EMULSIFIERS IN FROZEN DESSERTS

Minor Ingredient, Major Impact

October 20-21, 2025 • Presented by Jodi Price

AGENDA

1. SHORT INTRODUCTION TO IFF
2. GENERAL EMUSIFIER FUNCTIONALITY
3. EMULSIFIER FUNCTIONALITY IN ICE CREAM

MAKING JOY THROUGH SCIENCE, CREATIVITY AND HEART.

IFF is a global leader in flavors, fragrances, food ingredients, health and biosciences.

We deliver groundbreaking, sustainable innovations that elevate everyday products—advancing wellness, delighting the senses and enhancing the human experience.

OUR SOLUTIONS FOR FOOD & BEVERAGES

Our broad portfolio addresses formulation needs of indulgent, healthier and convenient products.

Plant Protein, Fibers, Probiotics

- Soy & Pea Protein enrichment
- Fiber enrichment
- Functional; improve health& wellbeing
- Enable better-for-you solutions
- Sustainable, label-friendly and health solutions

Texturants & Emulsifiers

- Improve texture
- Improve mouthfeel
- Maintain stability
- Reduce syneresis
- Increase shelf life
- Promote emulsification

Flavors, Inclusions, & Colors

- Flavor modulation tools for re-balancing the taste of low/no sugar and fat formulations
- Masking tools to mitigate plant protein off-notes
- Adding goodness of fruits with fruit inclusions / paste
- E-number free and natural colors
- Characterizing flavors to drive consumer preference, and create signature taste for specific product base

Starter Cultures, Protective Cultures & Food Protection

- Natural: provide a variety of taste and texture
- Reduce sugar addition
- Allow higher yield or quicker fermentation time
- Increase shelf life
- Reduce stickiness
- Sustainable sourcing

Enzymes

- Improve texture, mouthfeel, thickness
- Clean taste, no impact on flavor
- Enabling: lactose-free, sugar reduction, GOS dietary fiber generation
- Consumer-friendly labeling (processing aid)

System Blends

- Tailormade solutions to facilitate and successfully implement market trends
- Offer possibility for cost-optimized high-quality products through stabilization

Sweeteners

- Natural origin
- Reduced calories
- Enable sugar reduced solutions with a low glycemic index (GI)

GENERAL EMULSIFIER FUNCTIONALITY

DEFINITION OF EMULSIFIER

Surface active component located at the interface between oil and water, making the two immiscible faces miscible.

Emulsifiers can stabilize w/o or o/w emulsions.

An emulsifier is a substance which:

- Reduce interfacial tension of oil and water

Polar lipids as well as some proteins and hydrocolloids fit this definition.

Proteins and hydrocolloids will not be covered in this presentation.

INTRODUCTION TO GENERAL FUNCTIONALITY

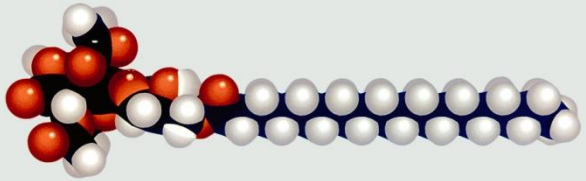
An emulsifier is a substance which:

- reduces interfacial tension of oil and water
- facilitates emulsification
- increases emulsion stability

Many of the products marketed as *emulsifiers* are not emulsifiers in terms of the physical definition, but have other functions such as:

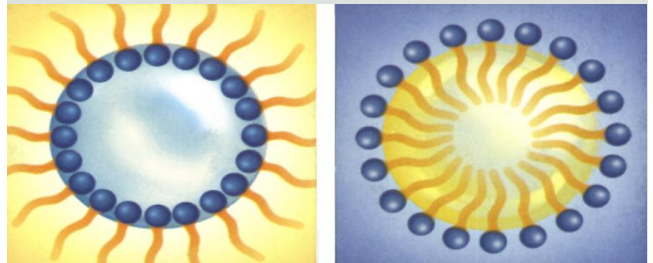
- **de-stabilisation of emulsions (whipped emulsions)***
- starch complexing
- **modification of fat crystallisation***
- structuring of low-fat food products

* Important for fat containing food foams



Water-in-oil emulsion

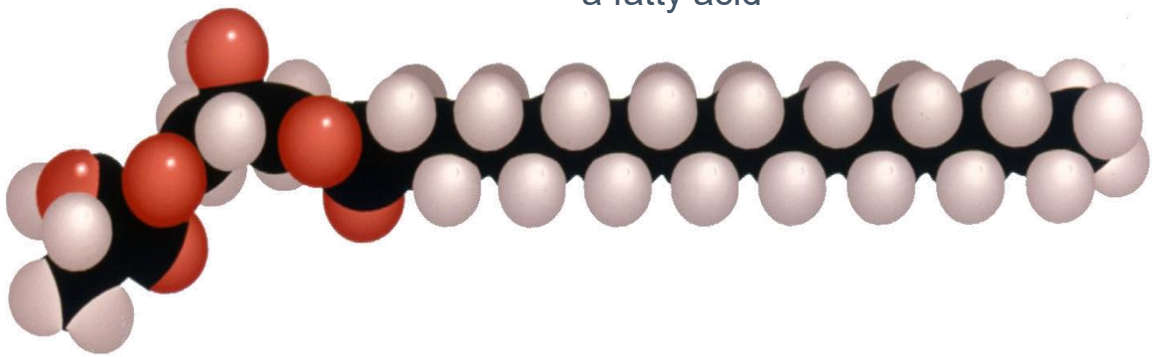
Oil-in-water emulsion



BASIC STRUCTURE OF AN EMULSIFIER?

An emulsifier is a surface-active substance consisting of molecules with hydrophilic and lipophilic parts – it is an amphiphilic molecule.

- Non-polar carbon chain, The lipophilic (hydrophobic) part of the emulsifier may consist of a fatty acid

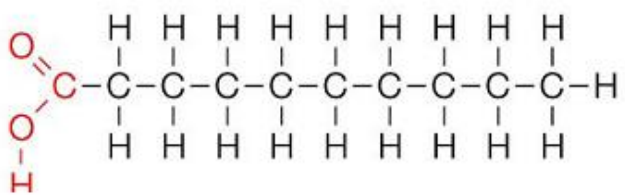


- Polar head, The hydrophilic part of the emulsifier may consist of glycerol or possibly esterified with acetic acid, lactic acid, tartaric acid or citric acid

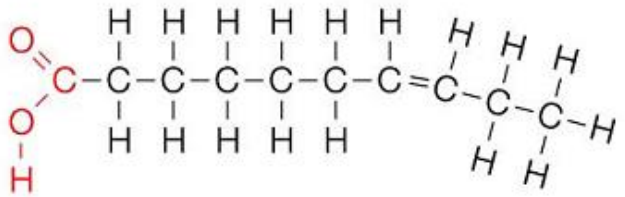
BASIC FATTY ACID STRUCTURE

- Saturated - carbon atoms have all the hydrogen they can hold
- Unsaturated - carbon atoms can hold more hydrogen
- Mono-unsaturated - only 1 carbon still has room for hydrogen
- Polyunsaturated - many carbons have room for hydrogen

Saturated



Unsaturated

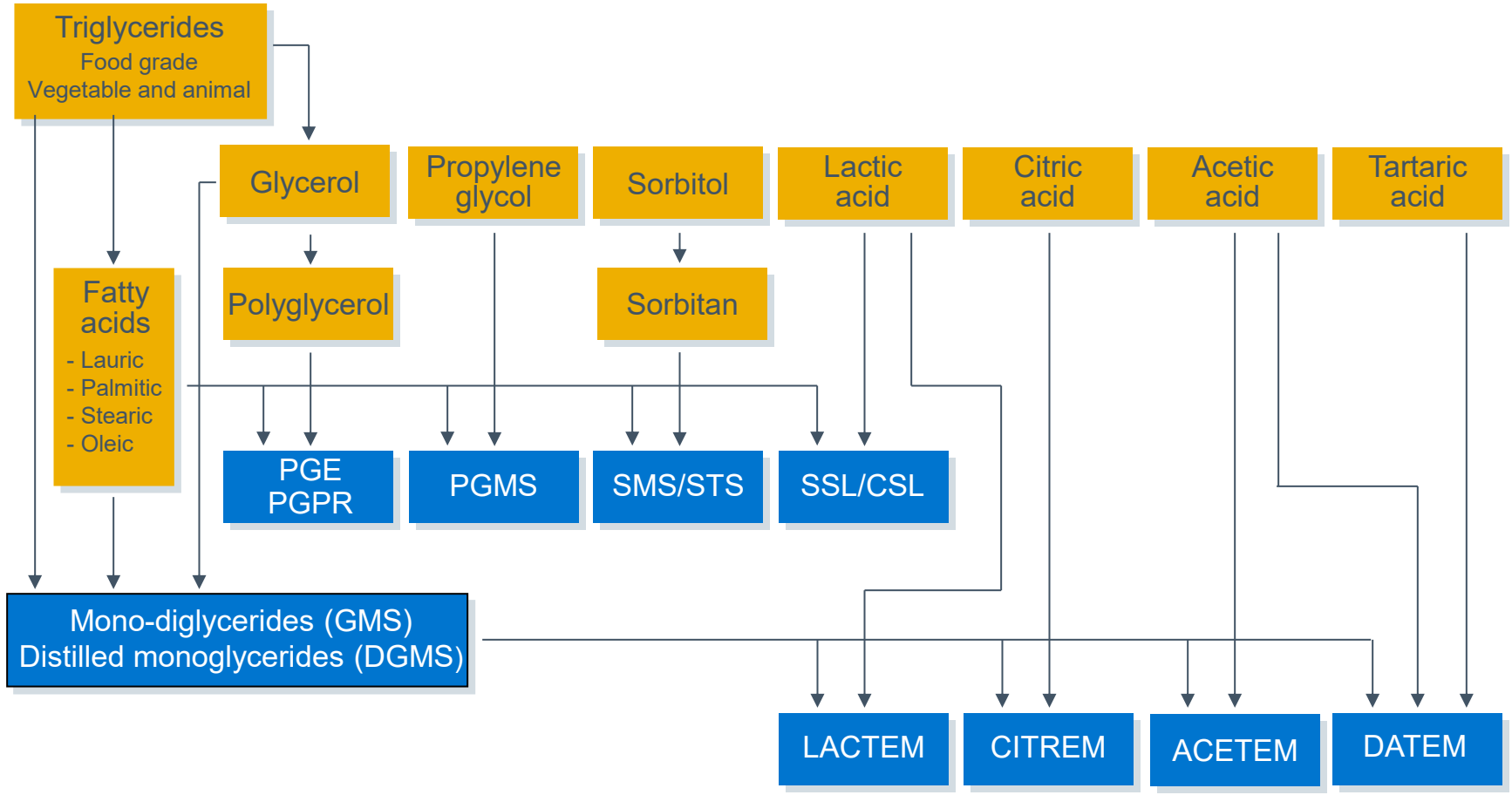


TYPICAL RAW MATERIALS

Edible fats and oils from natural raw materials

- Palm oil
- Rapeseed/Canola oil
- Sunflower oil
- Soybean oil
- Cottonseed oil

EMULSIFIERS AND THEIR RAW MATERIALS



Public

EMULSIFIER VARIATIONS

- Triglyceride raw material basis
  - Vegetable fat
  - Hardened/unhardened fat
  - Fractionated

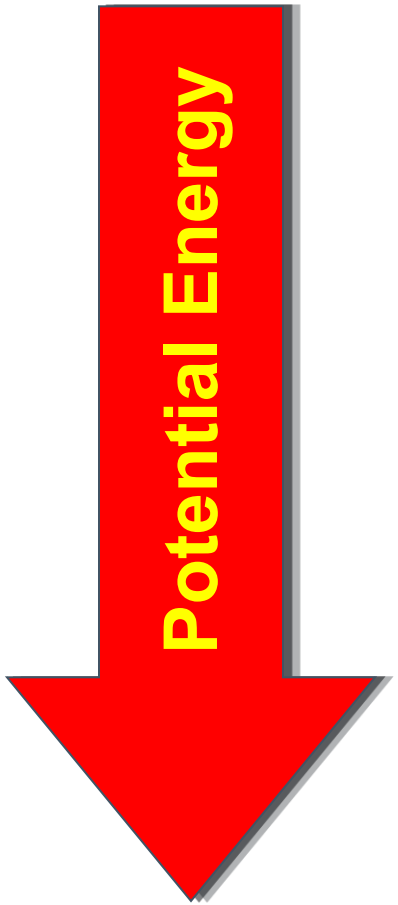
- Physical forms
  - Powder
  - Liquid
  - Hydrate
  - Flakes
  - Beads
  - Pellets

  } Special products

EMULSIFIER TERMINOLOGY

- Monoglyceride Content
  - Distilled minimum of 90%
- Iodine Value
  - Amount of unsaturated fat
  - Higher the number = unsaturation
  - Average Value
- Hydrophilic Lipophilic Balance (HLB)
  - Low Value - lipophilic
  - High Value - hydrophilic

EMULSION STABILITY



Stable Emulsions

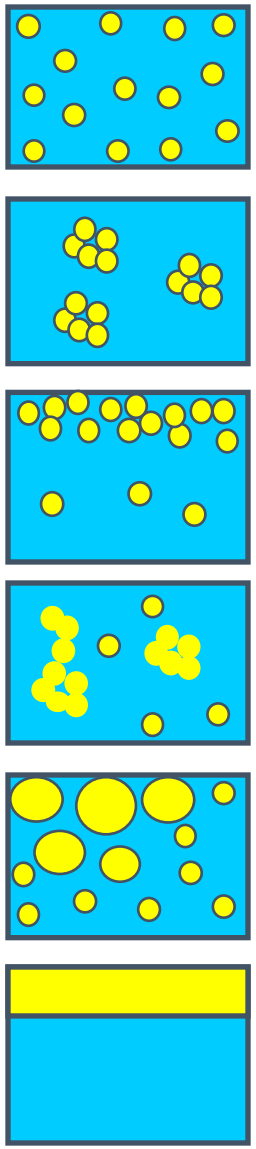
Flocculation

Creaming

Partial Coalescence
(Agglomeration)

