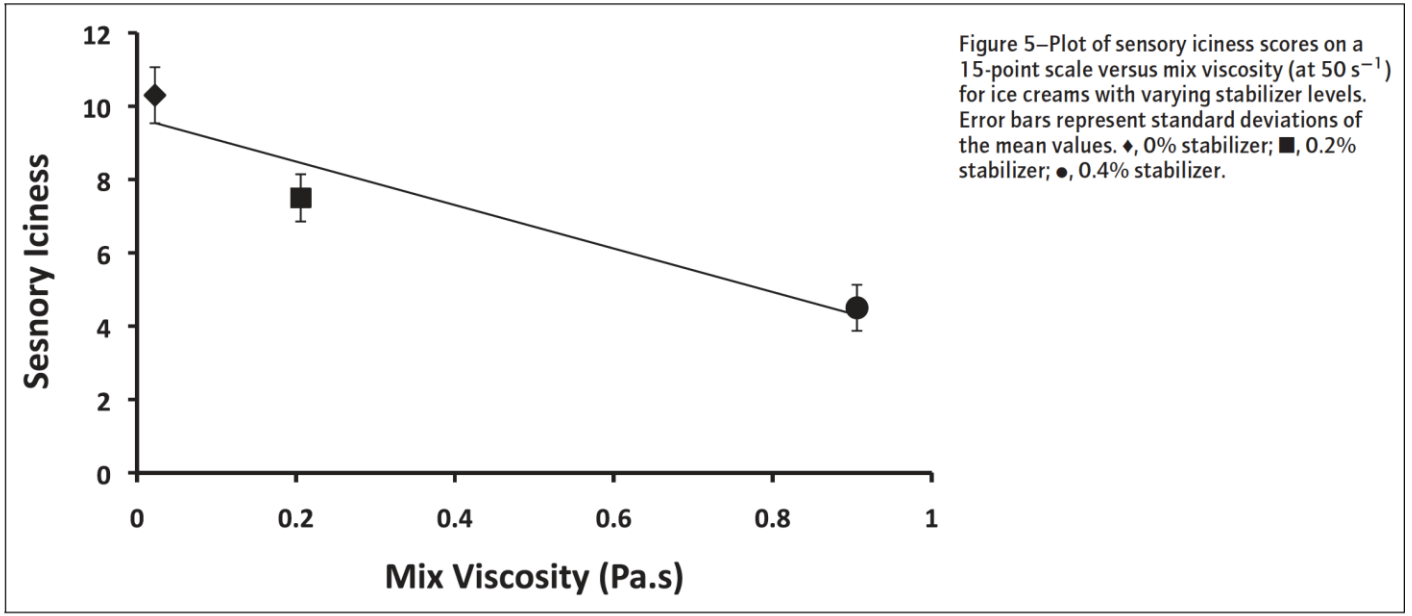


Figure 5–Plot of sensory iciness scores on a 15-point scale versus mix viscosity (at 50 s^{-1}) for ice creams with varying stabilizer levels. Error bars represent standard deviations of the mean values. ♦, 0% stabilizer; ■, 0.2% stabilizer; ●, 0.4% stabilizer.

Amador, Hartel and Rankin, 2017

Clean ingredients, healthy options dominate in frozen desserts

Ice cream makers are creating new pint lines with lower calories and sugar. Meanwhile, producers of frozen novelties and puddings focus on portion control, packaging and high-quality ingredients.

Dairy Foods, Sept., 2017

Clean Label

“Clean label refers to foods that are devoid of artificial flavors, colors and sweeteners, and synthetic additives.

Clean labels conveys notions of *quality, trust and transparency* to consumers.”

(A. Elizabeth Sloan, Food Technology)

Clean Label

- What does it mean for ice cream?
- Ingredients and ingredient functionalities :
  - Traditional (fresh) sources of milk ingredients
  - No hydrogenated fats
  - No corn-derived sweeteners (GMO or HFCS), hydrogenated polyols or non-natural high-potency sweeteners
  - Natural Stabilizers
  - Natural Emulsifiers, *e.g.* eggs
  - Natural Flavors and Colors

Random Vanilla ice cream labels from the US:

INGREDIENTS: Milk, Buttermilk, Sugar, Whey, Corn Syrup, Cream, Contains 2% or less of Mono & Diglycerides, Carob Bean Gum, Guar Gum, Natural and Artificial Flavors, Polysorbate 80, Carrageenan, Annatto for Color, Vitamin A Palmitate.

