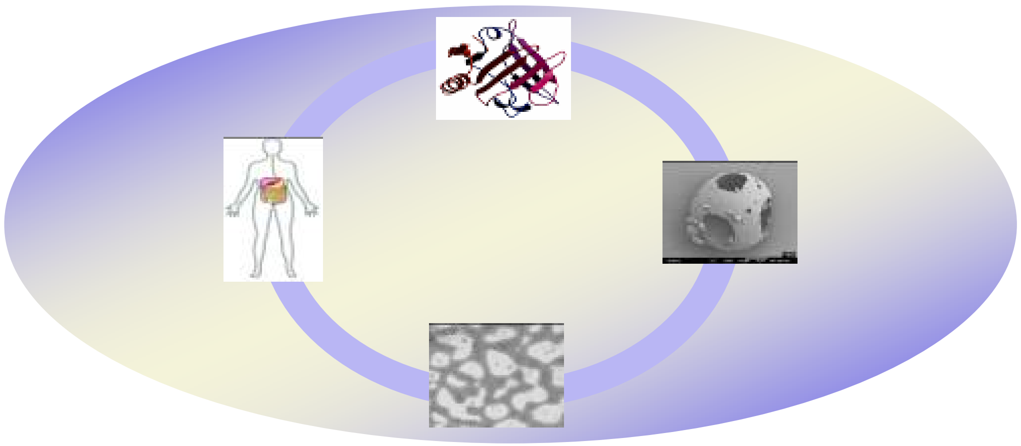
Food Emulsions and Foams

Dr. Simeon Stoyanov

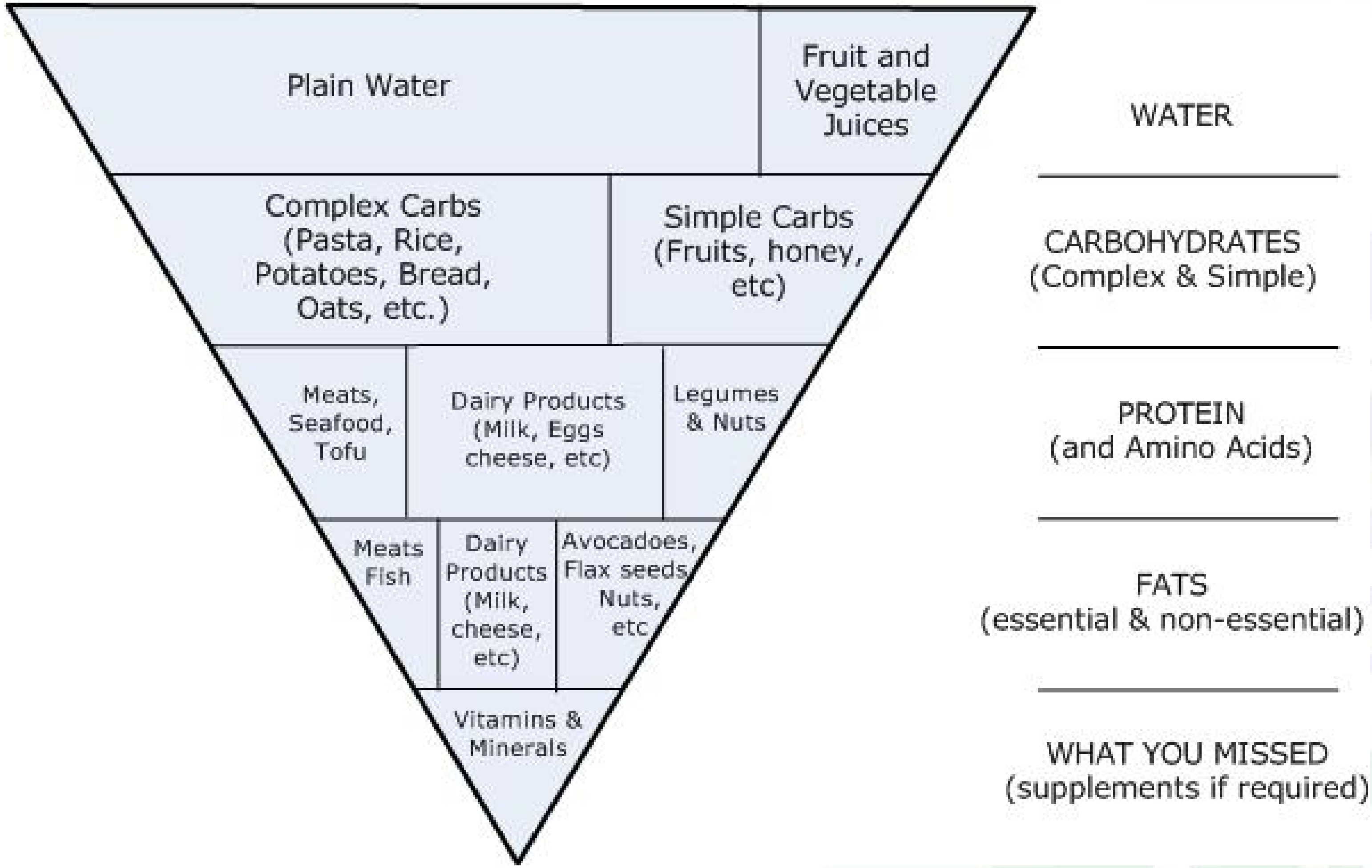


Unilever Food and Health Research Institute

Outline of the talk:

- ***Main Building blocks of food emulsions***
- ***Aren't these blocks too few ?***
- ***Food emulsions clock***
- ***Examples of food emulsions***
  - Ice Cream
  - Dressings (Mayo)
  - Spreads (Margarine)

Foods Building blocks



Oils/Fats (8kcal/g): TAGS, Saturated/ (Poly) unsaturated
Proteins (4 kcal/g): diary, egg, meat, (vegetables, cereals)
Carbohydrates (4 kcal/g): sugars, starch

Foods Building blocks

Multiple functions of macro-nutrients:

- To provide structure during processing

- To keep this structure during storage

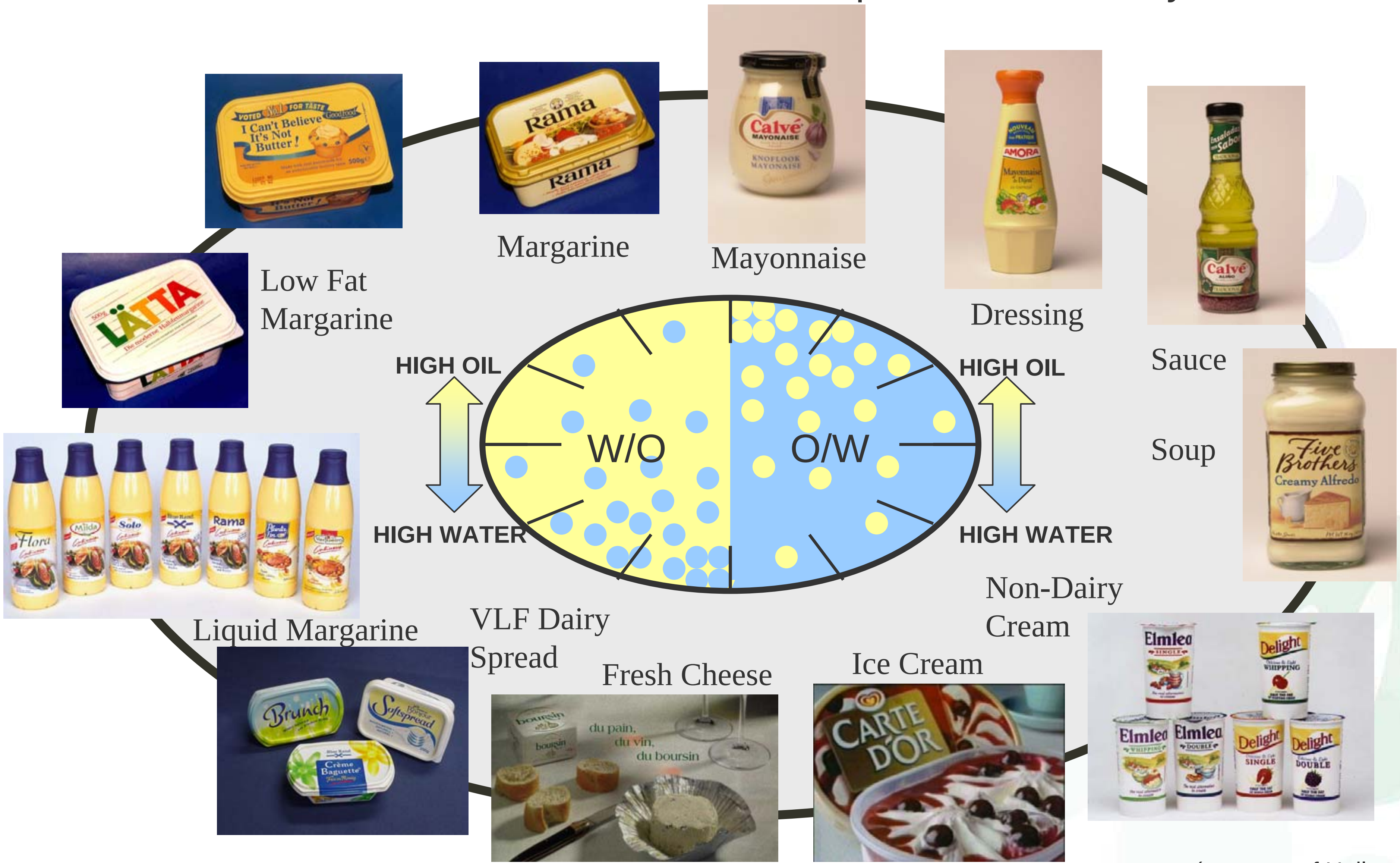
- To give pleasant mouth feel (taste/flavour) during eating

- <u>To deliver energy to human body in bioaccessible ways</u>


Where there is more "technology" and what are its applications ?

Foods emulsion clock

Most foods are emulsions. Both water and oil phases are usually structured.



(courtesy of Unilever)

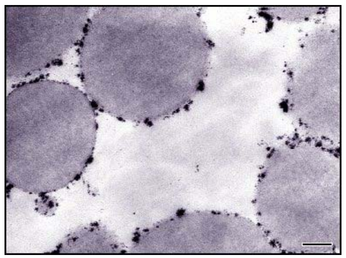
What is Ice Cream made of ?