Coalescence

Emulsion breakdown



GENERAL EMULSIFIER FUNCTIONALITY

Increase emulsion stability

- Oil-in-water emulsions
- Water-in-oil emulsions

Modification of fat crystallisation

- Prevent/reduce fat crystallisation
- Increase fat crystallisation
- Change fat morphology

Increase/decrease fat destabilisation/agglomeration

Aeration/foam stabilisation

Ice crystal control effect

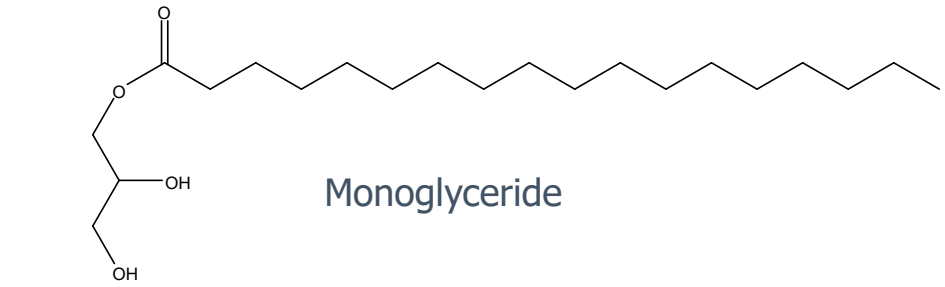
Improve homognization efficience

Starch complexing

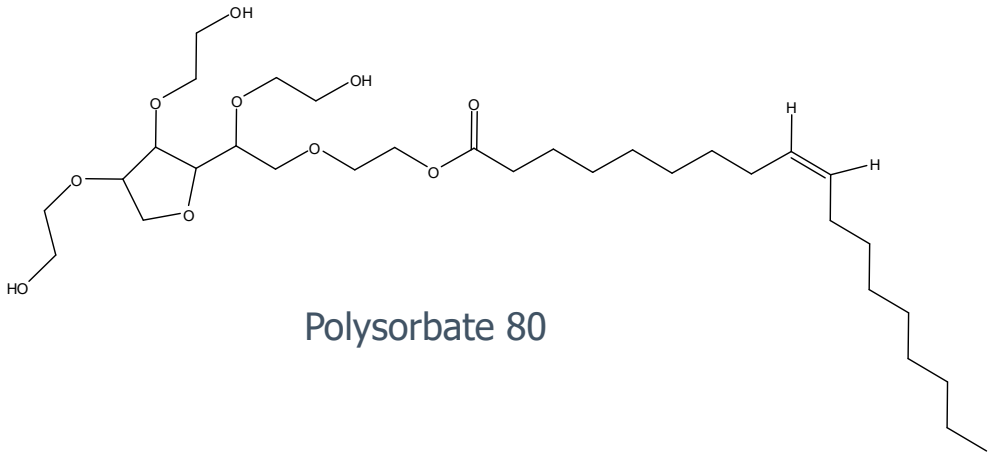
Anti-spattering

Improved dispersion and hydration of powders

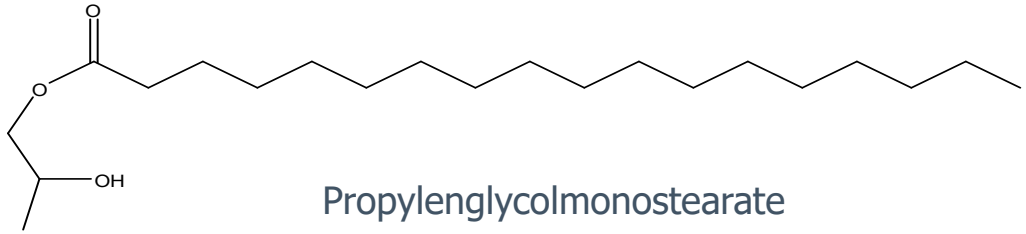
MOST IMPORTANT EMULSIFIERS FOR ICE CREAM



Monoglyceride



Polysorbate 80



Propylenglycolmonostearate

Polarity	Effect
Lipophilic	Ice Cream Production Foam Stability Melt down stability
Hydrophilic	Ice Cream Production Foam Stability Melt down stability
Very Lipophilic	Storage Stability (ice crystal growth control)

EMULSIFIER FUNCTIONALITY IN ICE CREAM

- Improve air incorporation
- Reduce risk of shrinkage
- Improve shape-retention
- Increase melting resistance
- Increase creaminess
- Reduce ice crystal growth
- Increase heat shock protection
- Increase quality shelf-life
- Facilitates production
- Enables fat reduction

Classic emulsifiers in ice cream: Mono-diglycerides of fatty acids (E471) and polysorbate 80 (E433) but also PGMS (E477) and Lactem (E472b)

EMULSIFIER AT DIFFERENT INTERFACES IN ICE CREAM

Emulsifier at the fat/water interface

- Ice cream mix: oil-in-water emulsion
- Facilitation of partial coclescence
- Facilitation of air-incorporation and stabilization

Emulsifier at the air interfaces

- Facilitation of air-incorporation and stabilization

Emulsifier at the ice interface

- Creation of smaller initial ice crystals
- Controlling ice crystal growth

EFFECT OF EMULSIFIERS ON THE PROCESS

Homogenization

- Secure a more uniform and smaller fat globule size

Ageing

- Increase the amount of desorbed protein from the fat globule
- Facilitate the crystallisation of the fat phase
- Improve dispersion of fat

Freezing

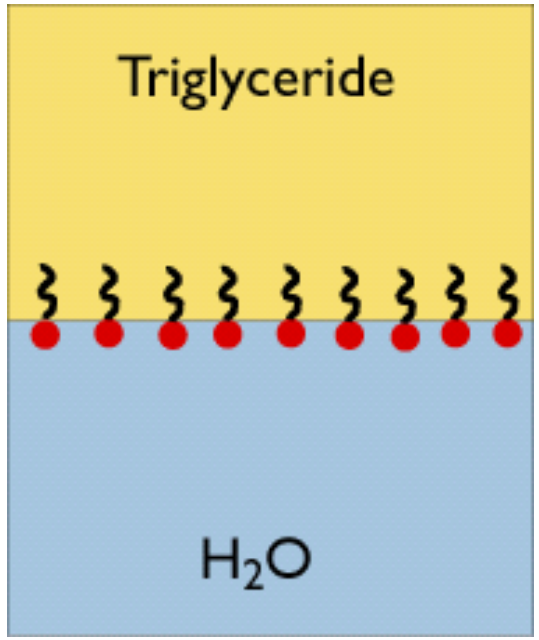
- Facilitate incorporation of air due to reduced surface tension
- Control agglomeration and coalescence of fat

EMULSIFIER FUNCTIONALITY – MIX PROCESSING AND AGEING

SOLID/LIQUID INTERFACIAL EFFECTS OF EMULSIFIERS

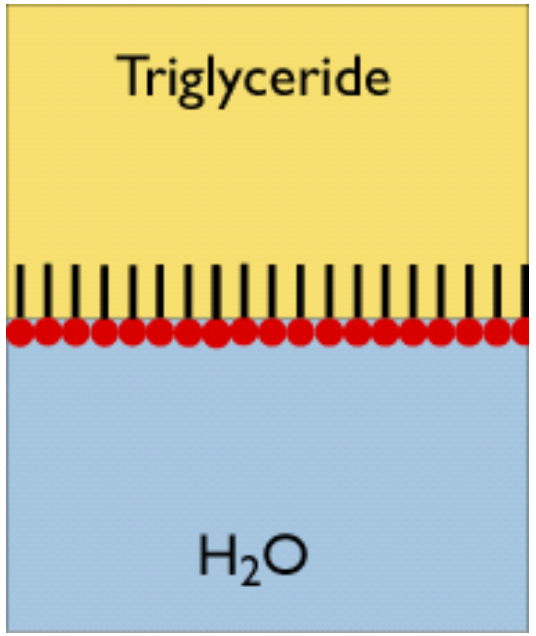
Liquid monolayer

γ =15



Solid monolayer

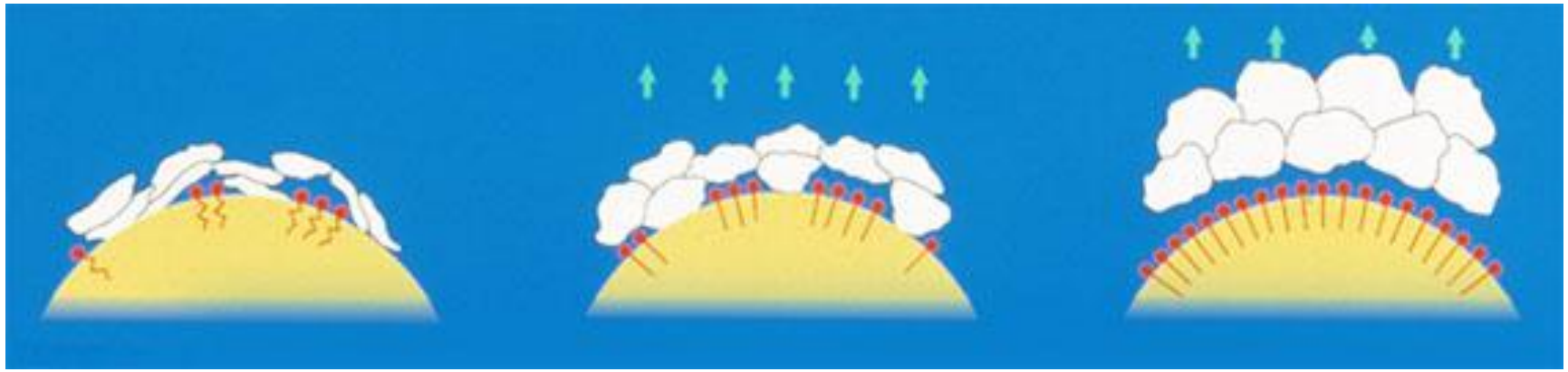
γ =1



When interfacially bound emulsifier crystallises, the hydrocarbon tails pack more closely and the interfacial concentration of polar head group increases. This results in a large drop in interfacial tension.

ICE CREAM MIX

>30ºC	**5ºC 1 hour**	**5ºC 24 hours**
Adsorbed casein micelles	Dissociation of ß-casein	Dissociation of ß-casein

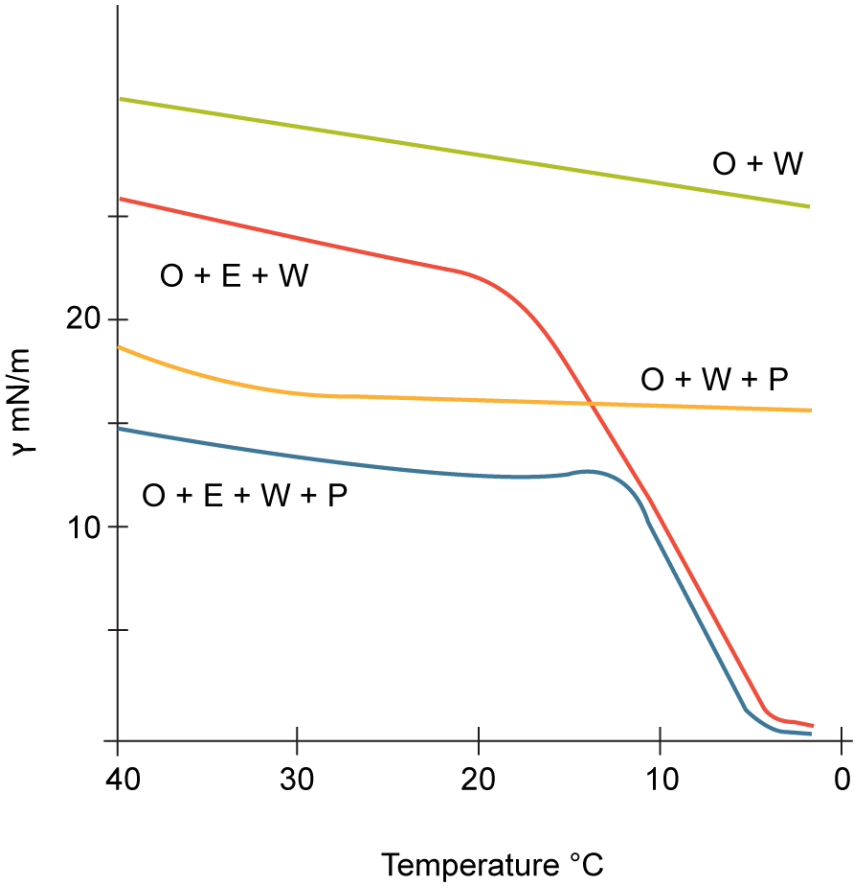


Melted fat phase Strong lipid-protein interaction	1. Emulsifier and fat crystallization 2. Weakened lipid-protein interaction 3. Increased protein hydration	1. Strengthening of hydrophilic effects 2. Release of coherent protein layers

Liquid emulsifier **Crystalline emulsifier** **Protein**

EMULSIFIER AT THE FAT/WATER INTERFACE

Effect of emulsifier and protein on interfacial tension of oil and water during cooling



- **Strong temperature dependence**
- **Very low surface tension with added emulsifiers**