INGREDIENTS: Milk, Cream, Sugar, Buttermilk, Whey, Corn Syrup, Mono- And Diglycerides, Guar Gum, Sodium Phosphate, Cellulose Gum, Sodium Citrate, Polysorbate 80, Carrageenan, Natural Flavor, Annatto (For Color).

Cream, skim milk, sugar, egg yolks, vanilla extract.

Cream, milk, sugar, vanilla, vanilla bean.

Natural Vanilla

Our Original Vanilla. Made with simple ingredients like fresh cream, sugar, milk and real flecks of vanilla bean. Perfectly pairs with Pies, Cobblers & Crisps.

▸ Nutrition Facts

SHOW ME STORES

Like 196 Pin it Tweet

Milk, cream, sugar, tara gum, vanilla beans, natural flavor, natural vanilla flavor.

bluebunny.com

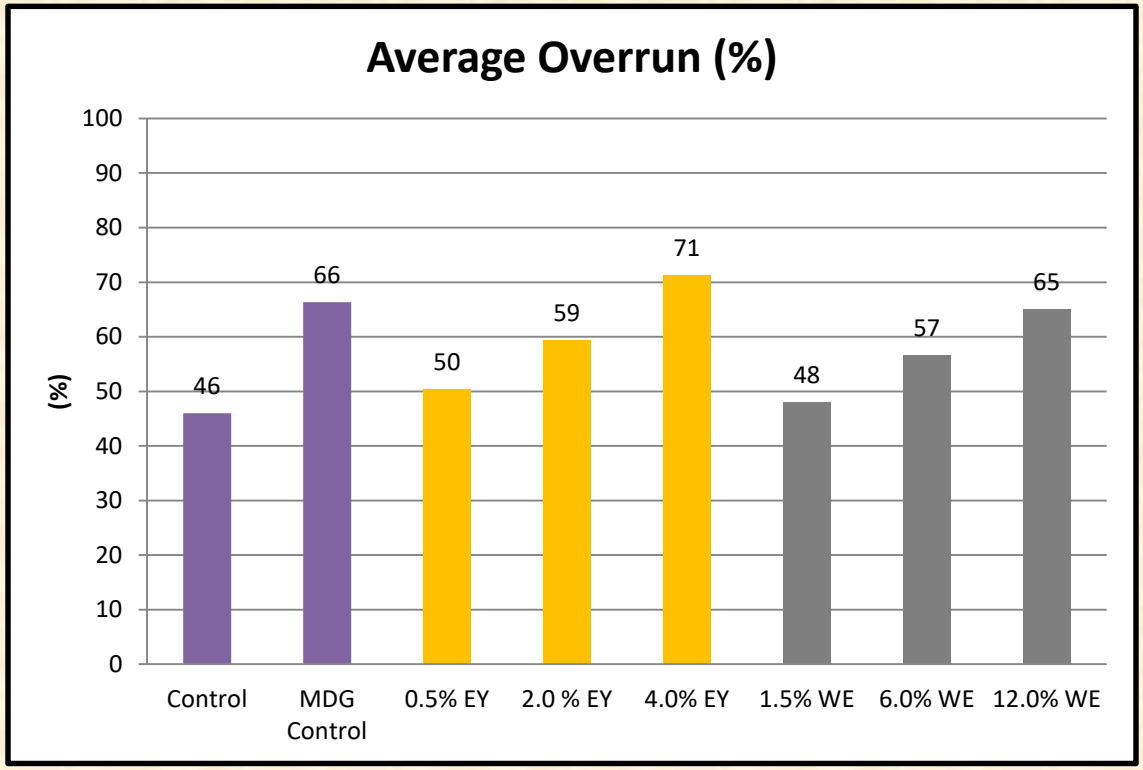
Milk, cream, skim milk, sugar, egg yolks, natural vanilla extract and vanilla bean specks.