Ice

Cream

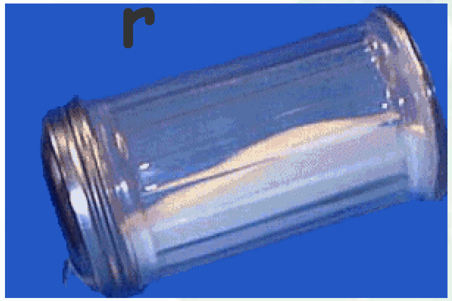
Fat

Milk Protein



Flavours

Suga
r



Air

What is Ice Cream ?

We think of ice cream as a 4 phase system:

partially frozen	ice crystals
an oil-in-water emulsion	fat droplets
a foam	air bubbles
in a dispersed phase	sugar solution (matrix)

Scientific Areas Involved ...

SUGAR
Food Chemistry

Regulatory Affairs

ICE
Ice Physics
Crystallisation
Water Chemistry
Molecular Science

AIR
Foam Science
Interfacial Chemistry

Quality Control

Consumer Science

Microbiology

FAT
Emulsion Science
Fat Chemistry
Colloids

FLAVOUR
Chemistry
Food Science

MILK/CREAM
Dairy Science
Colloid Science

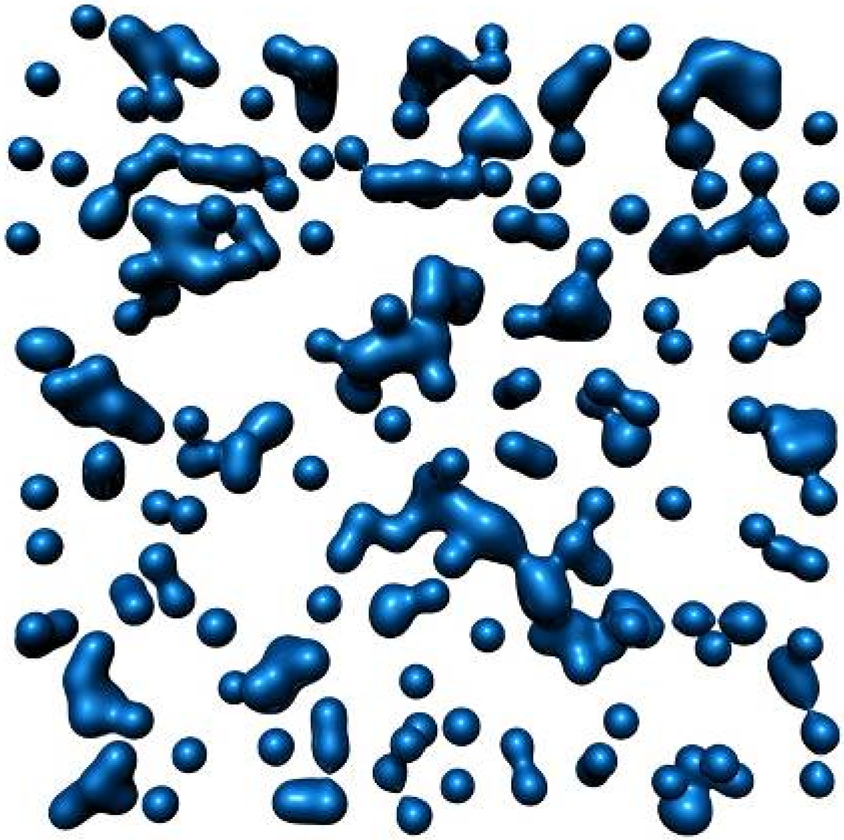
Nutrition

Process Engineering

Ice Cream

Ice

- 30% of volume
- No energy contribution



Volume

Energy

Total Energy

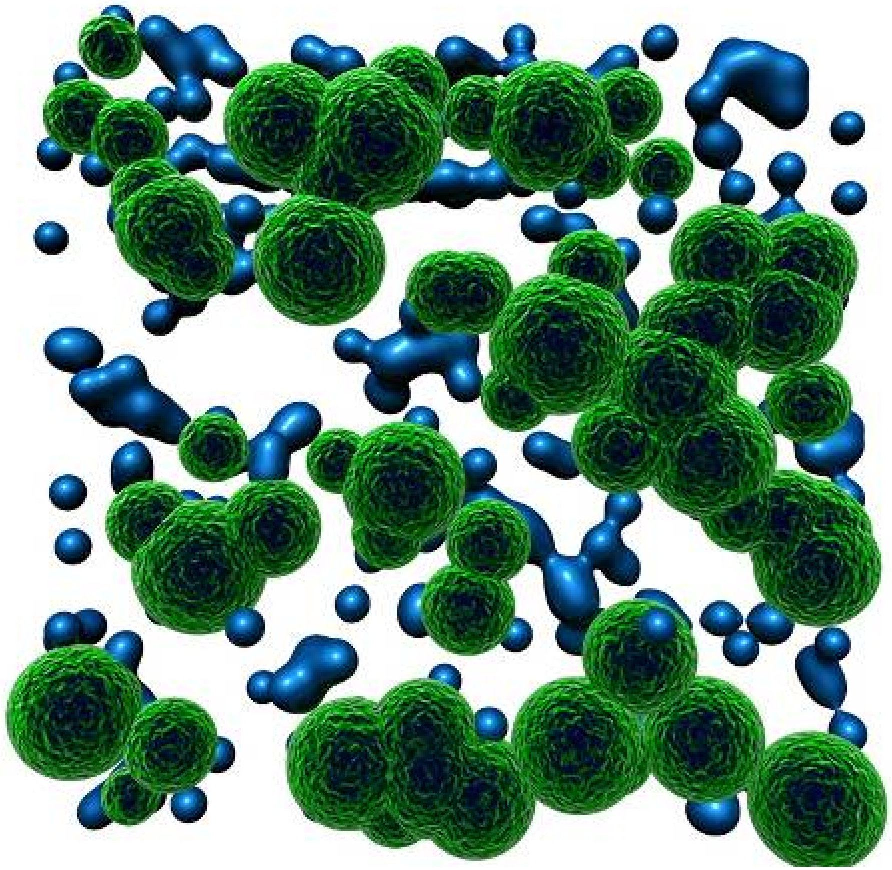
407kJoule/100ml
745kJoule/100g

Ice Cream

Air

- 50% of volume
- No energy contribution

Softens the ice cream
Provides smooth texture



Volume

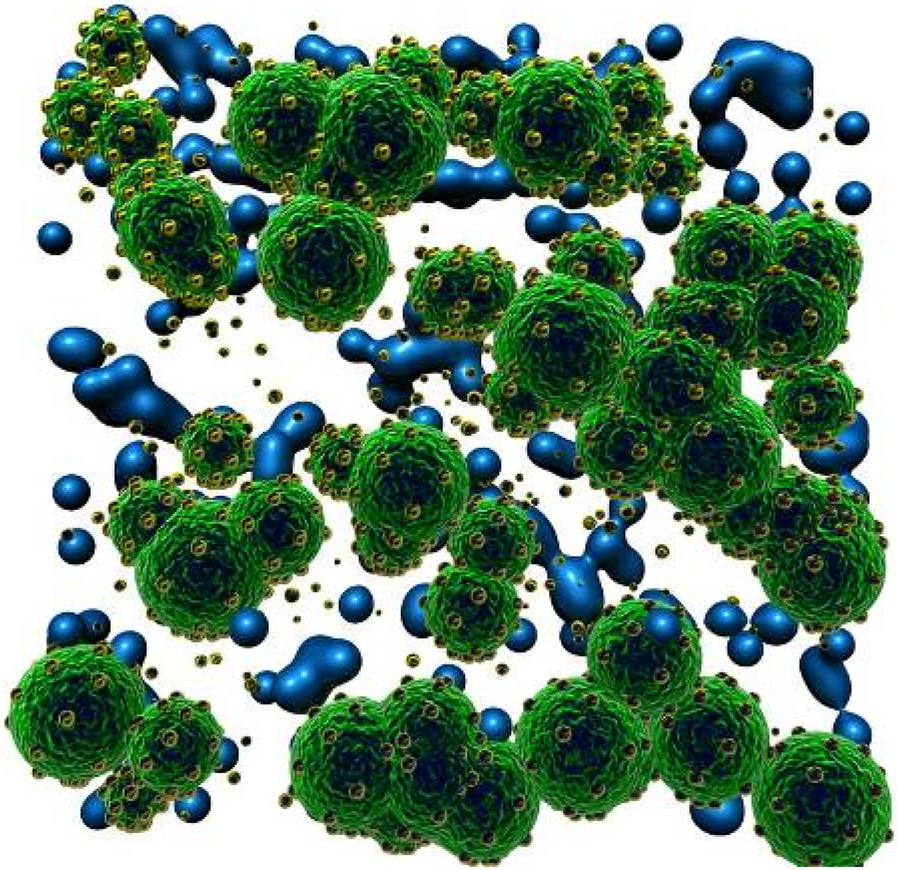
Energy

Total Energy 407kJoule/100ml
745kJoule/100g

Ice Cream

Fat

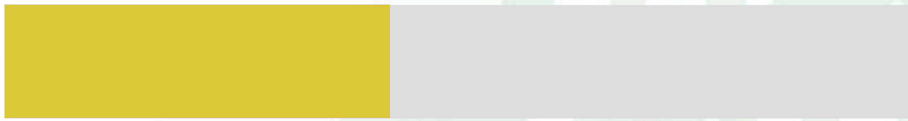
- 4.5% of volume
- 45% energy contribution



Provides structure
Carries and delivers flavour
Boosts creaminess
Stabilises the air bubbles