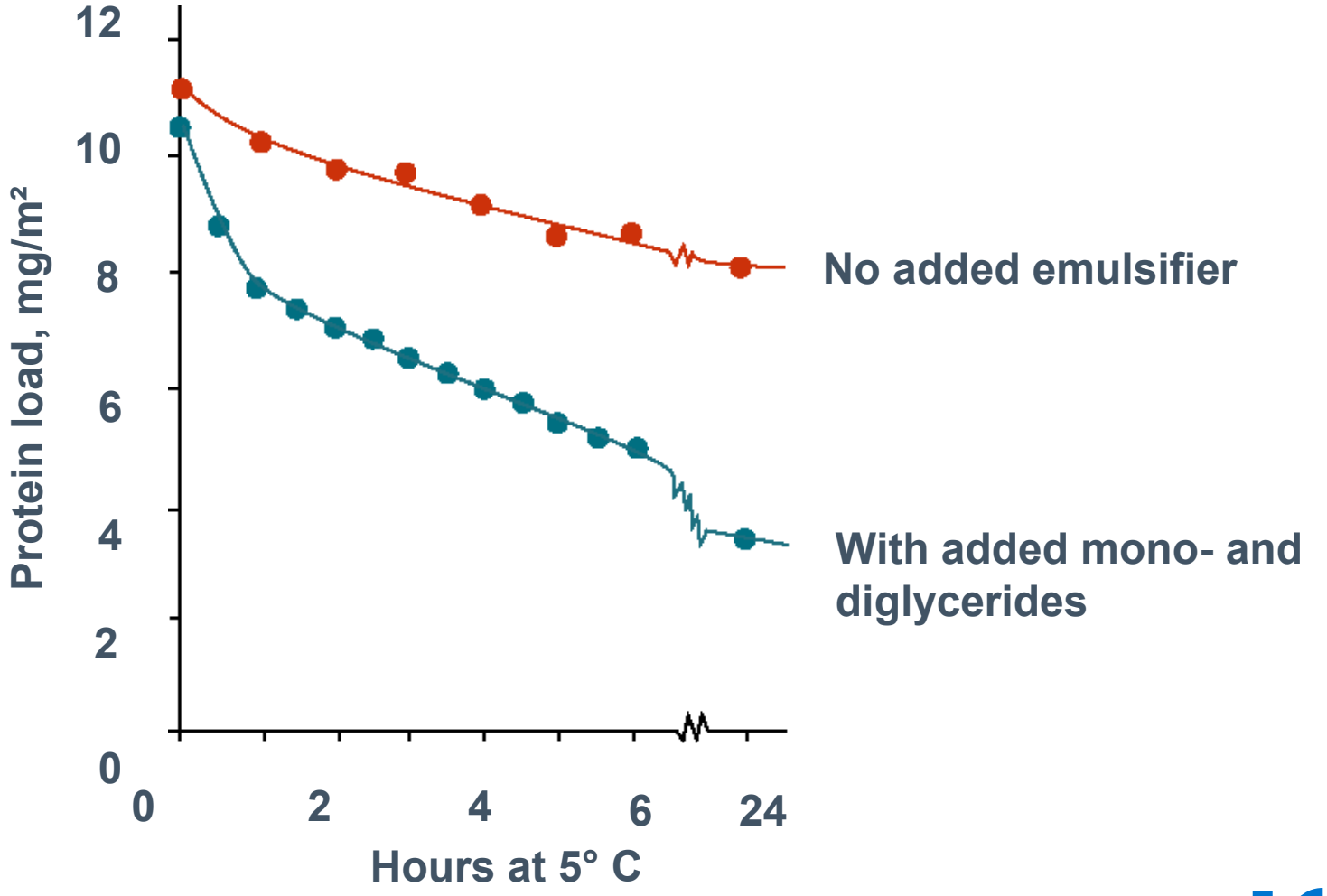
  at ageing temperature (5°C)
- **Lowering of surface tension leads to protein**

  desorption from the surface of the fat globules

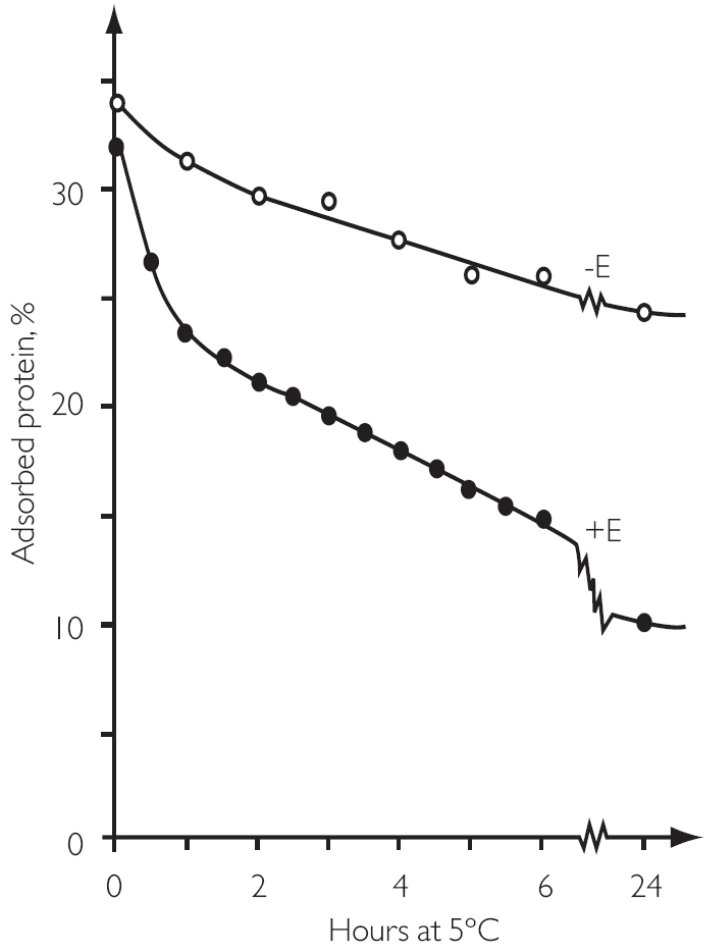
PROTEIN DESORPTION FROM FAT GLOBULES IN ICE CREAM MIX

Protein desorption makes the ice cream mix more susceptible to shear in the ice cream freezer facilitation partial agglomeration of the fat globules

The added emulsifier is de-stabilizing the fat globules, during ageing

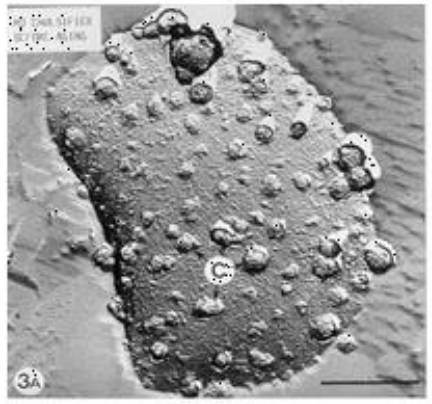
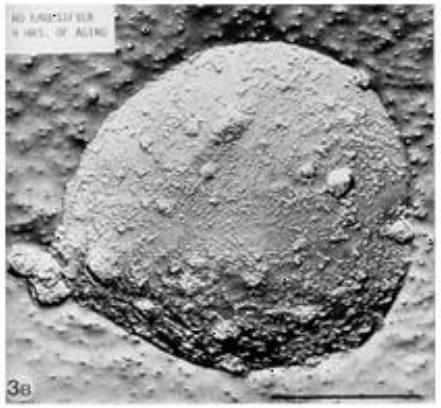
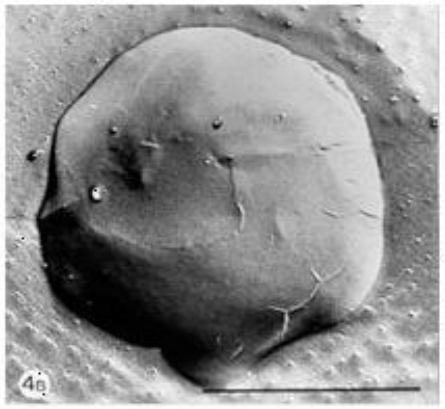


DISPLACEMENT OF MILK PROTEINS FROM FAT GLOBULE MEMBRANE



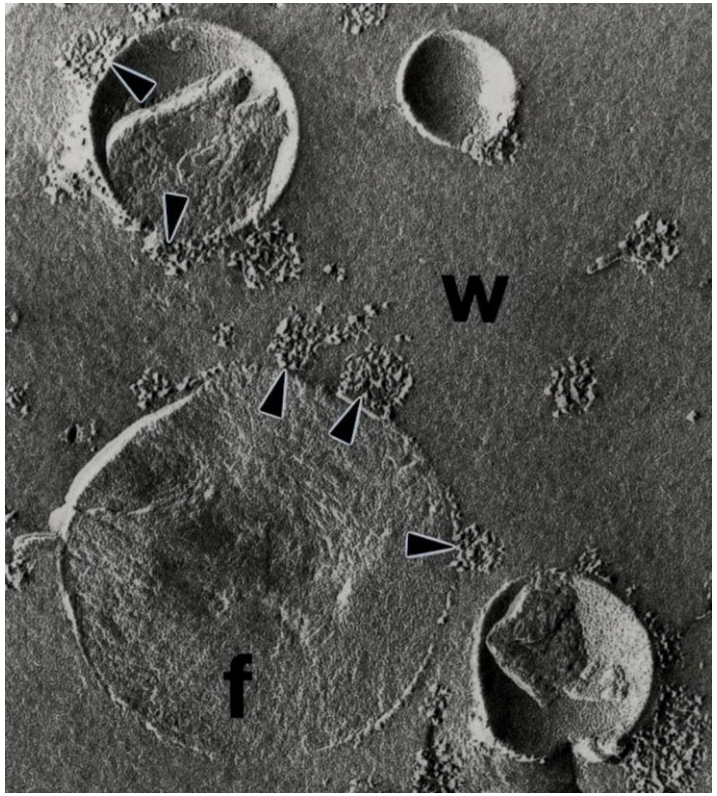
No emulsifier

With monoglyceride

Before aging	After 4 hours' aging
	
	

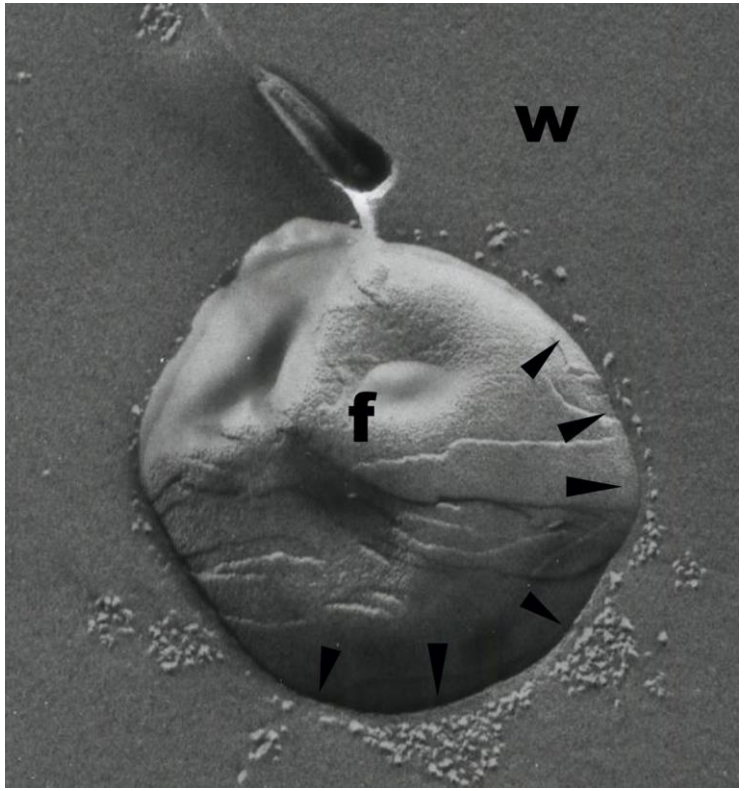
PROTEIN DESORPTION IN EMULSIONS DURING COOLING (AGEING)