Clean labelling and structure-enhancing strategies

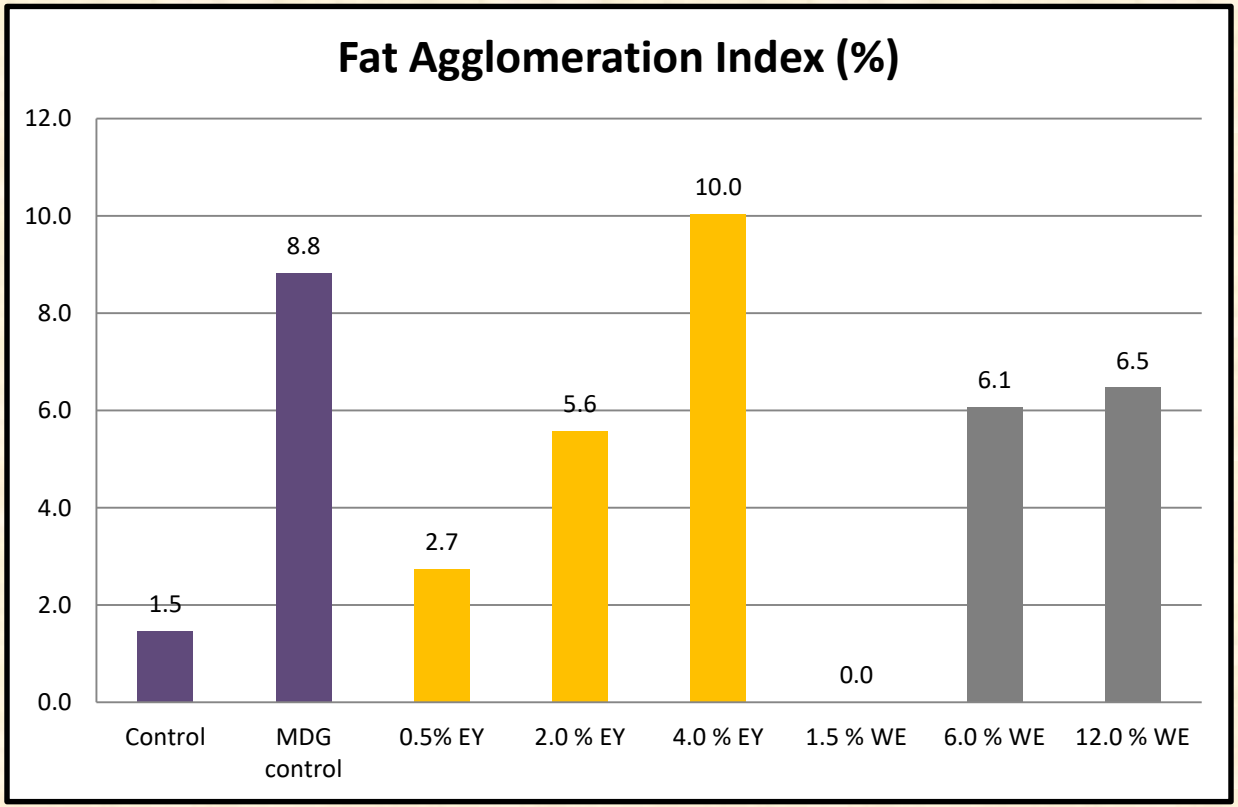
Fat-structuring/Replacement of Emulsifiers

- Egg yolk
- Protein functionality – heat and shear-induced aggregation, high pressure processing
- Buttermilk powder, milk phospholipids (?)
- Optimal ageing
- Higher shear during whipping (faster dasher speed, solid dasher), lower draw temperature

Eggs and Egg Yolk Functionality



Eggs and Egg Yolk Functionality




[redacted]
Vanilla
(continuous freezer)
+ Guar
+ Egg Yolk
+ Guar and
Egg Yo

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Food Hydrocolloids 20 (2006) 1050–1056
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Effects of whey protein aggregation on fat globule microstructure in whipped-frozen emulsions

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Received 25 January 2005; accepted 18 November 2005

Replacement of native whey proteins by a mixture of aggregated proteins and casein promoted a smaller air bubble size, a higher attachment of fat globules to the air bubble, and more aggregation of fat globules, despite a higher total adsorbed protein content.

Clean labelling and structure-enhancing strategies

Aqueous structure / Replacement of Non-natural Stabilizers

- Single source natural (organic) guar or locust bean gum
- Protein functionality
- Low draw temperature, faster hardening
- Minimize heat shock, tight control of cold chain

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Peer-reviewed scientific article

High pressure processing for better ice cream

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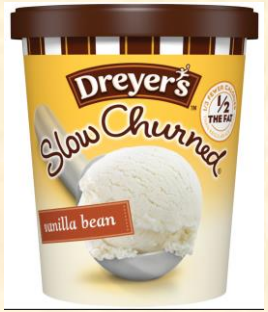
NOT-SO-SOFT SERVE

Courtesy of Erich Windhab/ETH Zürich

When ice cream comes out of the high-tech freezers at the Federal Institute of Technology in Zürich, it is much firmer and colder than normal—around 5 degrees Fahrenheit—with finer ice crystals and smaller bubbles. That means it's very creamy and will stay creamy, without being too fatty.