Volume

Energy



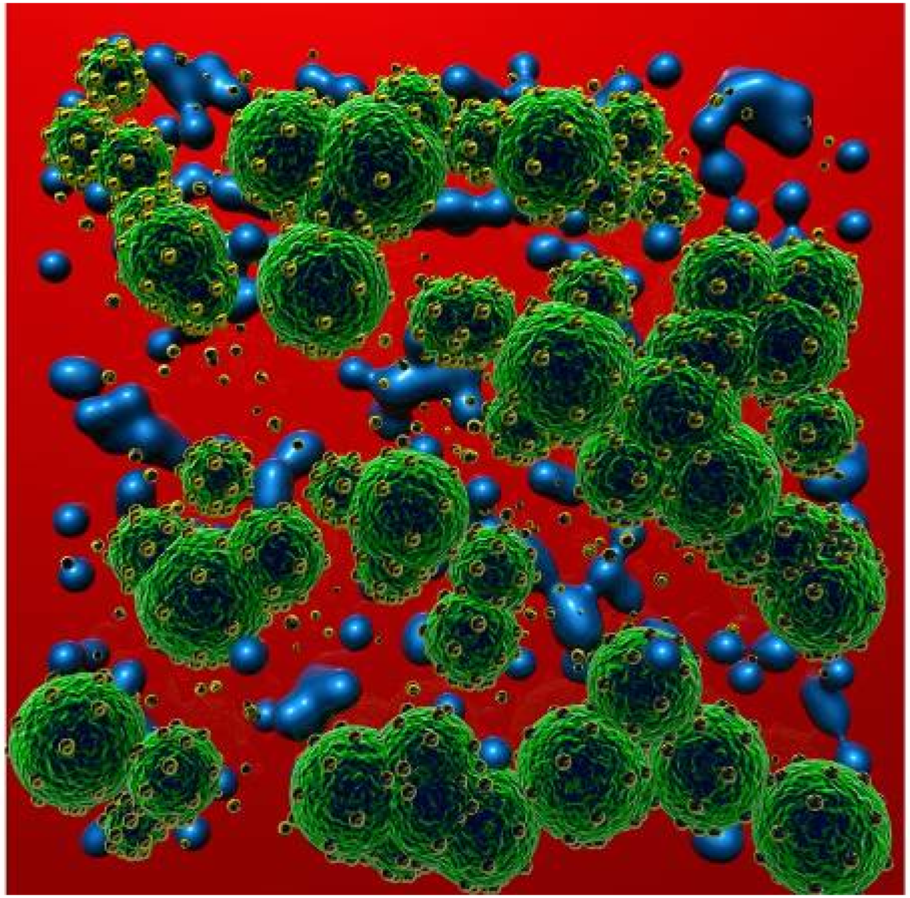
Total Energy

407kJoule/100ml
745kJoule/100g

Ice Cream

Matrix

•15% of volume



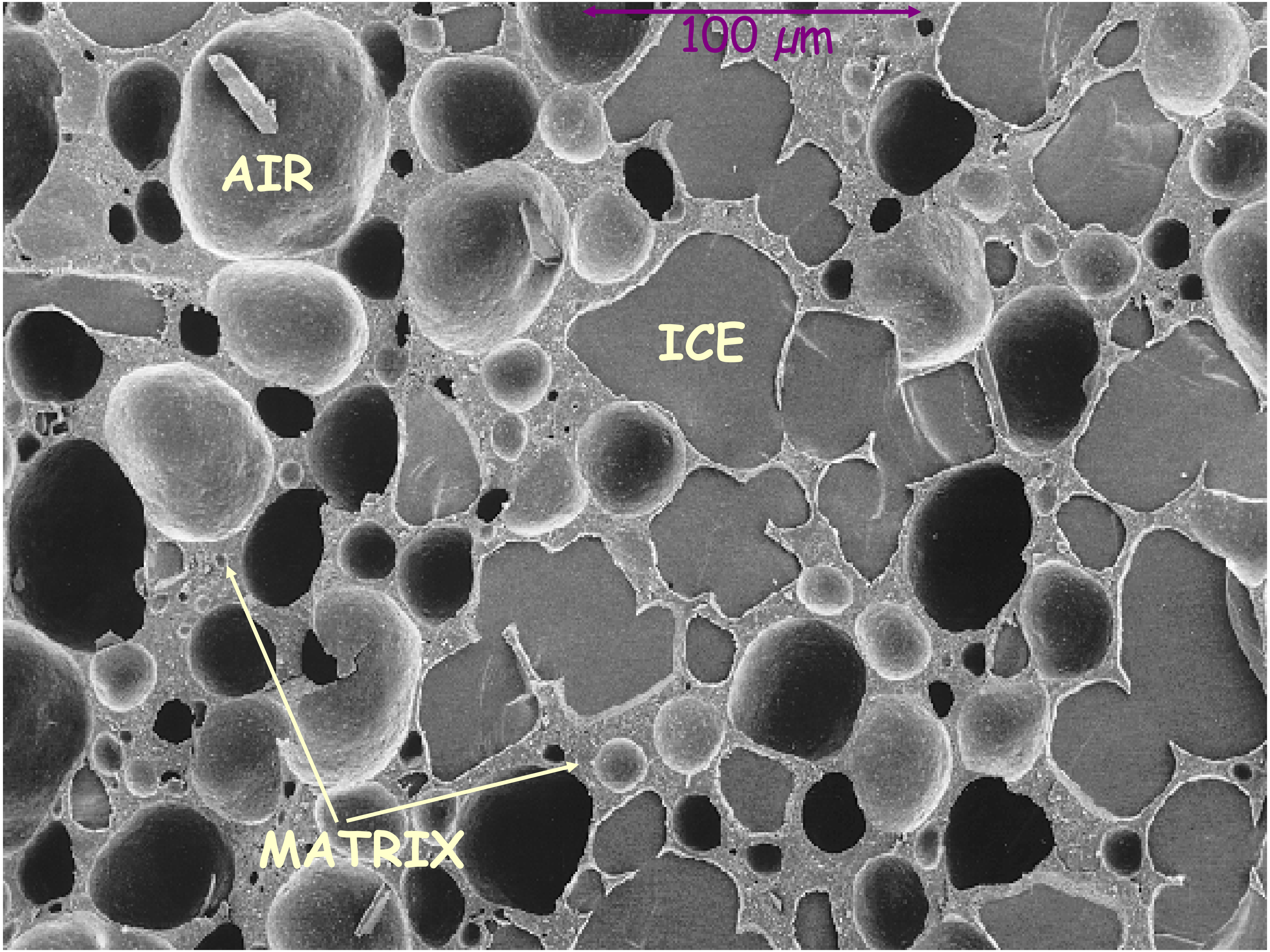
Protein	Sugars	Stabilisers
•8% of energy •Stabilises fat droplets •Stabilises air bubbles •Contributes to flavour	•50% of energy •Controls ice content •Provides sweetness •Gives thickness	•<1% of energy •Heat shock stability •Gives thickness