Ice cream mix with monoglycerides



At room temperature

Casein strongly bound to fat interface



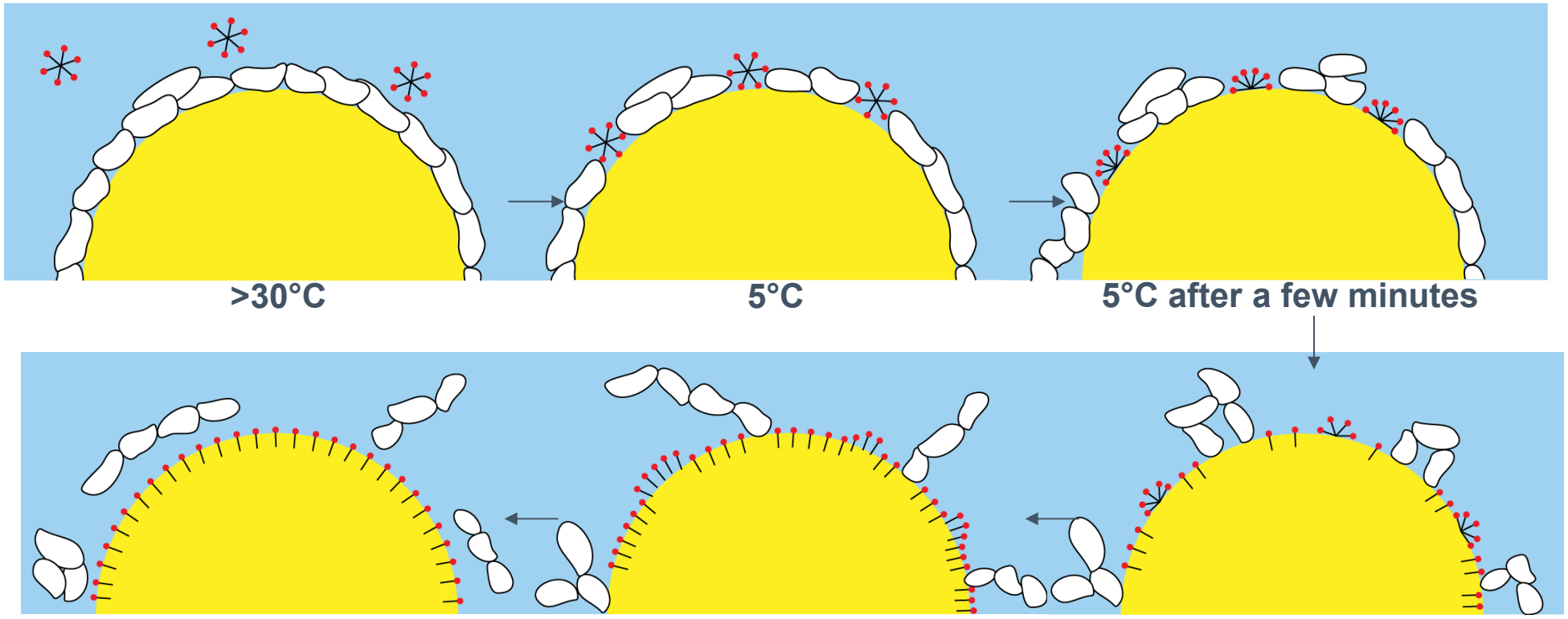
After 24 hours at 5ºC

Casein desorbed from fat interface, sometimes as coherent layers

Barfod et al., 2001

PROTEIN DESORPTION FROM FAT GLOBULES OF ICE CREAM MIX

With Polysorbate 80



Ageing time is shorter with Polysorbate 80 than with monoglycerides

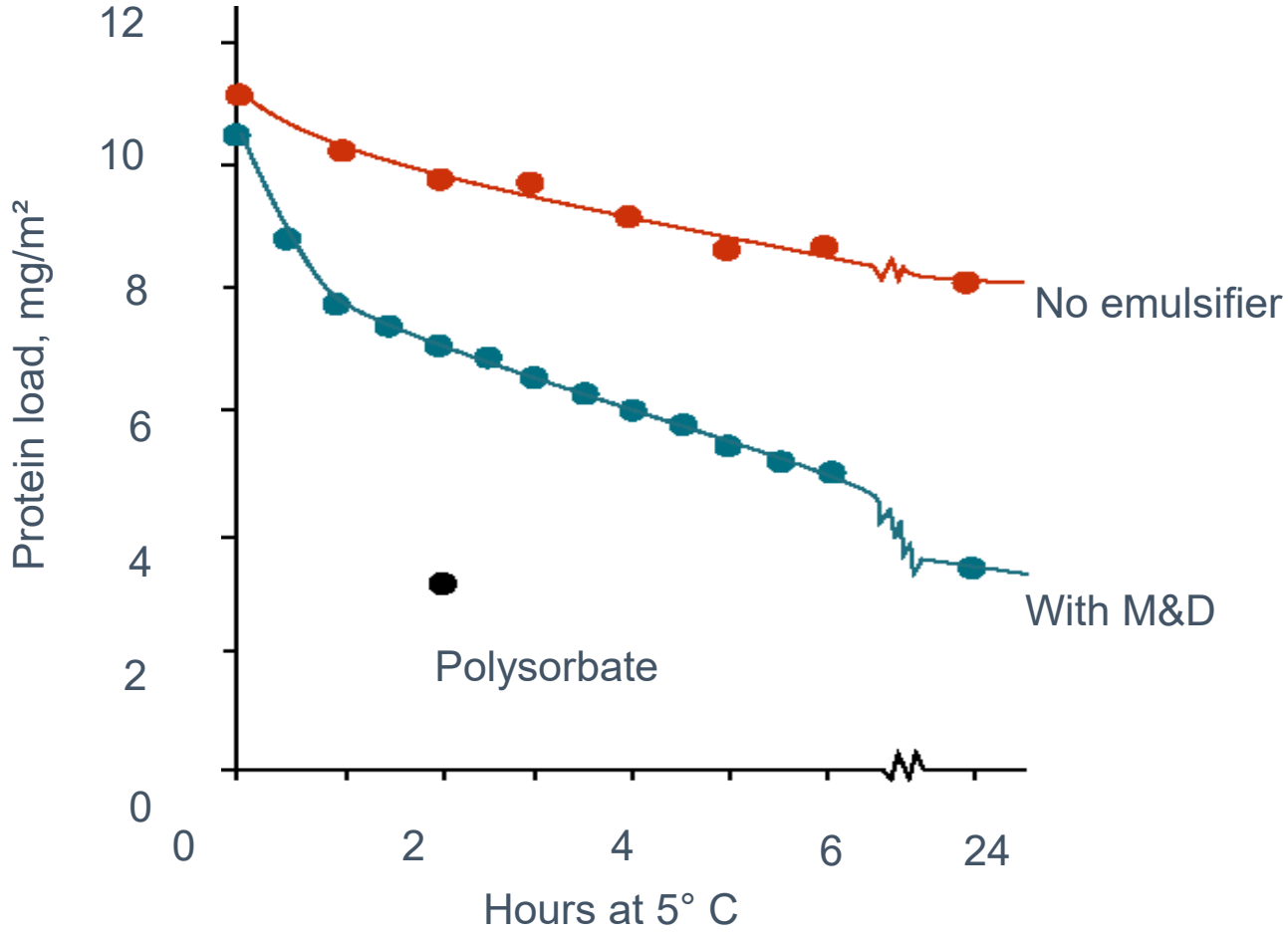
FUNCTIONALITY OF POLYSORBATE 80 IN ICE CREAM

Polysorbate 80 is generally used in combination with other emulsifiers such as mono-diglycerides

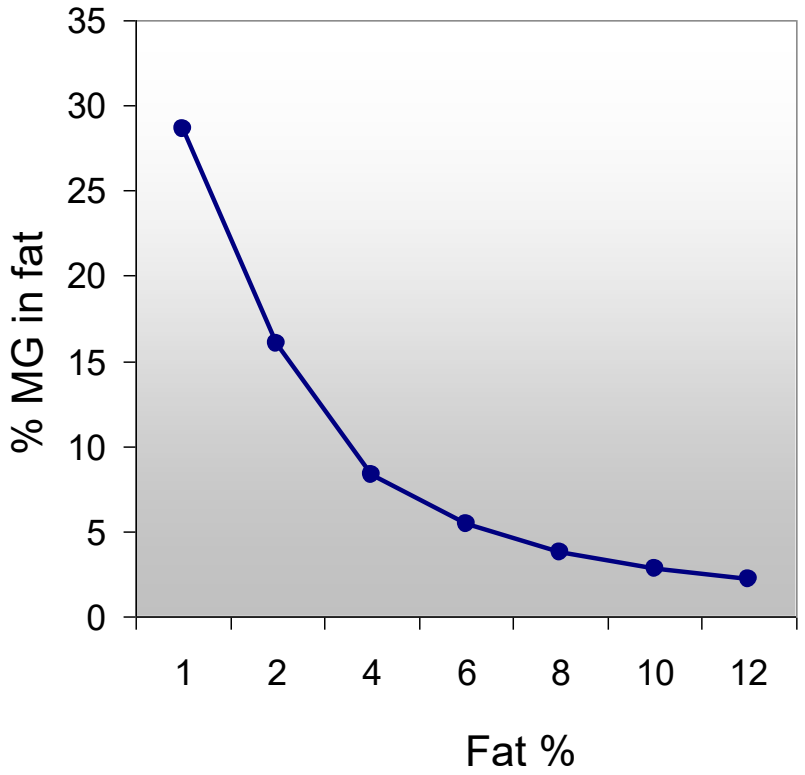
Typical ratio: 4 parts mono-diglycerides to 1 part Polysorbate 80

Advantages using Polysorbate 80	Disadvantages using Polysorbate 80
Gives dry extrusion	Declaration/ chemical, not natural
Water soluble	Taste (off-taste)
Very powerful (low dosage)	Extra E-number
Cost-effective	Does not promote fat crystallisation
Significant effect on melting resistance	Tends to promote over-churning

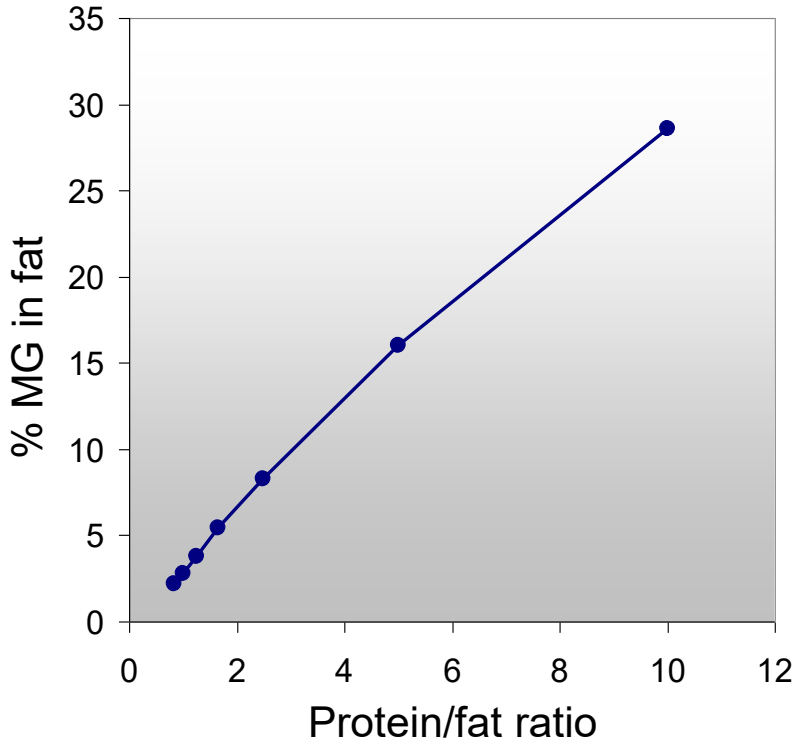
PROTEIN DESORPTION FROM FAT GLOBULES OF ICE CREAM MIX



RECOMMENDED EMULSIFIER (M&D) DOSAGES FOR ICE CREAM



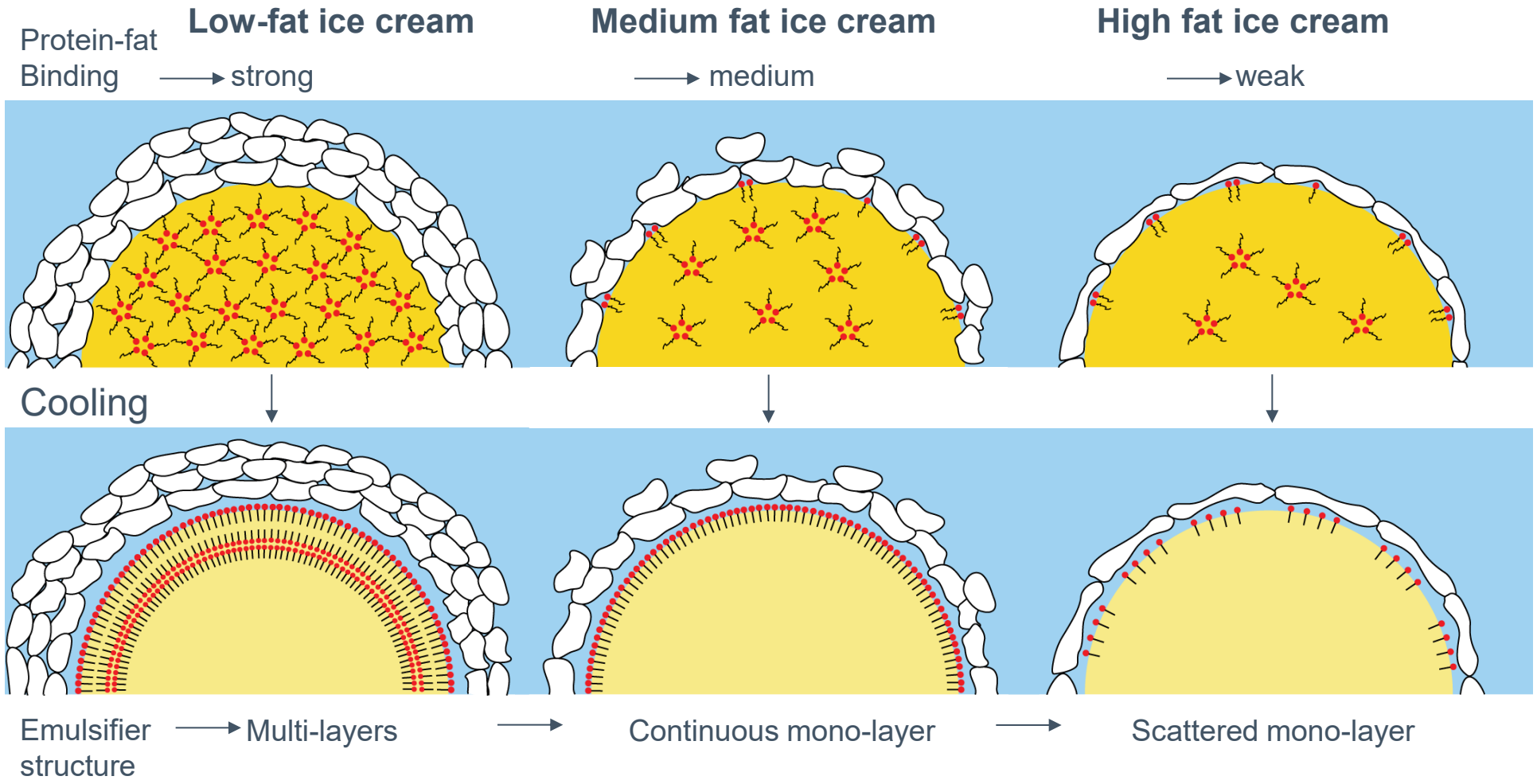
When the level of fat decreases, the need for emulsifier increases