Low Temperature Extrusion



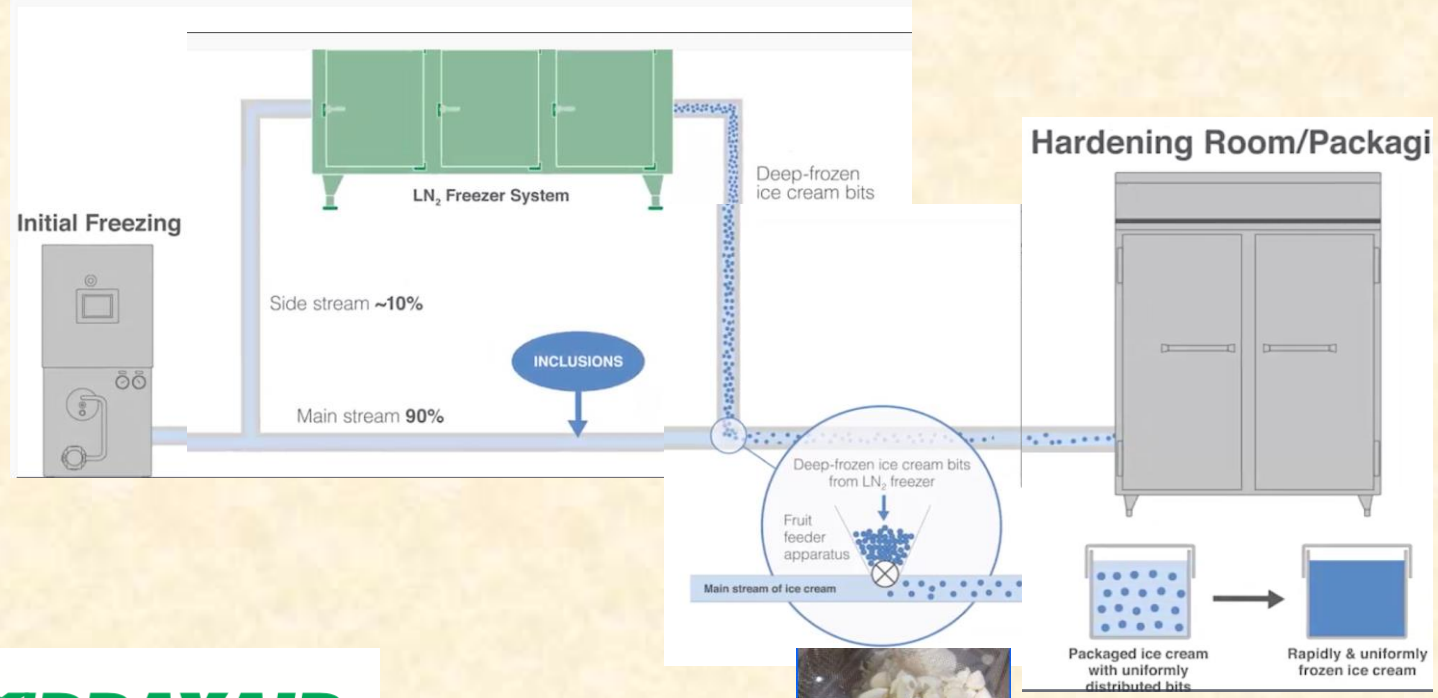
GRAM EQUIPMENT

The "CREAM" Freezer

Tetra Pak® Continuous Freezer LT – low temperature second stage ice cream freezers

PROTECTS Tetra Pak® WHAT'S GOOD

ColdFront™ Ice Cream Hardening



PRAXAIR

Making our planet more productive

Clean labelling and structure-enhancing strategies

Aqueous Structure / Replacement of Sweeteners

- Natural (organic)
- Optimize sweetness and freezing point depression
- Starch hydrolysate (glucose solids) functionality – milk proteins?

Conclusions

- **The study of ice cream structure has allowed a much greater understanding of ingredient functionality and product performance.**

- **New formulations focusing on arising health concerns or clean labelling require structure-enhancing technologies; opportunities for new developments.**