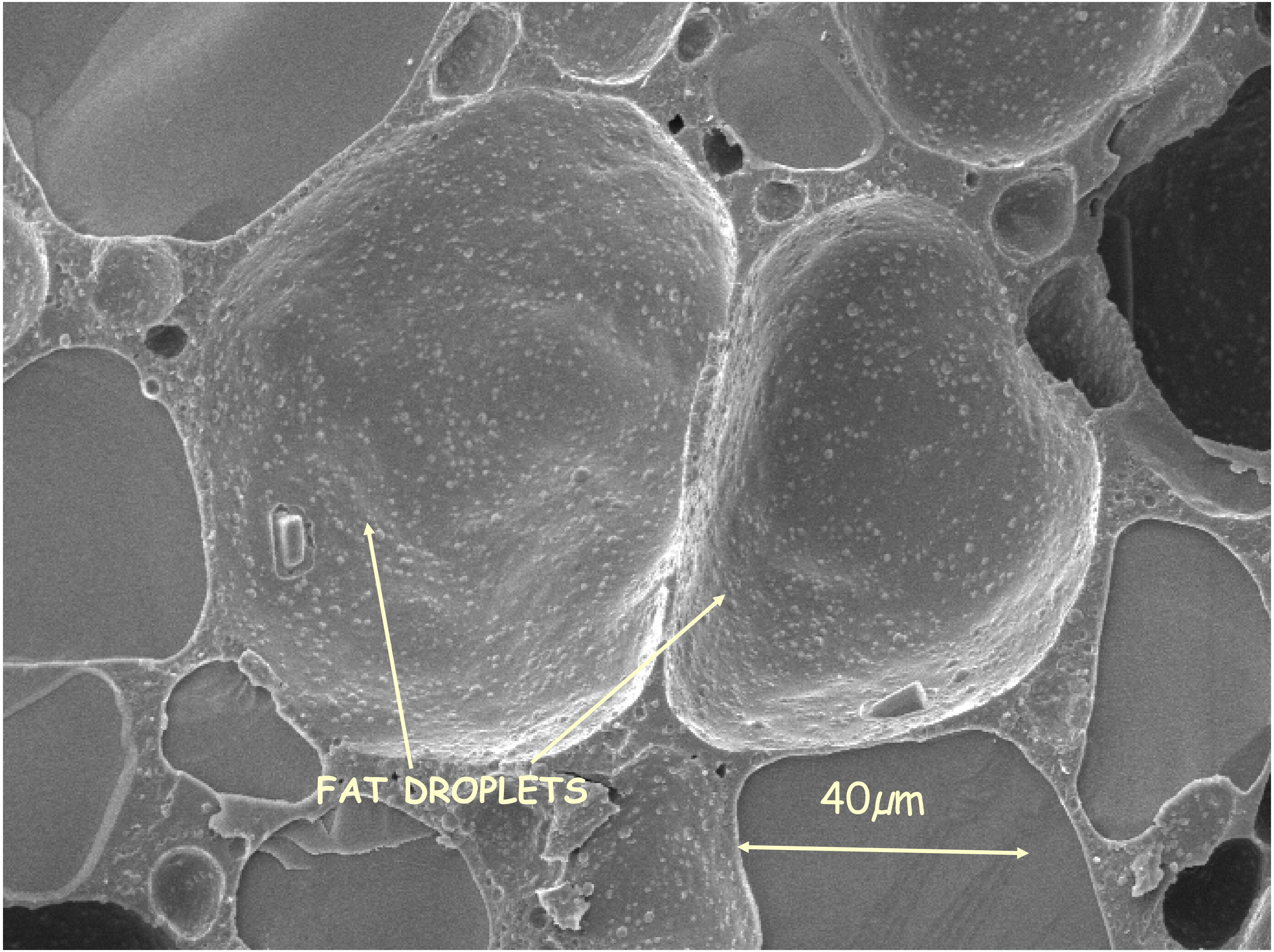
Volume

Energy

Total Energy

407kJoule/100ml
745kJoule/100g


100 μm
AIR
ICE
MATRIX


FAT DROPLETS
40μm

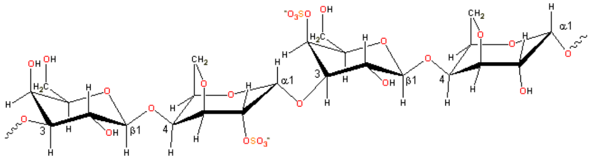
Ingredients

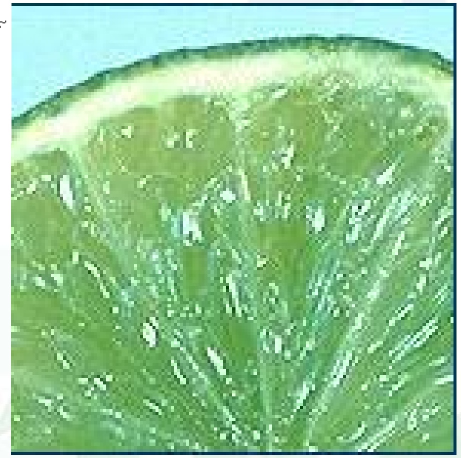
Water
Milk / Cream
Fat / Oil
Air
Sugar

Flavours
Emulsifiers
Stabilisers
Colours

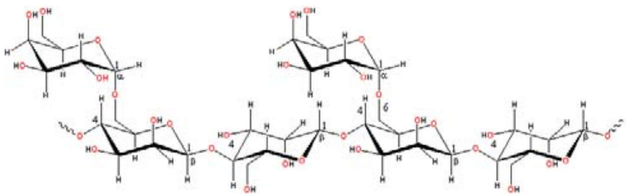
Ingredients: Stabilisers / Thickeners

Sea Weed
(Carrageenan)

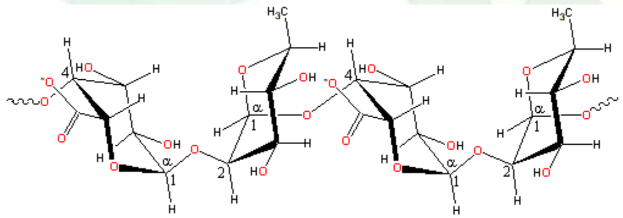




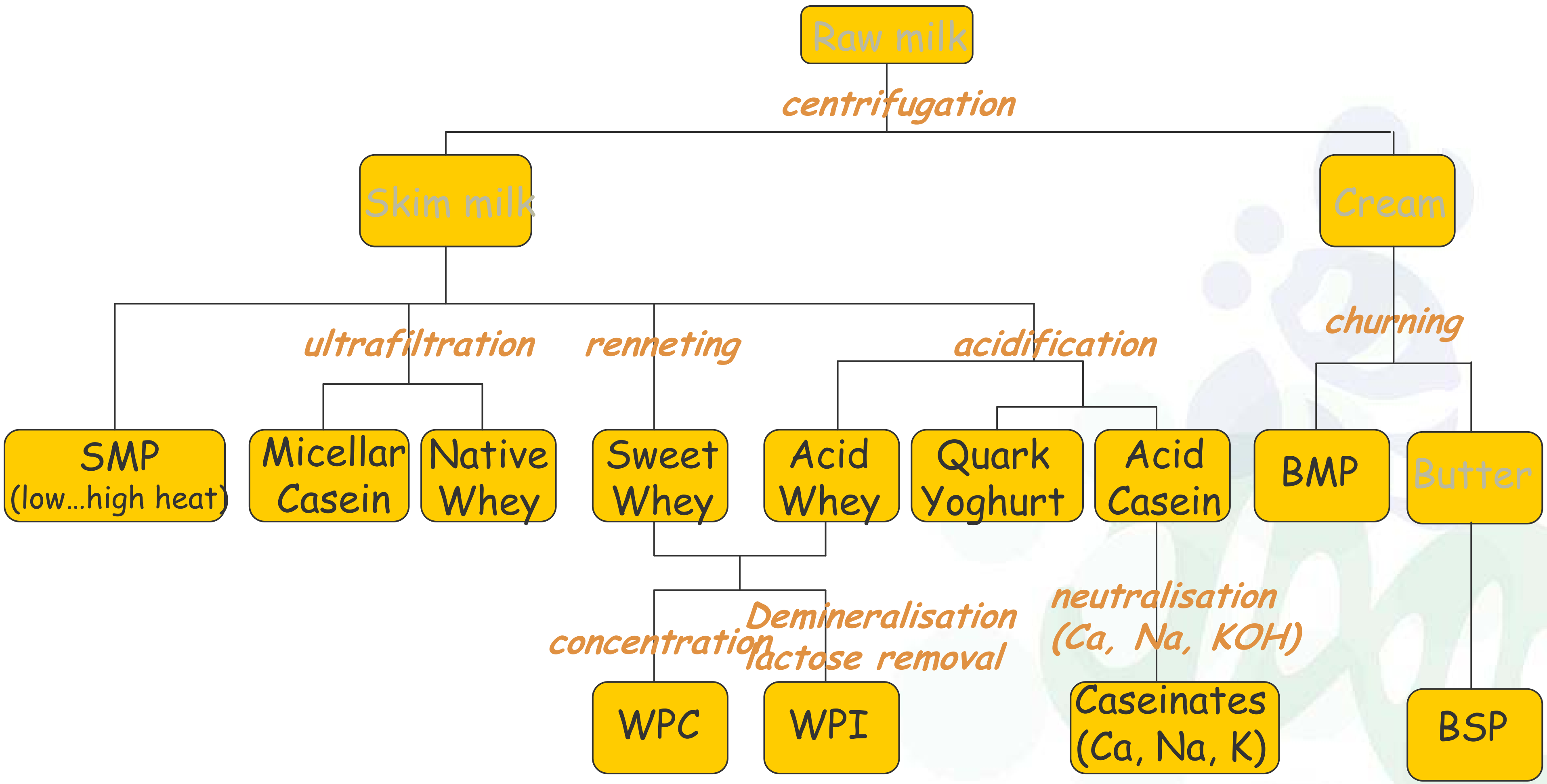
Seeds
(Guar)



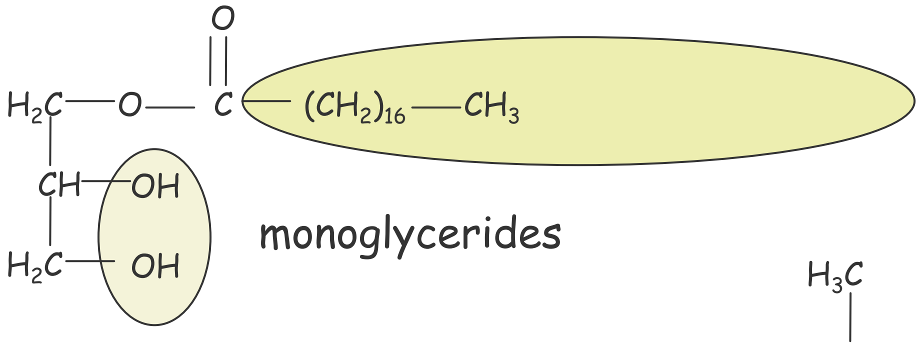
Fruit
(Pectin)