The ratio between protein and fat also changes
At lower levels of fat, there is more protein (high protein/fat ratio)

- churning becomes more difficult
- more emulsifier needed

STRUCTURE OF FAT GLOBULES OF ICE CREAM WITH VARYING FAT CONTENT

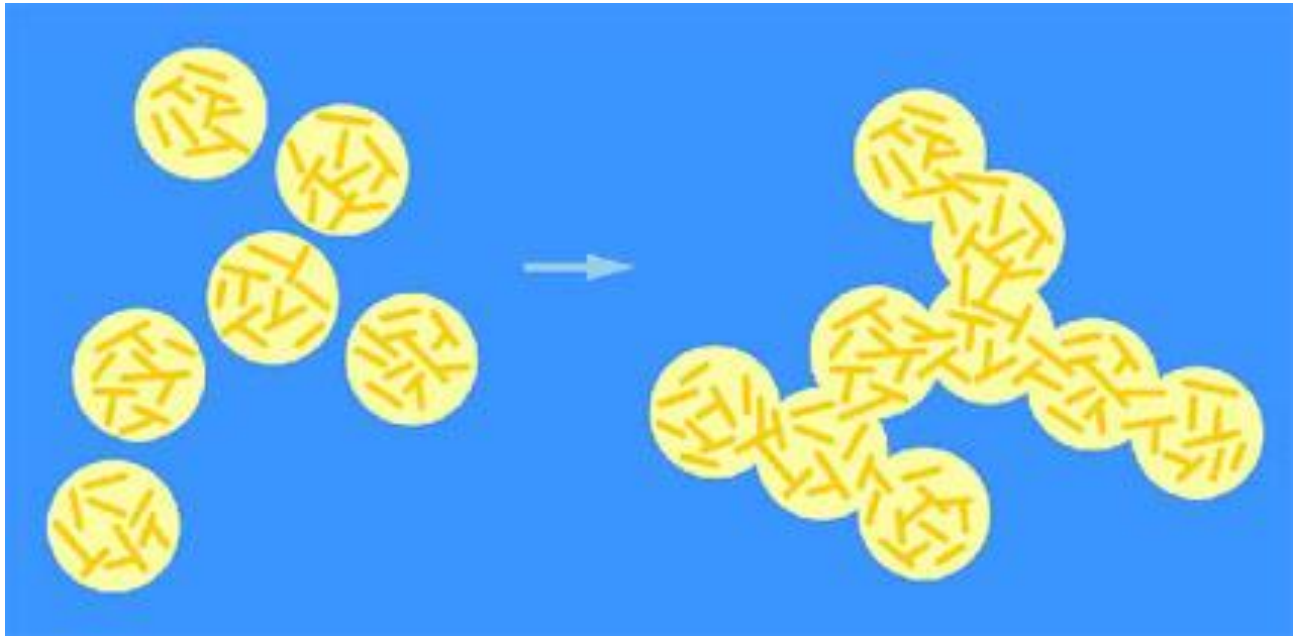


CONCLUSION

Emulsifiers **weaken protein-fat binding** in ice cream mix leading to **partial emulsion destabilisation** during freezing process

EMULSIFIER FUNCTIONALITY – FREEZING

PARTIAL COALESCENCE OF FAT GLOBULES

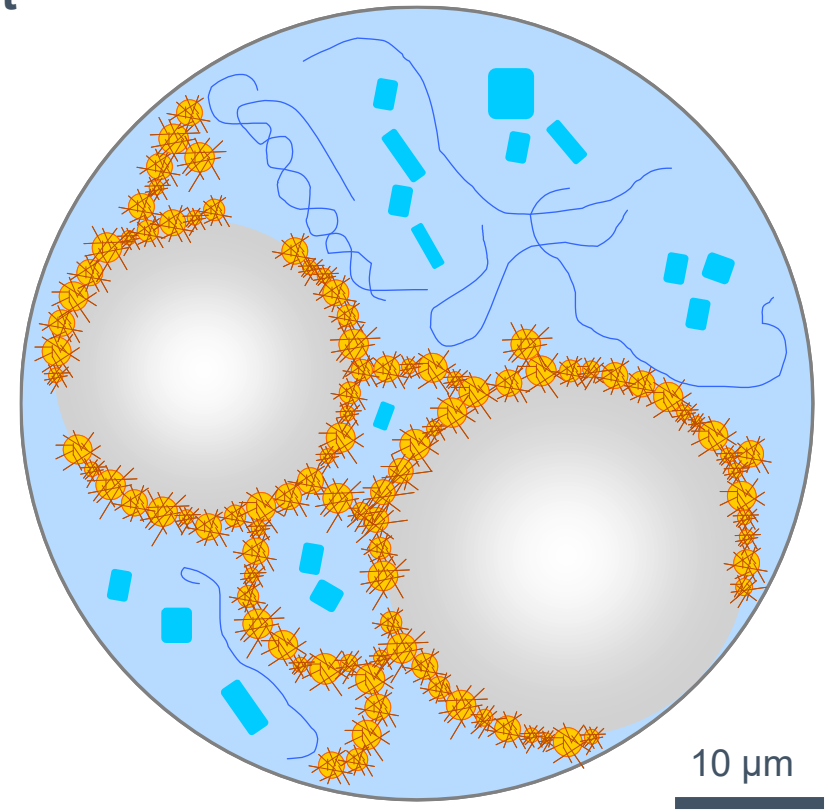


Requirements

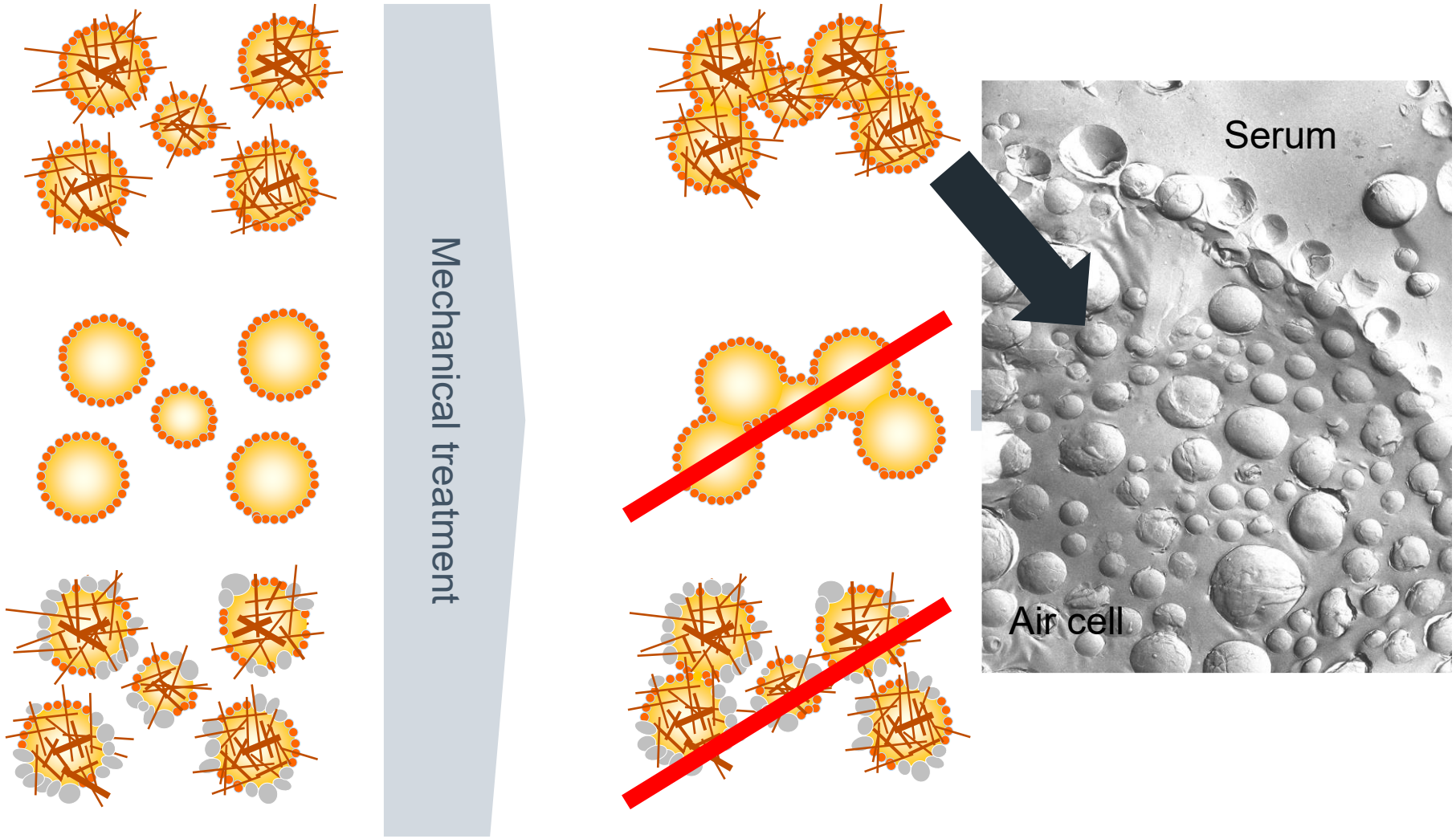
- Sufficient amount of protein desorption (destabilization)
- Sufficient amount of solid fat to ensure that the fat globules will not agglomerate completely (rigid structure)
- Sufficient amount of mechanical treatment in the ice cream freezer

FREEZING

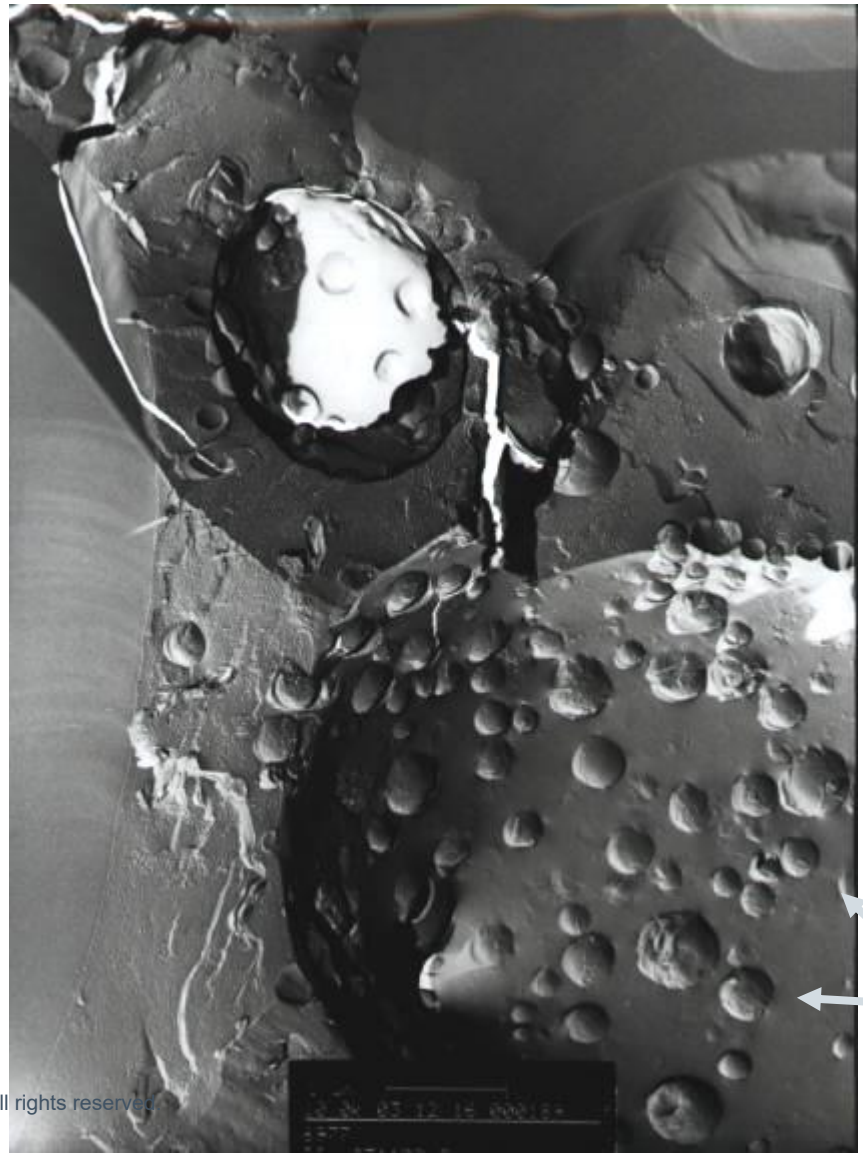
- Facilitate incorporation of air due to reduced surface tension
- Control agglomeration and coalescence of fat