Dairy raw materials and ingredients

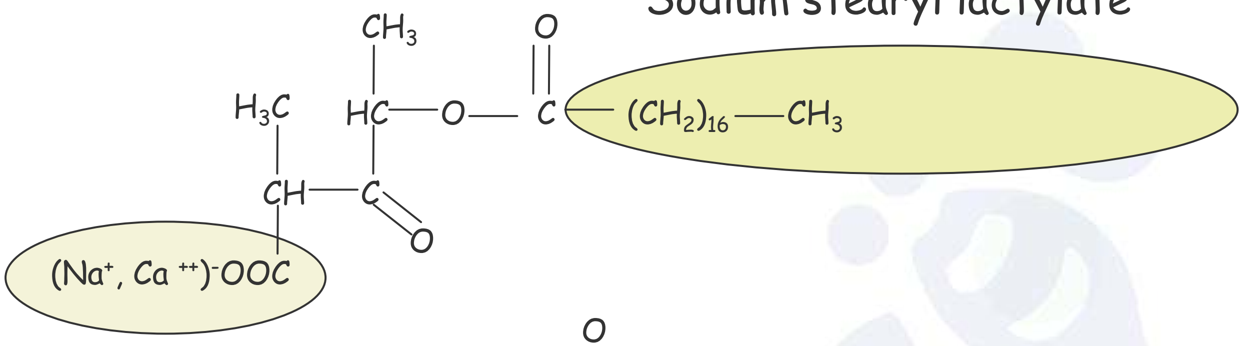


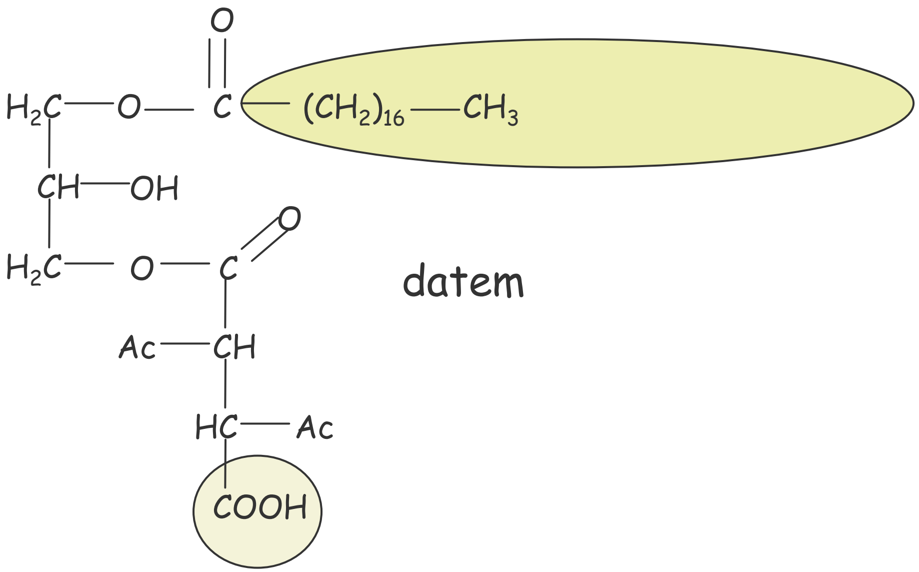
Ingredients: emulsifiers



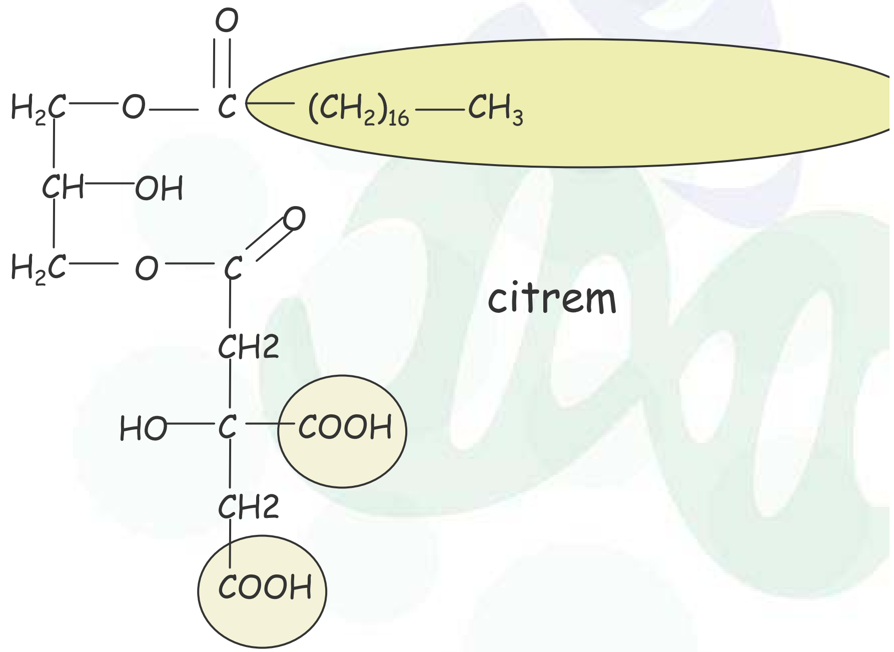
monoglycerides

Sodium stearyl lactylate





datem



citrem

What is Ice Cream Made of ?

Ingredients

Water
Milk / Cream
Fat / Oil
Air
Sugar
Flavours
Emulsifiers
Stabilisers
Colours

Ice Crystals

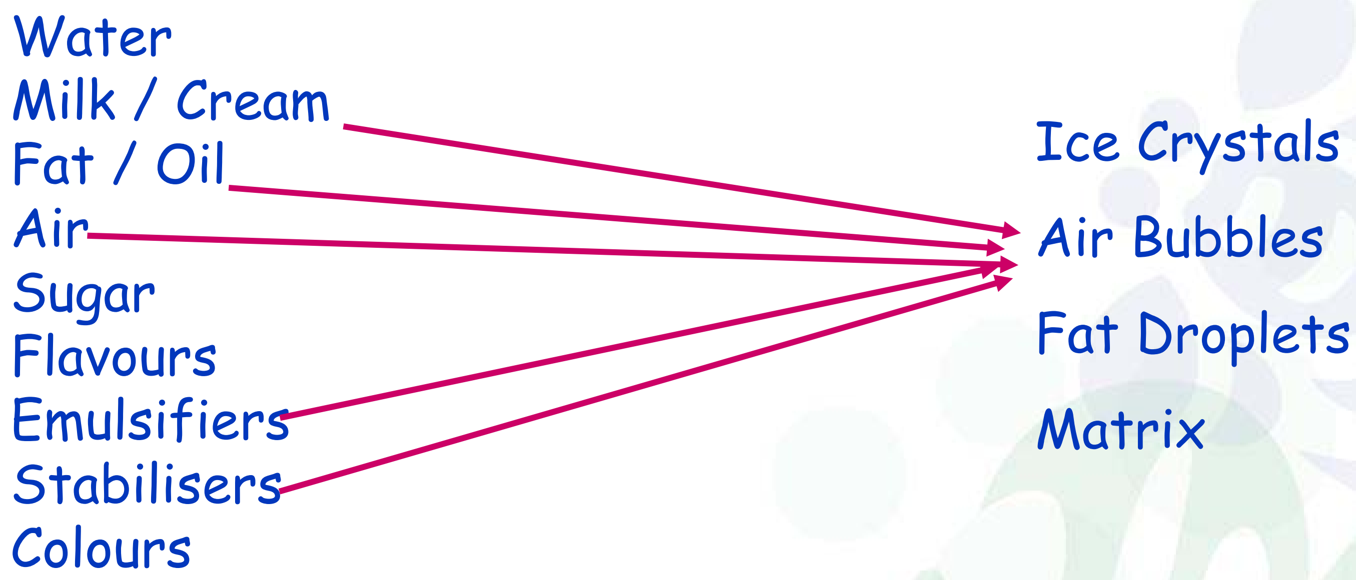
Air Bubbles

Fat Droplets

Matrix

Structural Components

What is Ice Cream Made of ?



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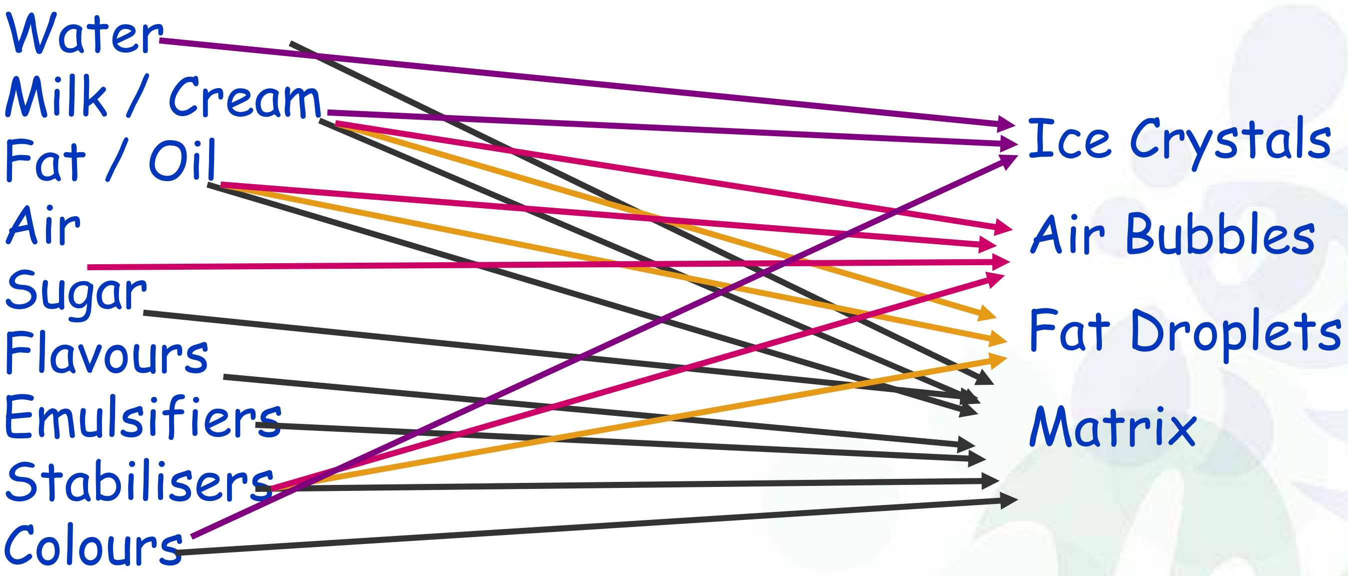
- Stabilisers
- Colours

→

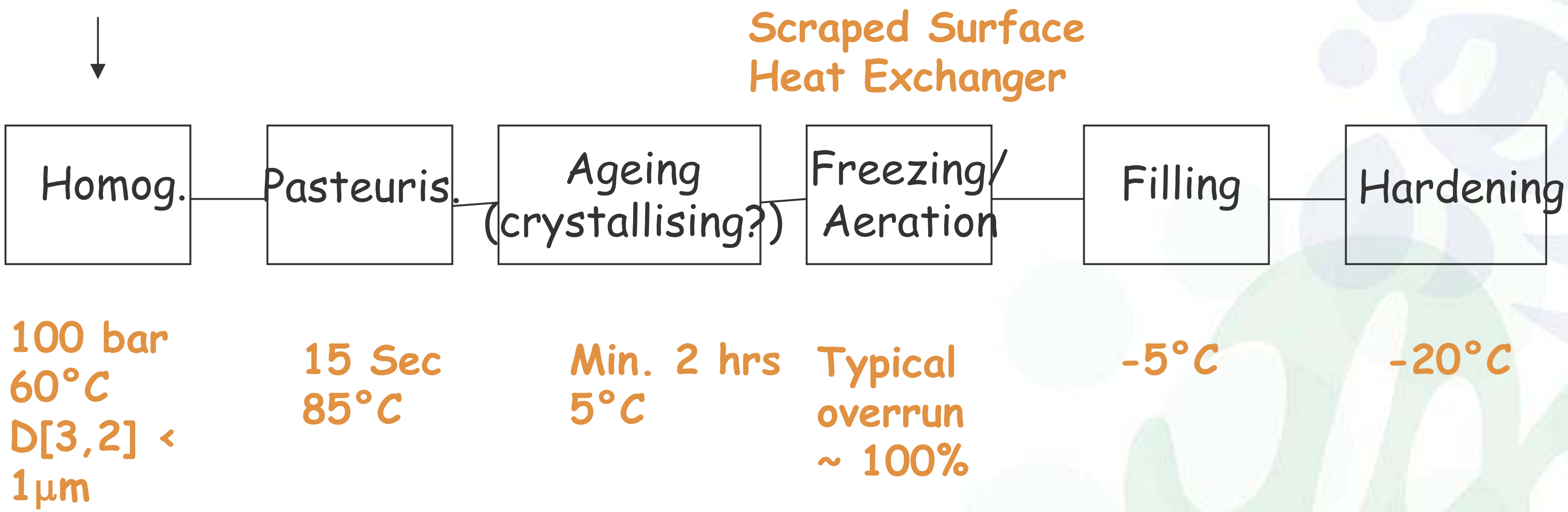
- Ice Crystals
- Air Bubbles
- Fat Droplets
- Matrix

What is Ice Cream Made of ?

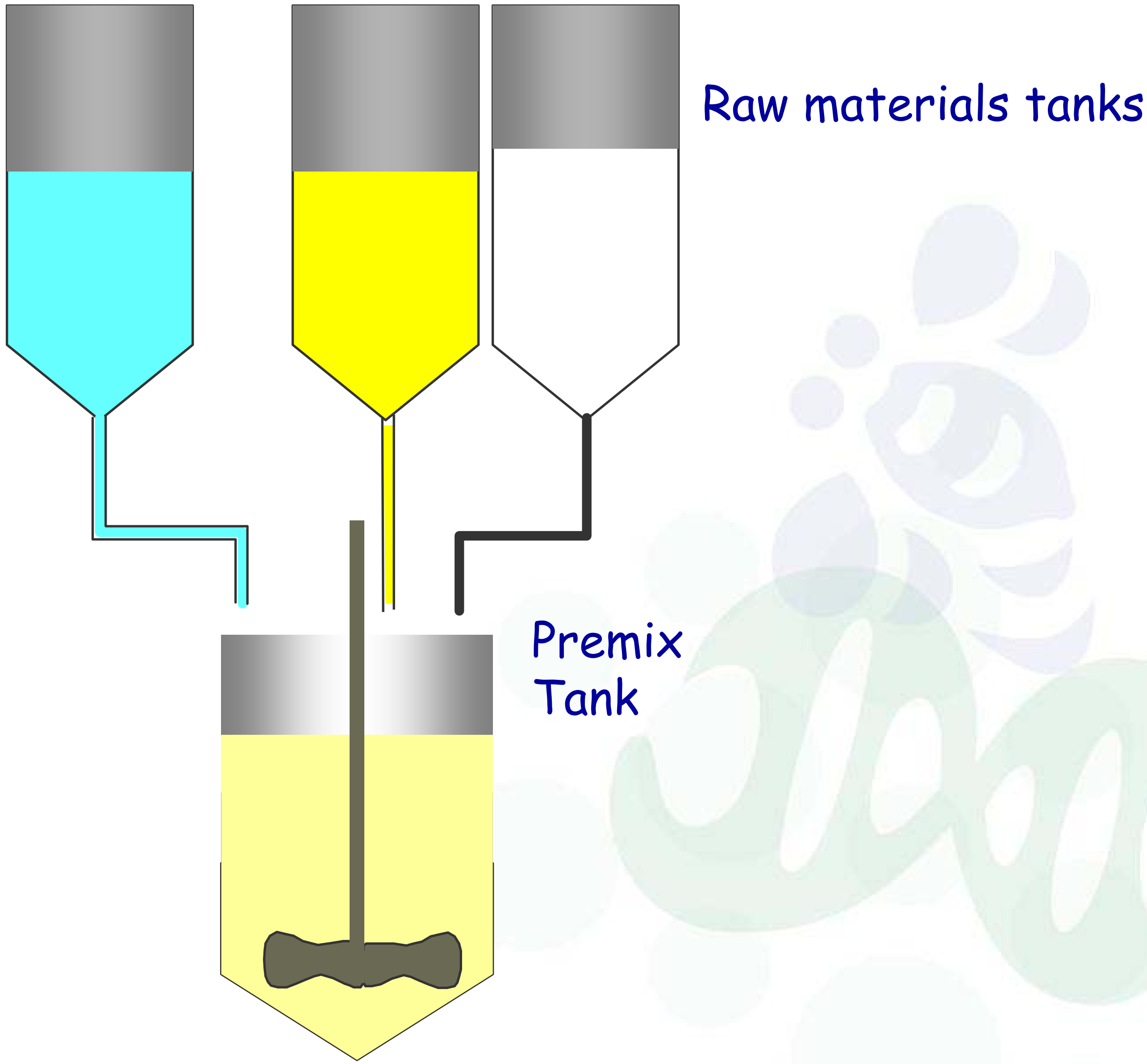


Manufacturing of Ice Cream

Fat,
Milk powder,
Emulsifiers
Sugar,
Thickeners



Mixing ...



Ice Cream Manufacture

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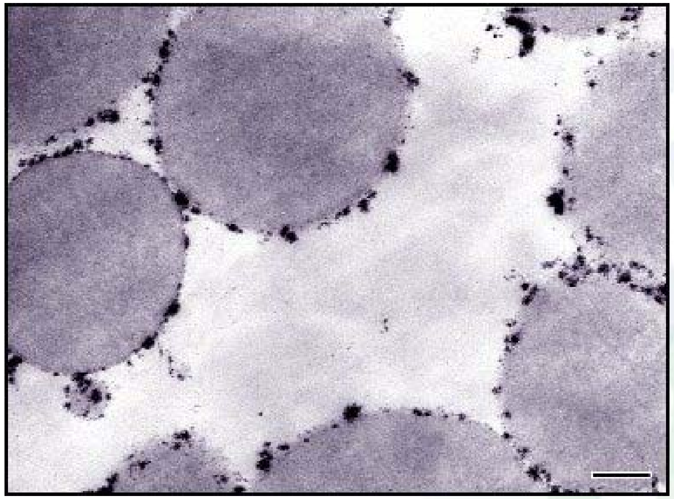
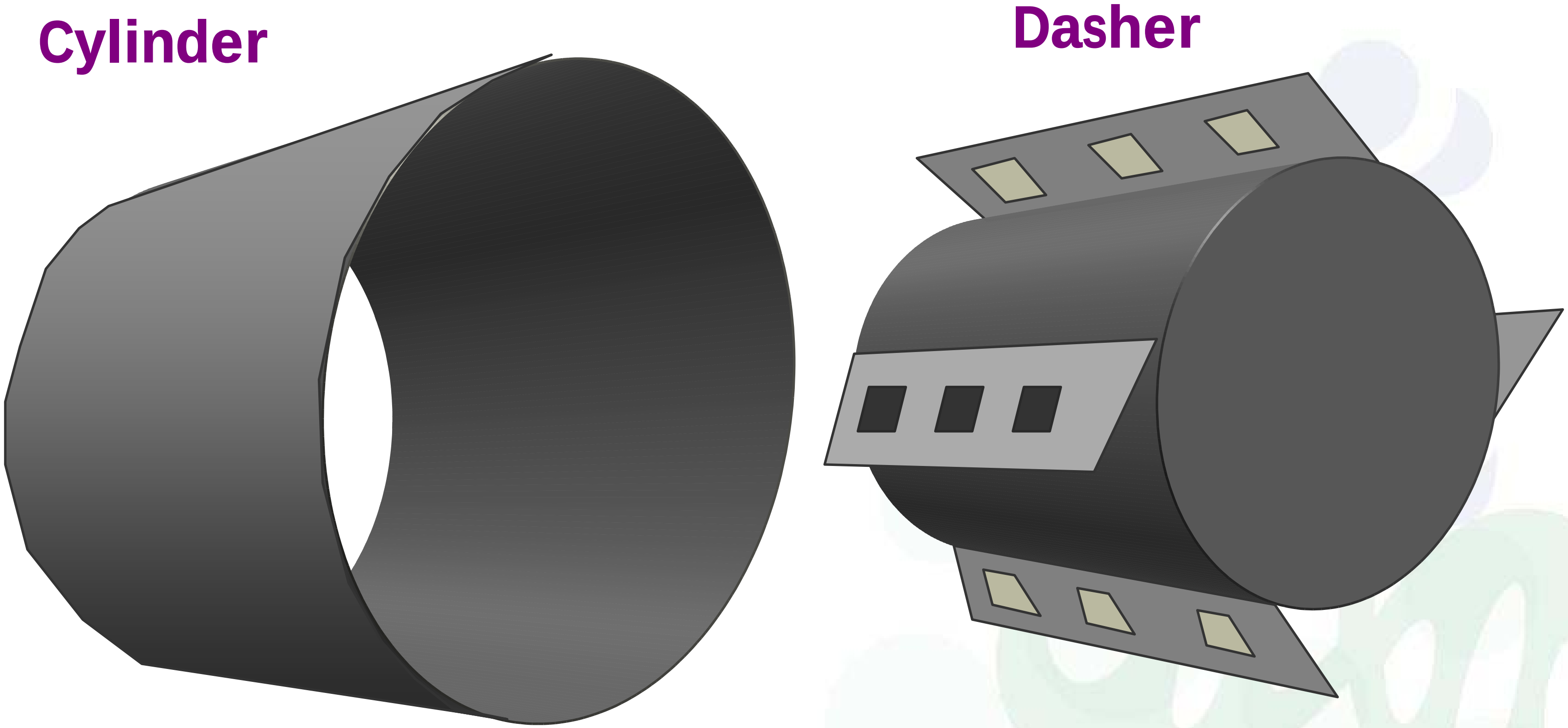
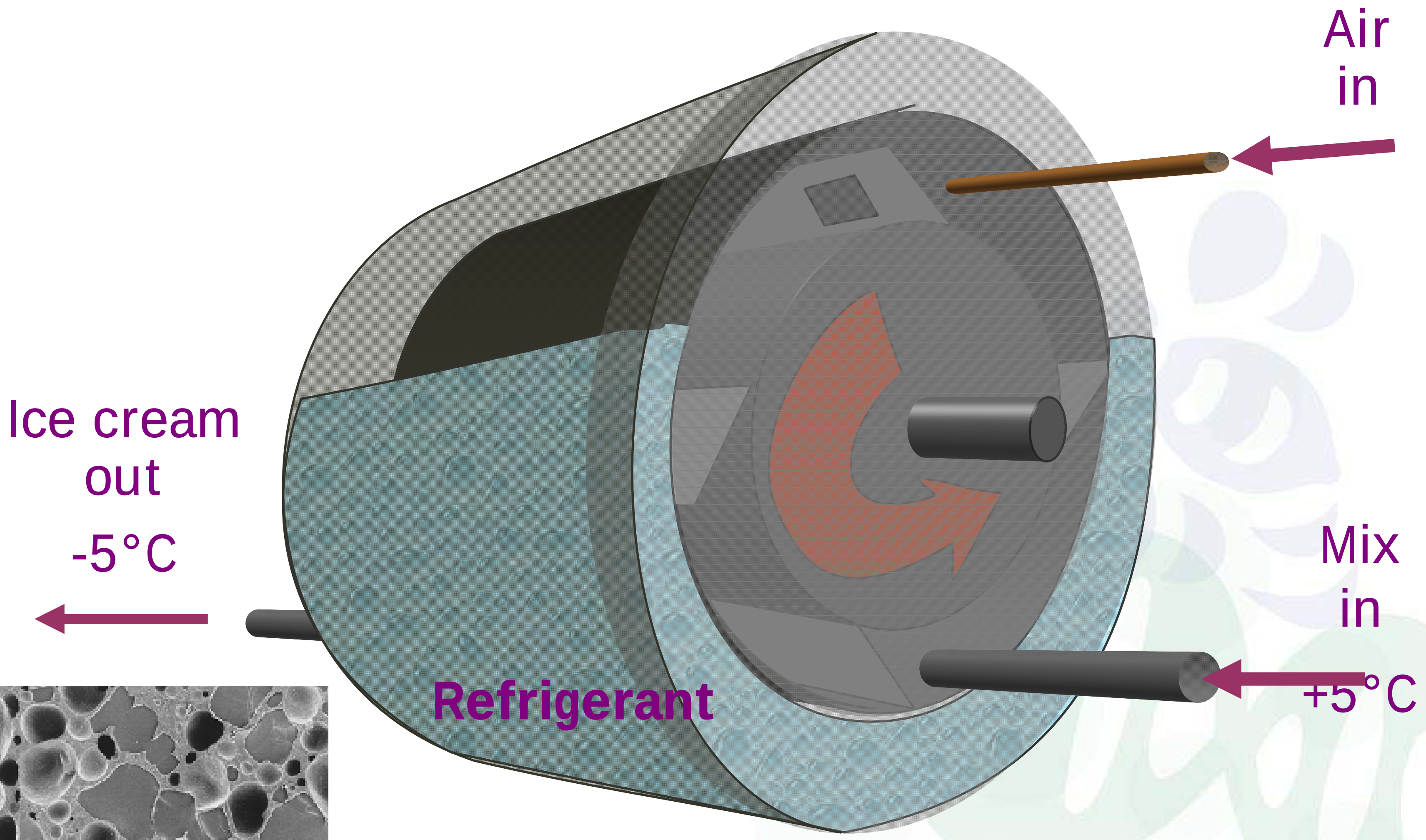