FAT AGGLOMERATION / COALESCENCE



TRANSMISSION ELECTRON MICROSCOPY OF FROZEN ICE CREAM



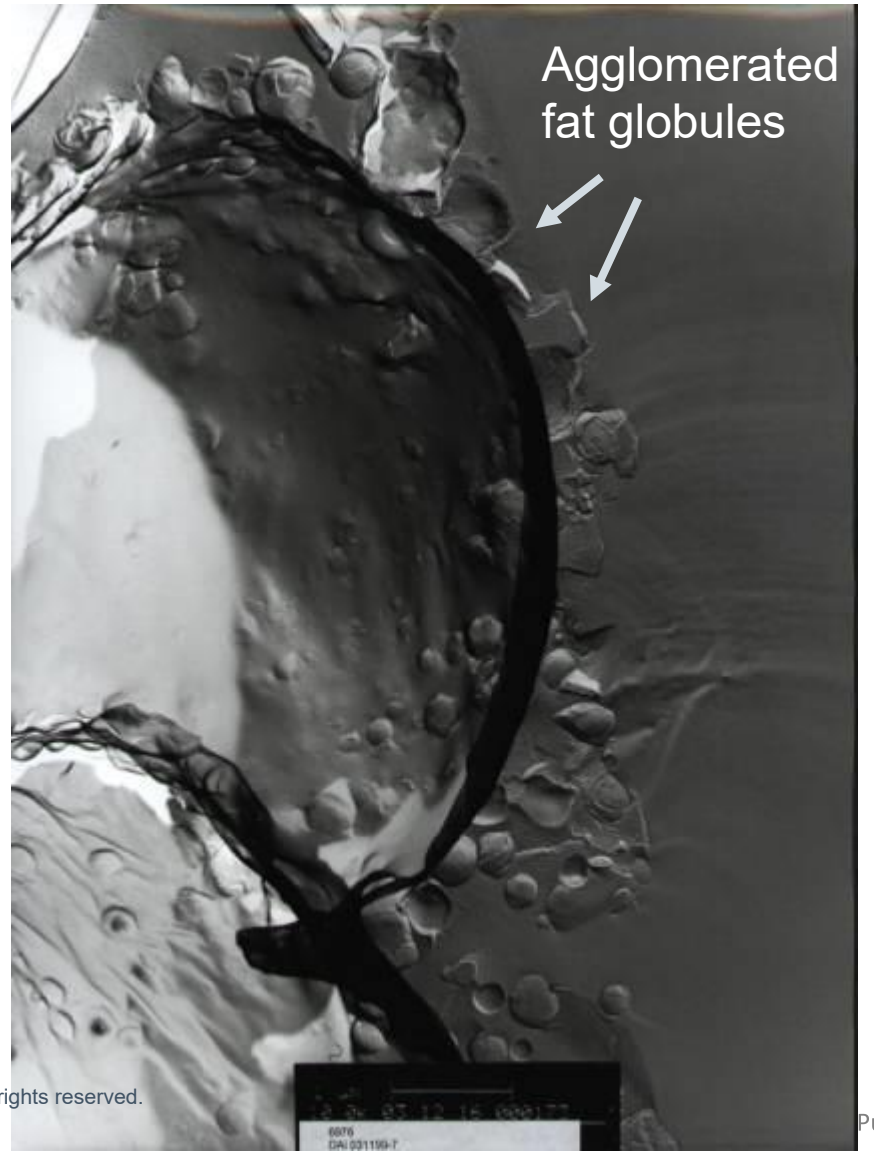
Ice cream with **no emulsifiers**

Two air bubbles, about 1 µm and 10 µm in diameter, stabilised by individual undeformed fat globules This indicates low air bubble stability.

Individual fat globules

Public

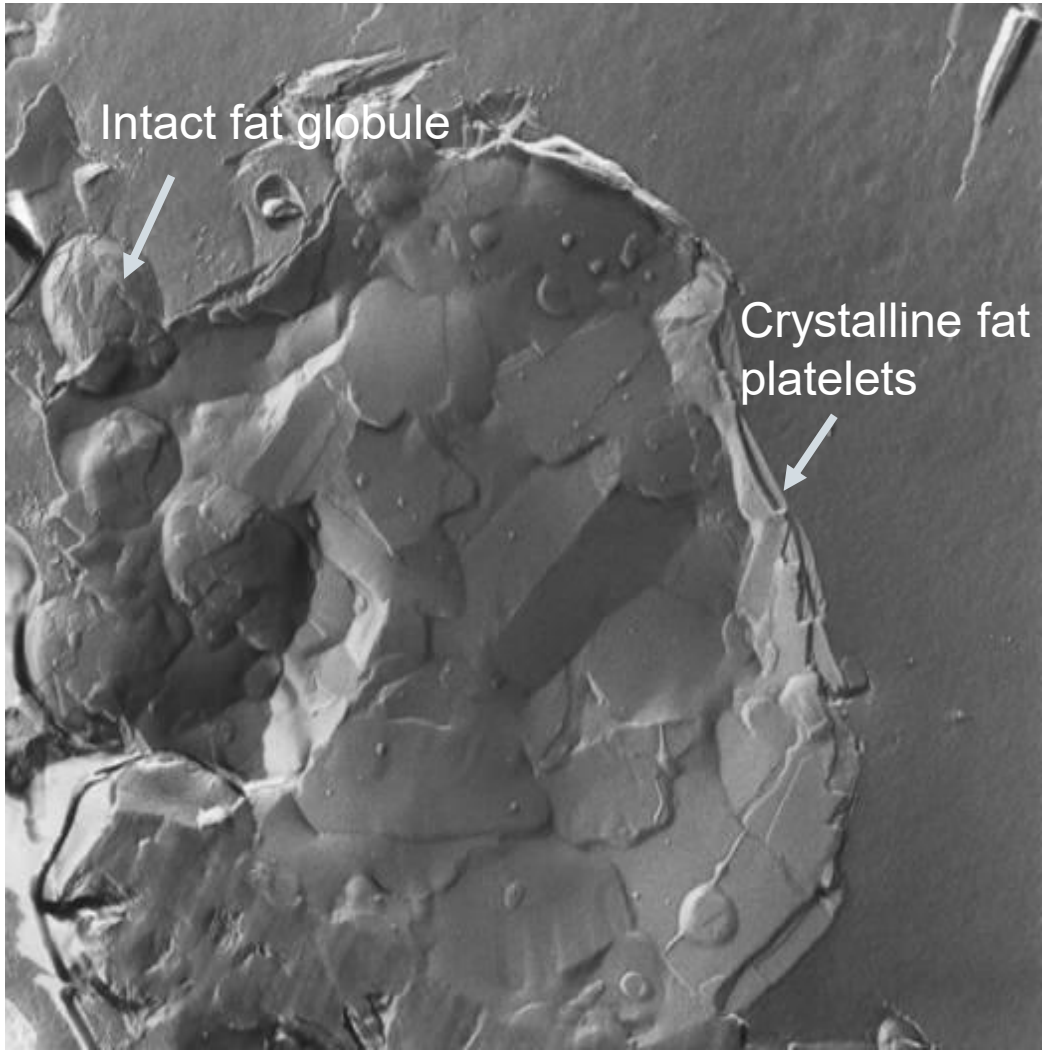
TRANSMISSION ELECTRON MICROSCOPY OF FROZEN ICE CREAM



Ice cream with **saturated M&D**

Air bubble, about 10 µm in diameter, stabilised by partially deformed and agglomerated fat globules. This indicates high air bubble stability.

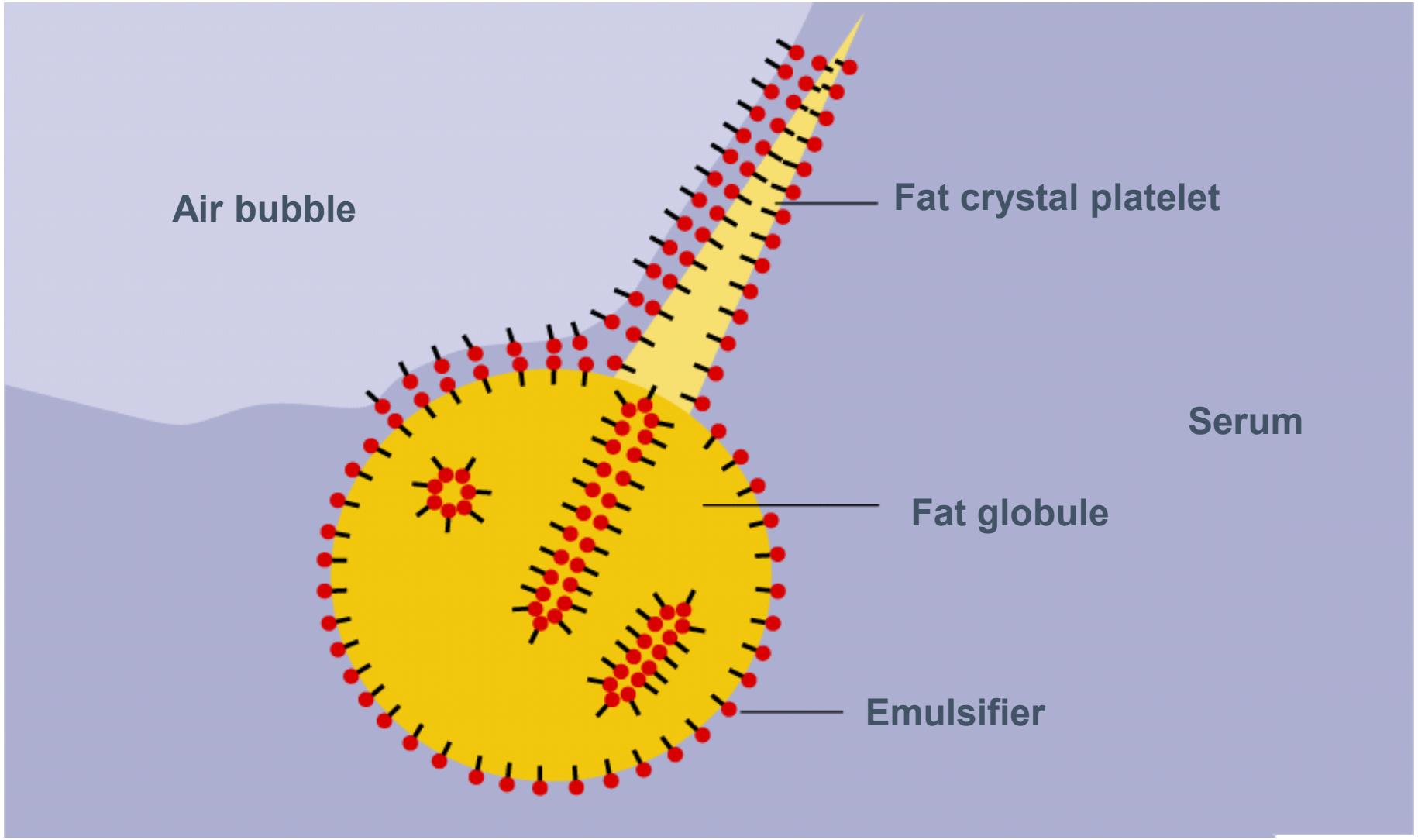
TRANSMISSION ELECTRON MICROSCOPY OF FROZEN ICE CREAM



Ice cream with **unsaturated M&D**

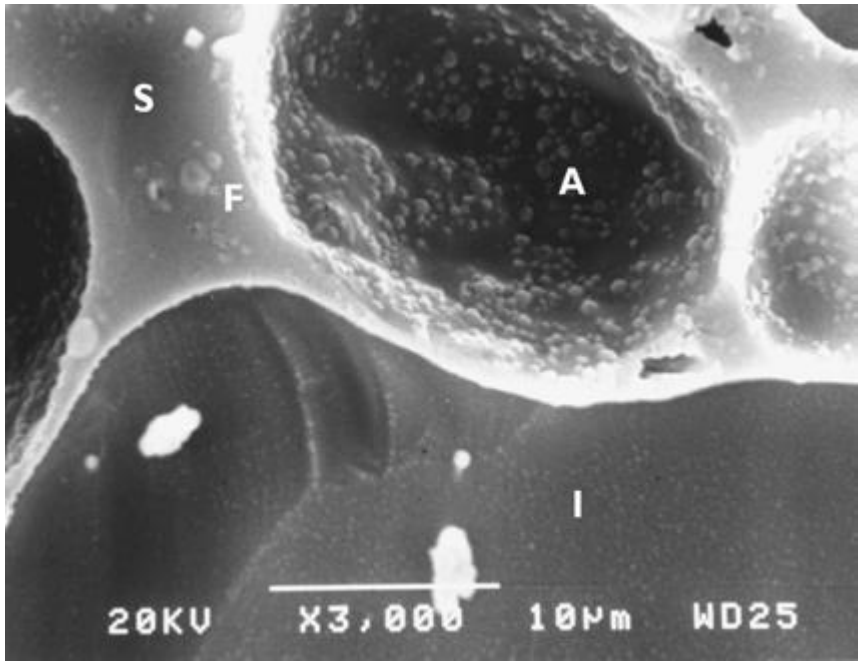
Air bubble, about 5 µm in diameter, stabilised by crystalline fat platelets and a few intact fat globules. This gives extremely high air bubble stability.

AIR STABILISATION OF FAT CRYSTAL PLATELETS PROTRUDING OUT OF FAT GLOBULES



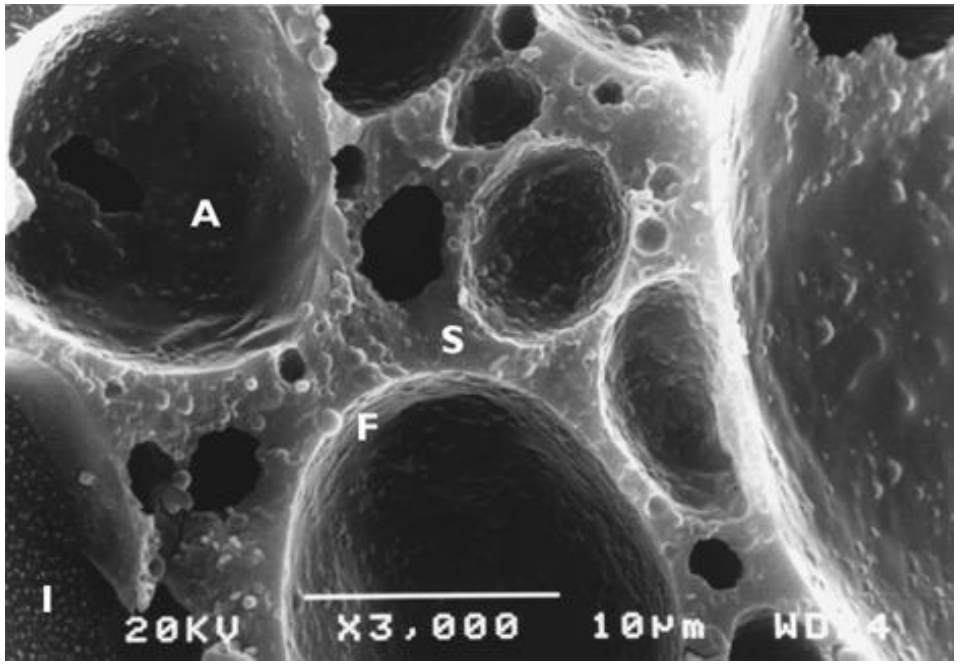
SCANNING ELECTRON MICROSCOPY OF FROZEN ICE CREAM

With saturated monoglyceride



A few fat globules (F) in serum phase (S)

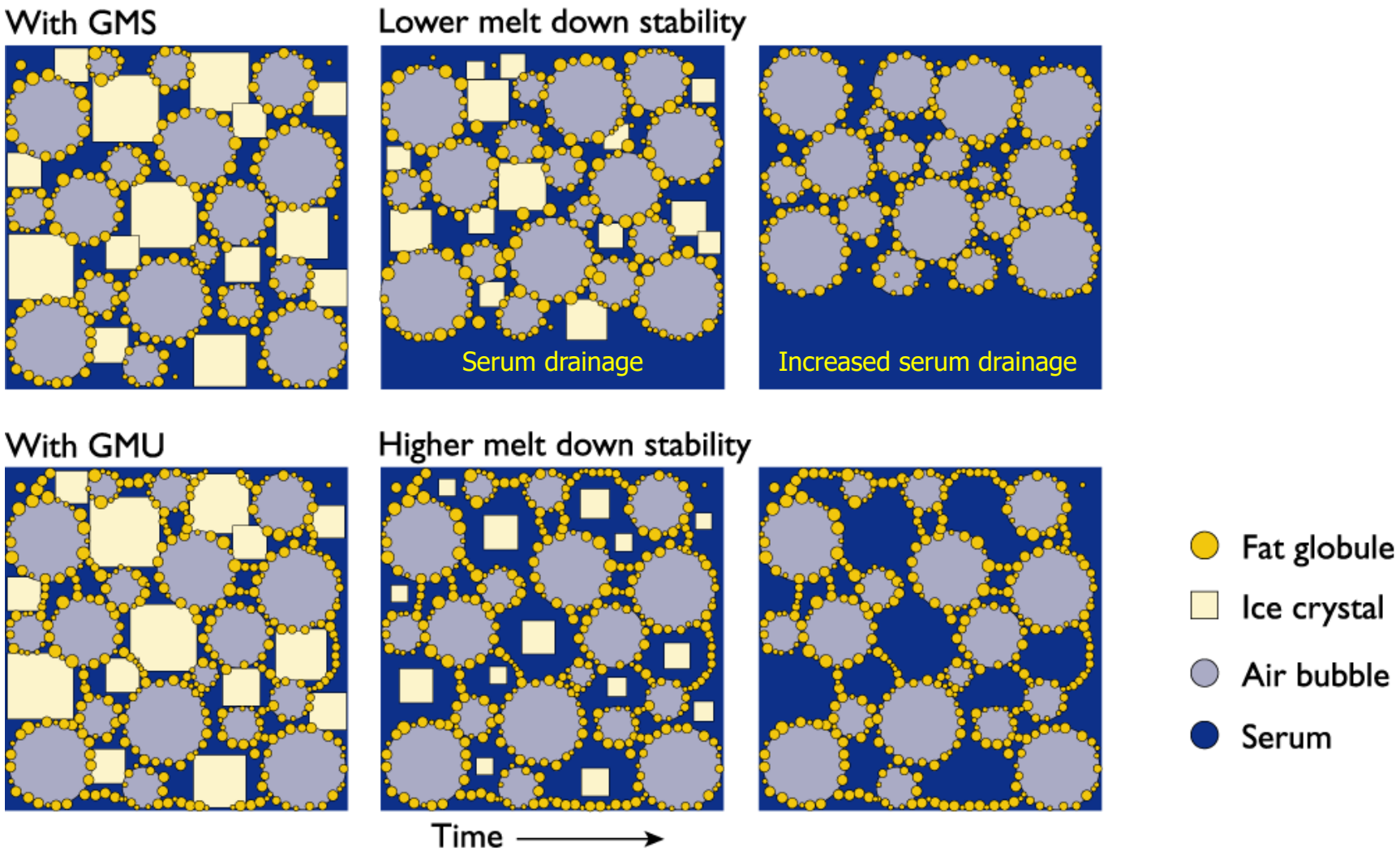
With unsaturated monoglyceride



Coherent structure of coalesced fat globules (F) in serum phase (S)

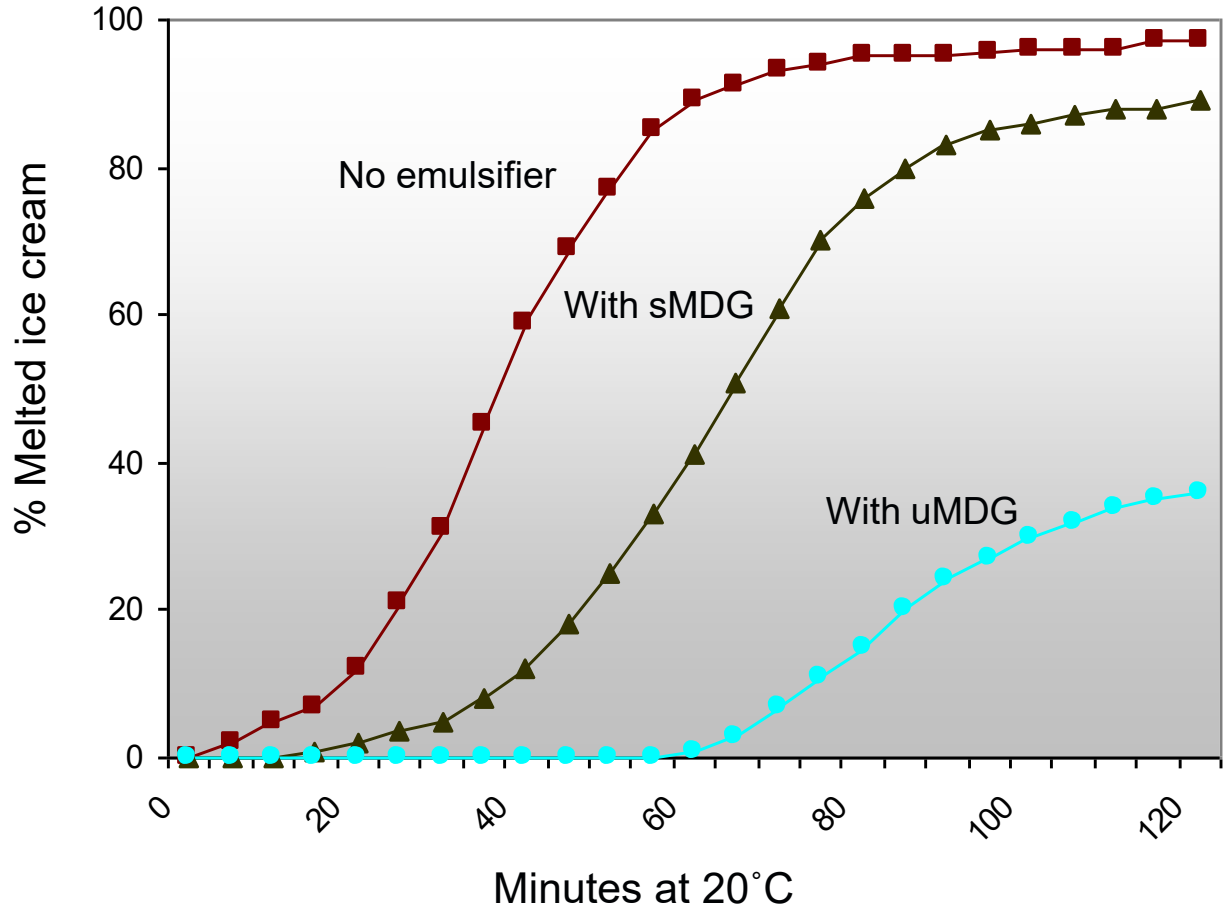
A: air bubble, I: ice crystal

MELT DOWN OF ICE CREAM AT 20°C



MELTDOWN OF ICE CREAM

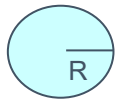
Unsaturated Mono-di brings high degree of partial coalescence = higher melting resistance



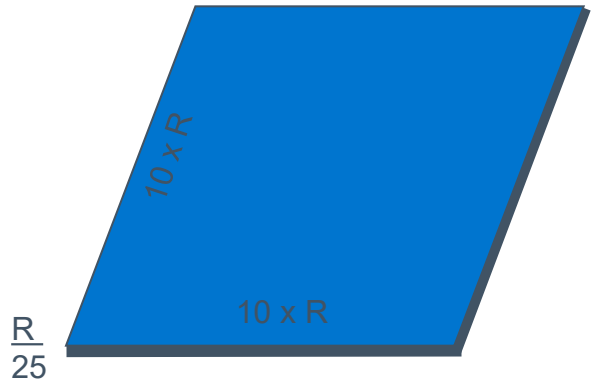
SURFACE AREAS OF FAT GLOBULES AND FAT PLATELETS WITH SAME MASS

Calculations show that 10 to 20 times more surface area is formed with fat crystal platelets compared to fat globules

Fat globule



Fat crystal platelet



Dimensions of structures estimated from TEM pictures

FAT AGGLOMERATION IMPROVES ICE CREAM QUALITY

Emulsifiers are also one of the most important ingredients in ice cream that helps the shape retention and promotes lower melting rate, resulting in a good quality ice cream across the shelf life.

Note the meltdown test result and how the samples changed during the time (start, 10 min, 20 min, 30 min and 40 min)

No Emulsifier

With Emulsifier

Best Shape Retention

CONCLUSION

Emulsifiers make fat globules of ice cream mix more functional by aggregation and strong binding to air bubbles during ice cream production leading to **enhanced air stability.**

EMULSIFIER AT THE ICE INTERFACE

HEAT SHOCK IN ICE CREAM

Heat Shock is the exposure of ice cream to repeated thawing and freezing cycles

- Number ONE enemy for ice cream quality
- Ice Cream's limitation for shelf life
- Results in failed customer expectation

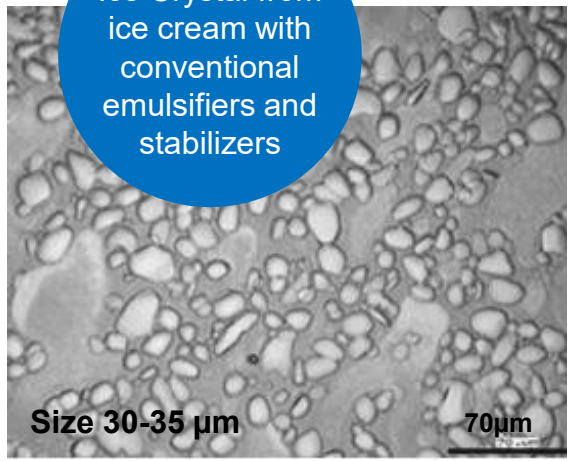
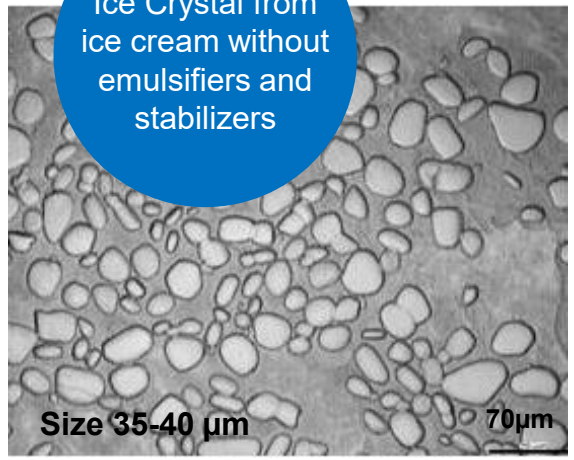
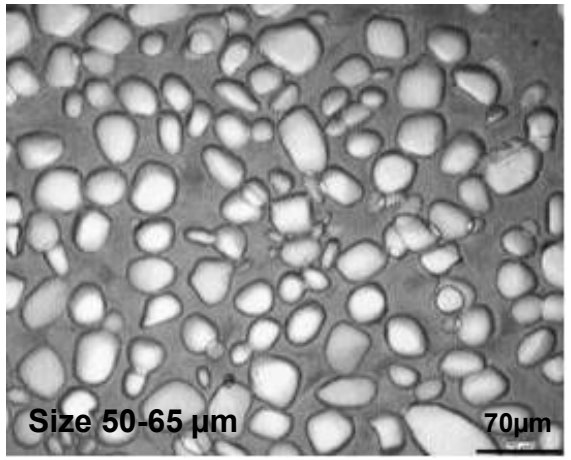
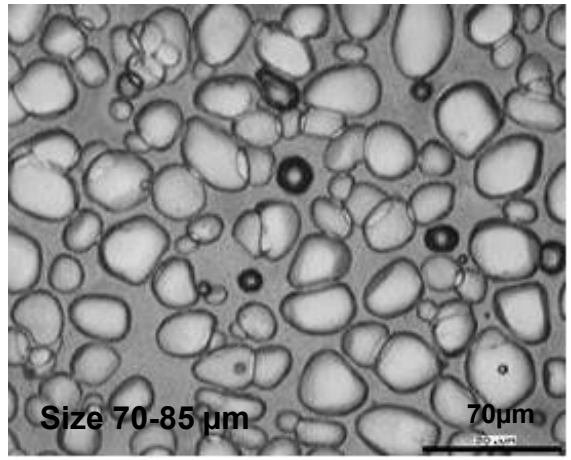
GRINDSTED® IcePro stabilizer/emulsifier systems are the best available way on the market to control heat shock in ice cream!