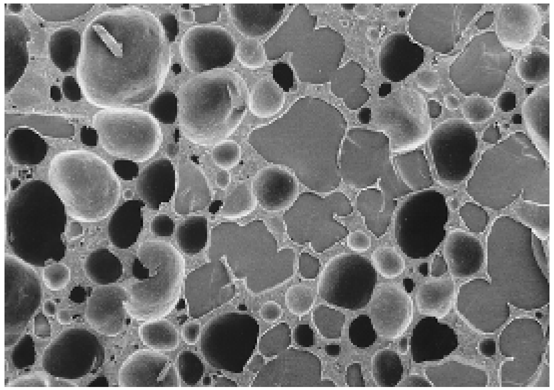
Ice cream emulsion comprises droplets of ca. 1 μm

Ice Cream Freezer



Ice Cream Freezer





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Real World ...

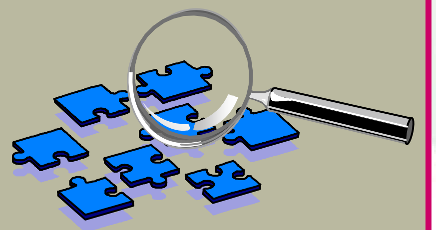
Eating
creamy
smooth
soft
cold
icy

The Engineering World...

Physics & Materials Science
viscosity
density
hardness
heat capacity

The Microstructure World ...

Microstructure
ice crystals
air bubbles
fat droplets
sugar solution



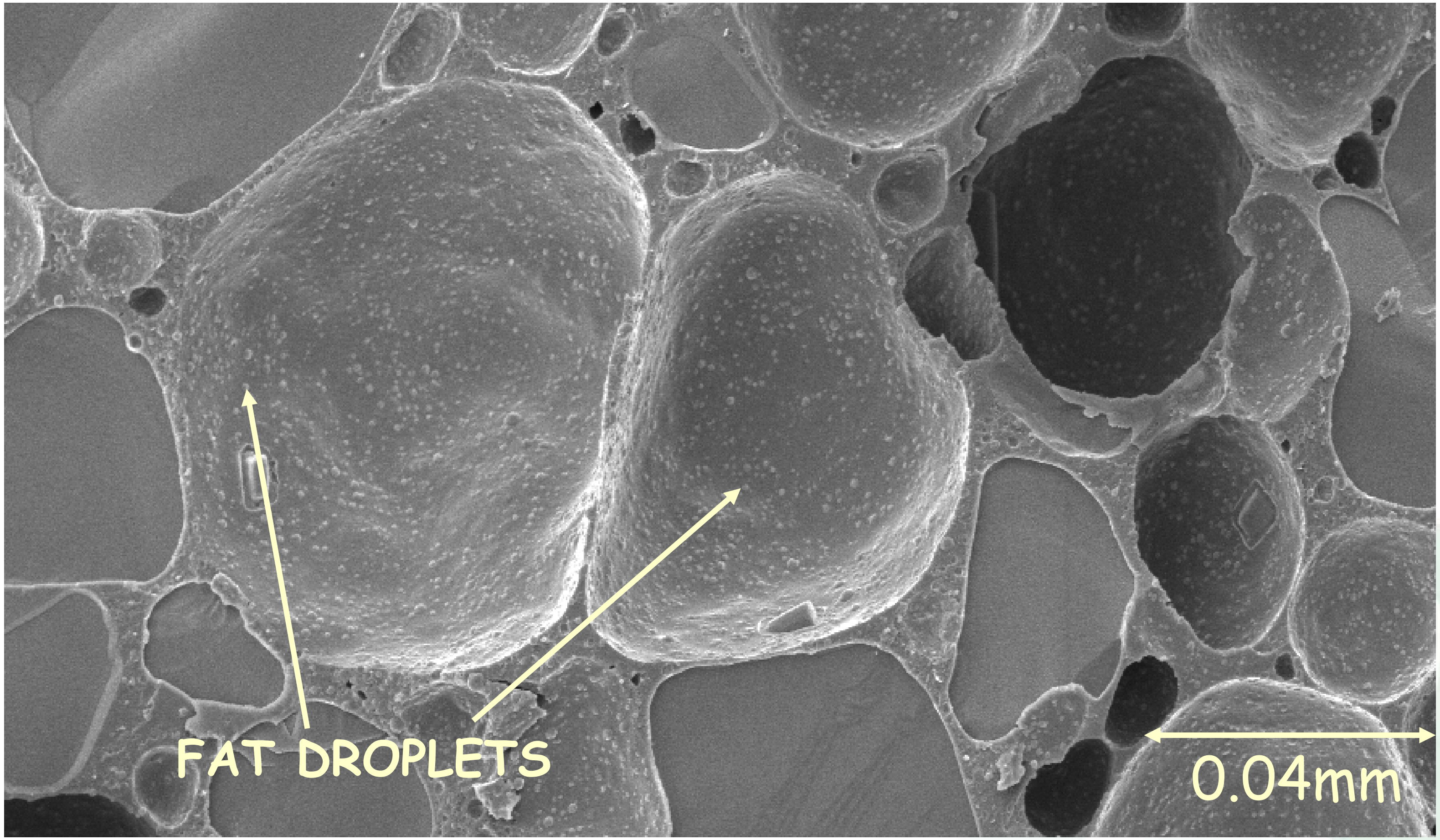
Foam stability (50% air)

Emulsion (fat particle) stability

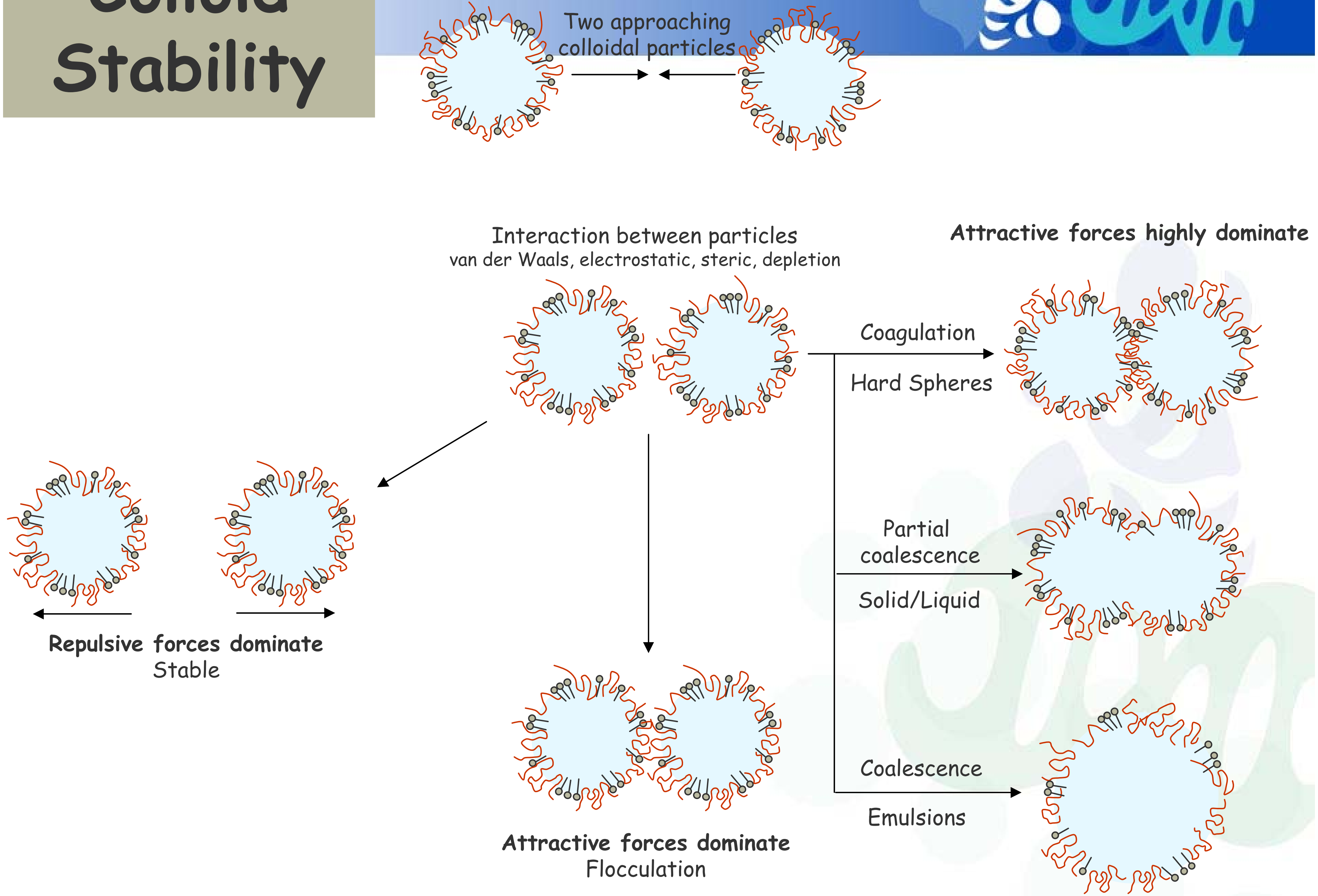
Ice crystal stability

Colloids are stabilised by surface active agents:
Milk Protein

Close up of an air bubble ...