TRADITIONAL SOLUTION FOR HEAT SHOCK

Stabilizers and emulsifiers are used to slow growth of ice crystals over time and improve the consumer eating experience.

- A typical blend of stabilizer and emulsifier used in ice cream are:
  - **Mono & Diglycerides, Locust Bean Gum, Guar Gum and Carrageenan**

TRADITIONAL STABILIZER AND EMULSIFIERS RETARD ICE CRYSTAL GROWTH

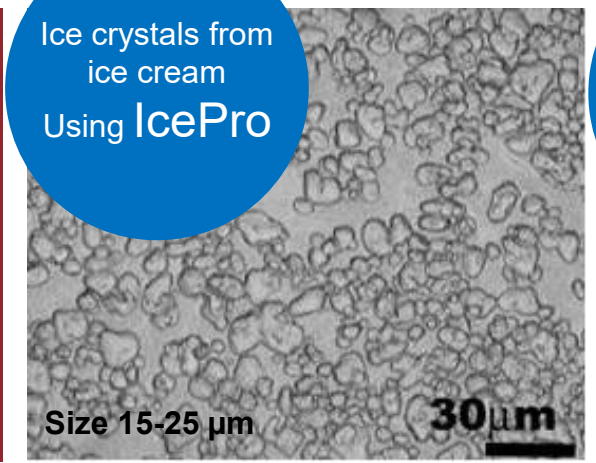
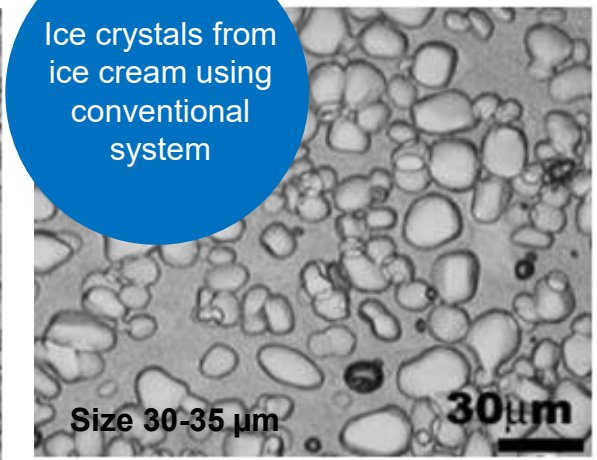
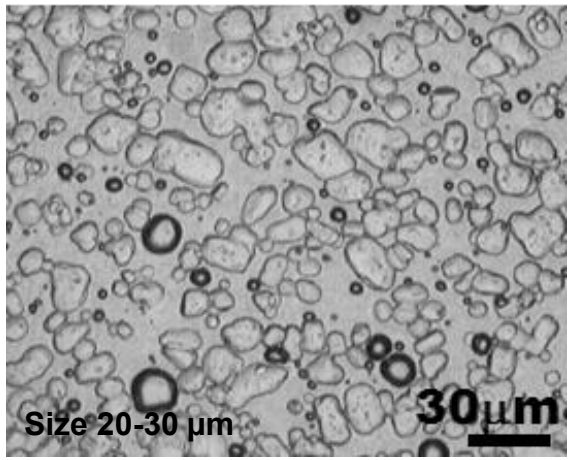
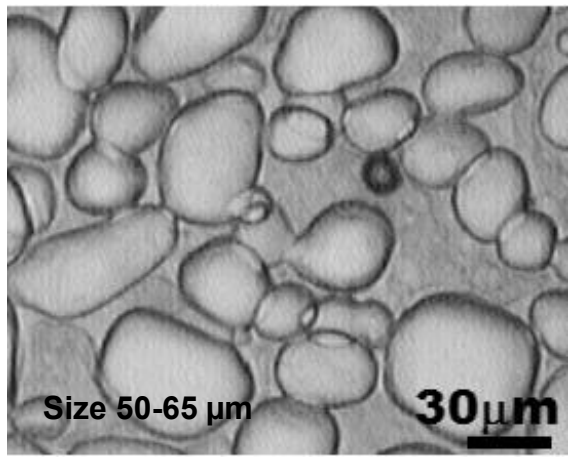
Before heat shock		
After heat shock		

WHAT IS GRINDSTED® ICEPRO?

- IcePro is the best in class solution for controlling heat shock and its effects on the consumer eating experience.
- IcePro is a stabilizer and emulsifier system utilizing Propylene glycol monoester (PGMS) as a key ingredient
  - IcePro GSD 2346
    (propylene glycol monoesters, mono & diglycerides, guar gum, locust bean gum, carrageenan)

Propylene glycol monoesters - food approved, propylene glycol monoester is made from fully hydrogenated vegetable oil. Propylene glycol monoesters are an emulsifier, commonly used in bakery products, non-dairy whipped topping and ice creams.

IcePro Lowers Ice Crystal Size Compared to Conventional Solutions

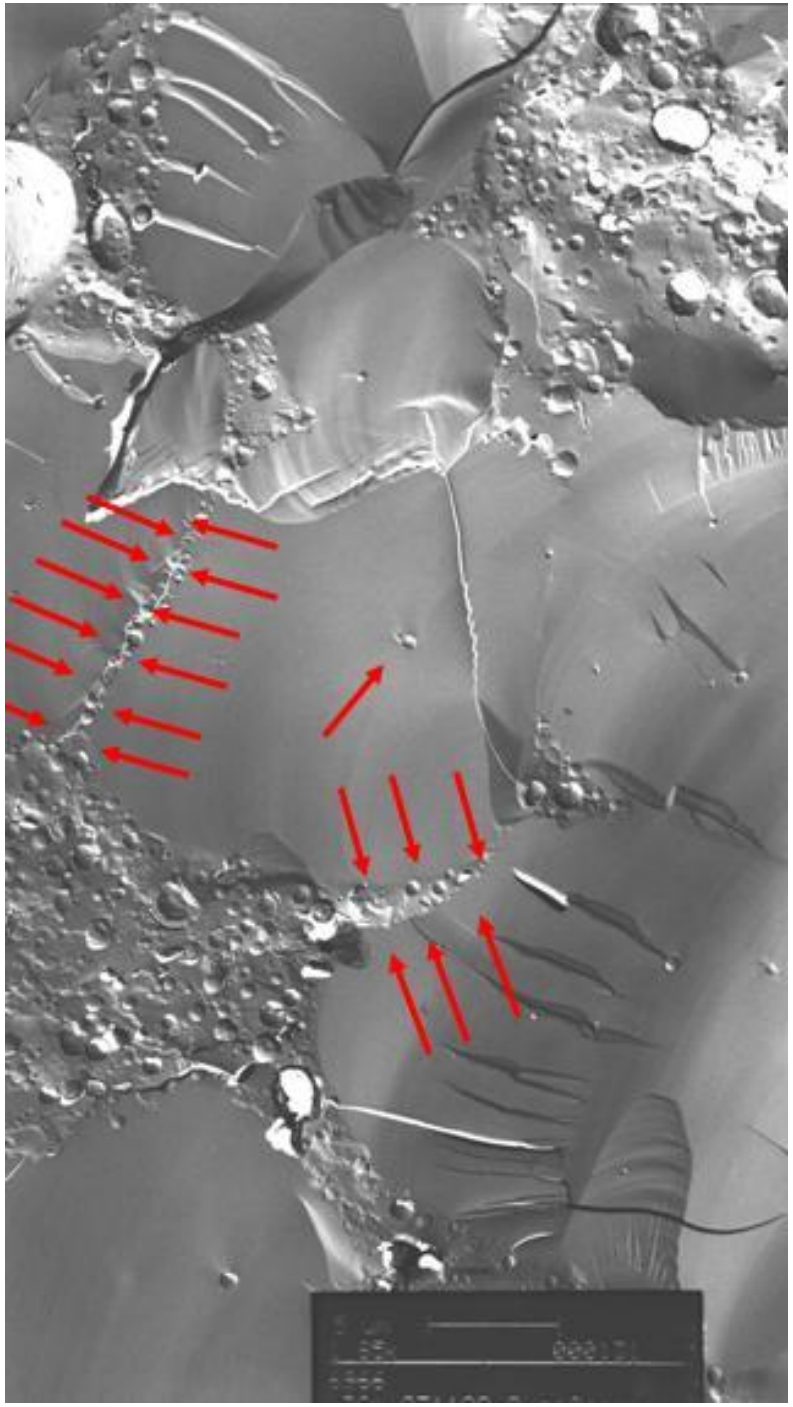
	Ice crystals from ice cream Using IcePro	Ice crystals from ice cream using conventional system
Before heat shock		
After heat shock		

TRANSMISSION ELECTRON MICROSCOPY OF FROZEN ICE CREAM

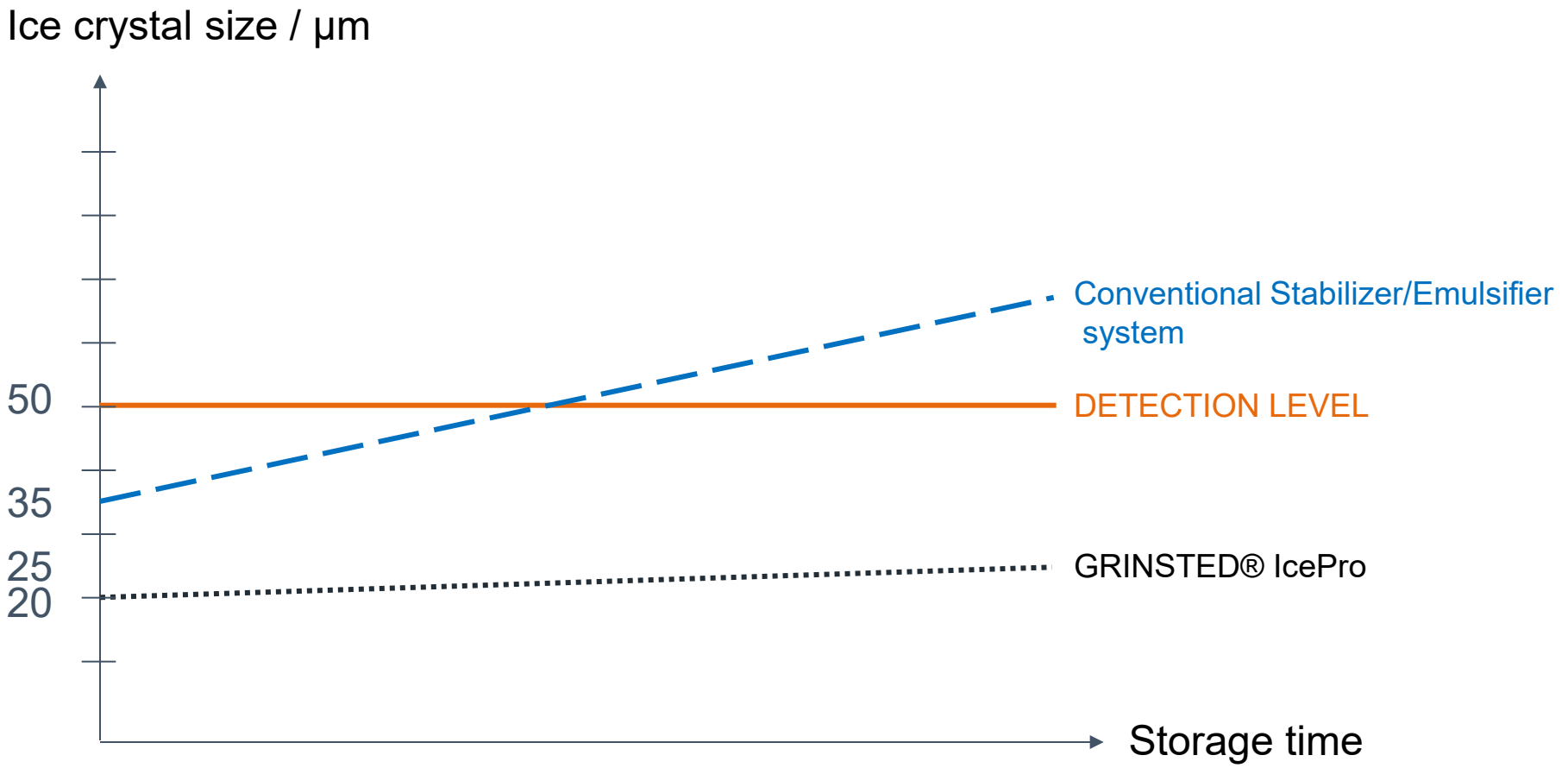
DEMONSTRATION OF MECHANISM

1) Propylene glycol monoester is effective in conditioning fat globules in such a manner to allow for physical interaction with ice crystals which can form hydrophobic borders blocking the contact of individual ice crystals. This reduces ice crystal fusion and retains small size.

2) Hydrophilic fat globules are sometimes even seen trapped inside the ice crystals.



IcePro Removes Major Limitation of Shelf Life in Ice Cream



BEST AVAILABLE ICE CRYSTAL CONTROL

GRINDSTED® IcePro

- Creates smaller initial ice crystals
- Dramatically slows the growth of the ice crystals during temperature fluctuations
- Improves sensory scores on iciness removing the major limitation in shelf life of ice cream

EMULSIFIERS IN FROZEN DESSERTS

Minor Ingredient major impact on product quality

- **Emulsifiers play an important role in processing and quality of finished product**
  - Excellent air cell distribution and air cell stability
  - Better melt resistance and shape retention
  - Improves texture – creamy mouthfeel and warmer-eating
  - Heat shock stability
- **Selecting the right one is critical!**

UNCOMMON ANSWERS START WITH BOLD QUESTIONS

We are looking forward to hearing yours!

DISCLAIMER

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THANK YOU.

Now, let’s ignite delicious dairy experiences...