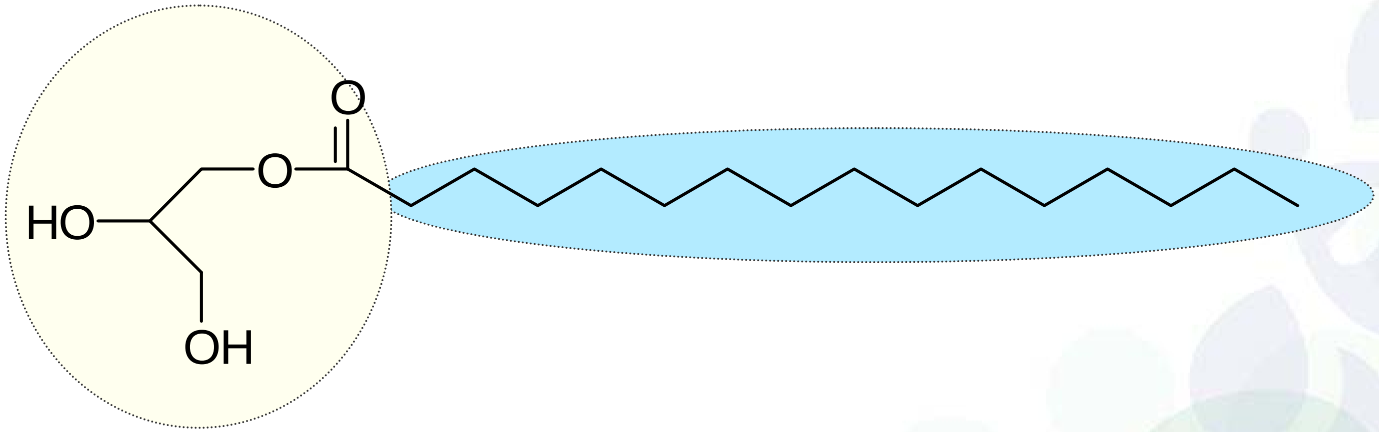


Colloid Stability



Role of the emulsifier

Saturated monoglycerides are often added to ice cream to improve quality



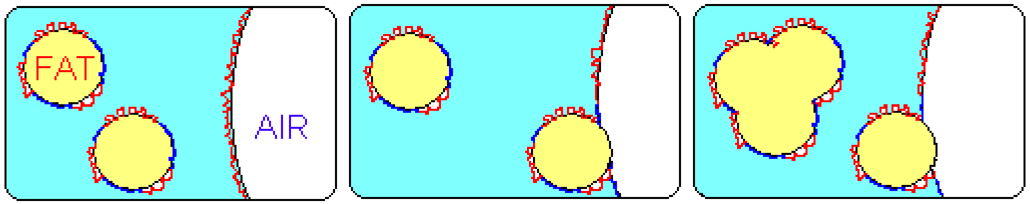
- Fat droplets containing emulsifiers contribute to gas phase stability through:

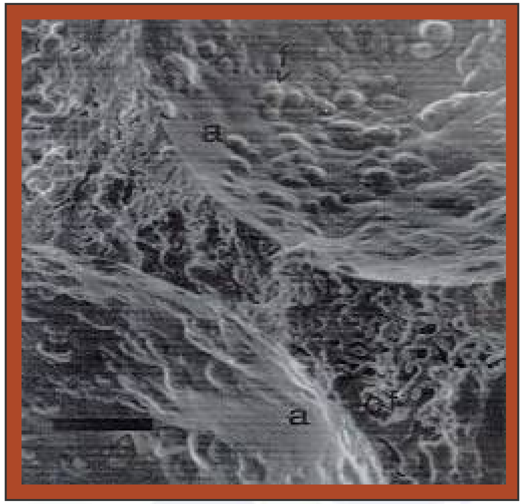
  Direct adsorption of fat at the air interface

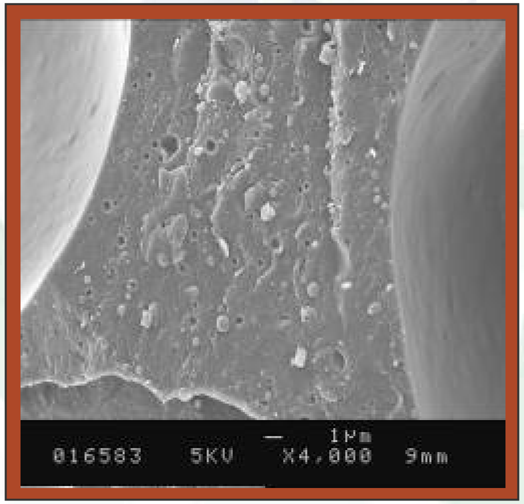
  and/or

  Structuring of fat in the matrix (partial coalescence)

- Aeration assists directly in the mechanism of partial coalescence

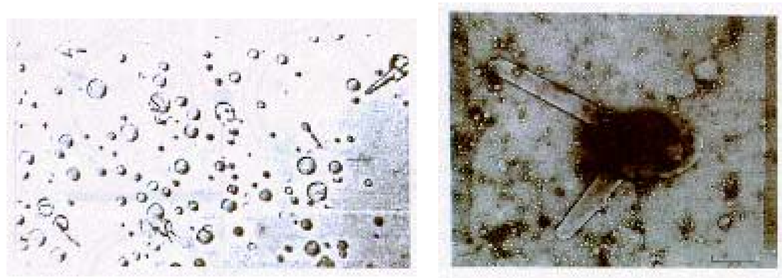


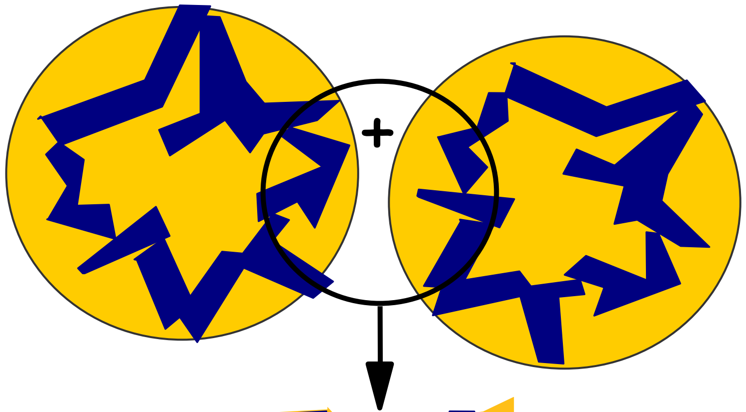




Proposed mechanism for partial coalescence

Mechanism of surface roughening - applies to weak thin (monolayer) interfaces





touch and prick through membrane

fuse and wet, by capillary action fill up the gap, liquid bridge formation

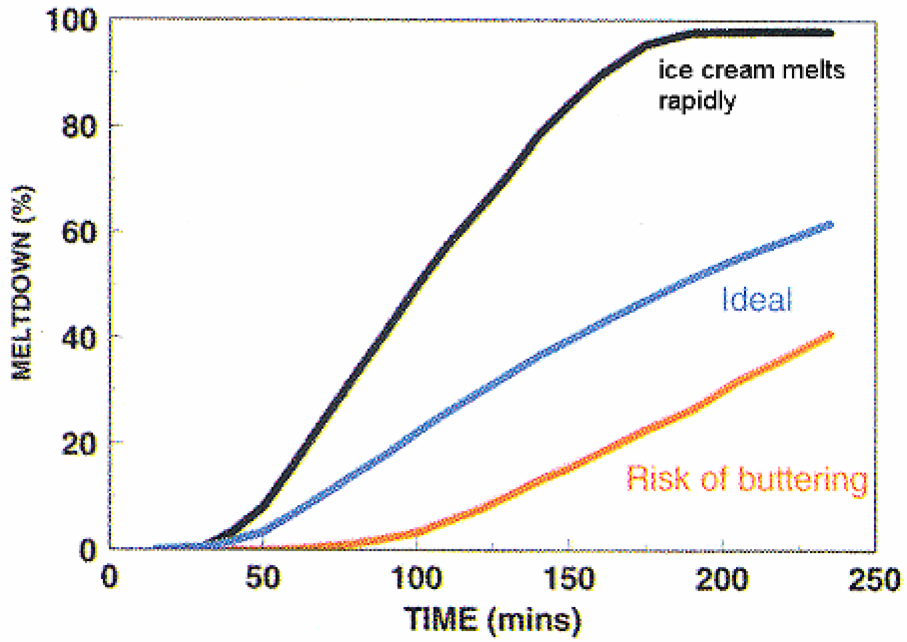
by sintering crystals grow together

Advantages of emulsifier fat destabilization in ice cream:

-improved air phase stability
-greater stability against meltdown
-perceived creamier texture
-dryness on extrusion

Disadvantages:

-loss of all-natural label
-excessive destabilization can cau
buttering



Perceived quality of ice cream is highly dependent on the controlle destabilization of fat

(cut to movie)

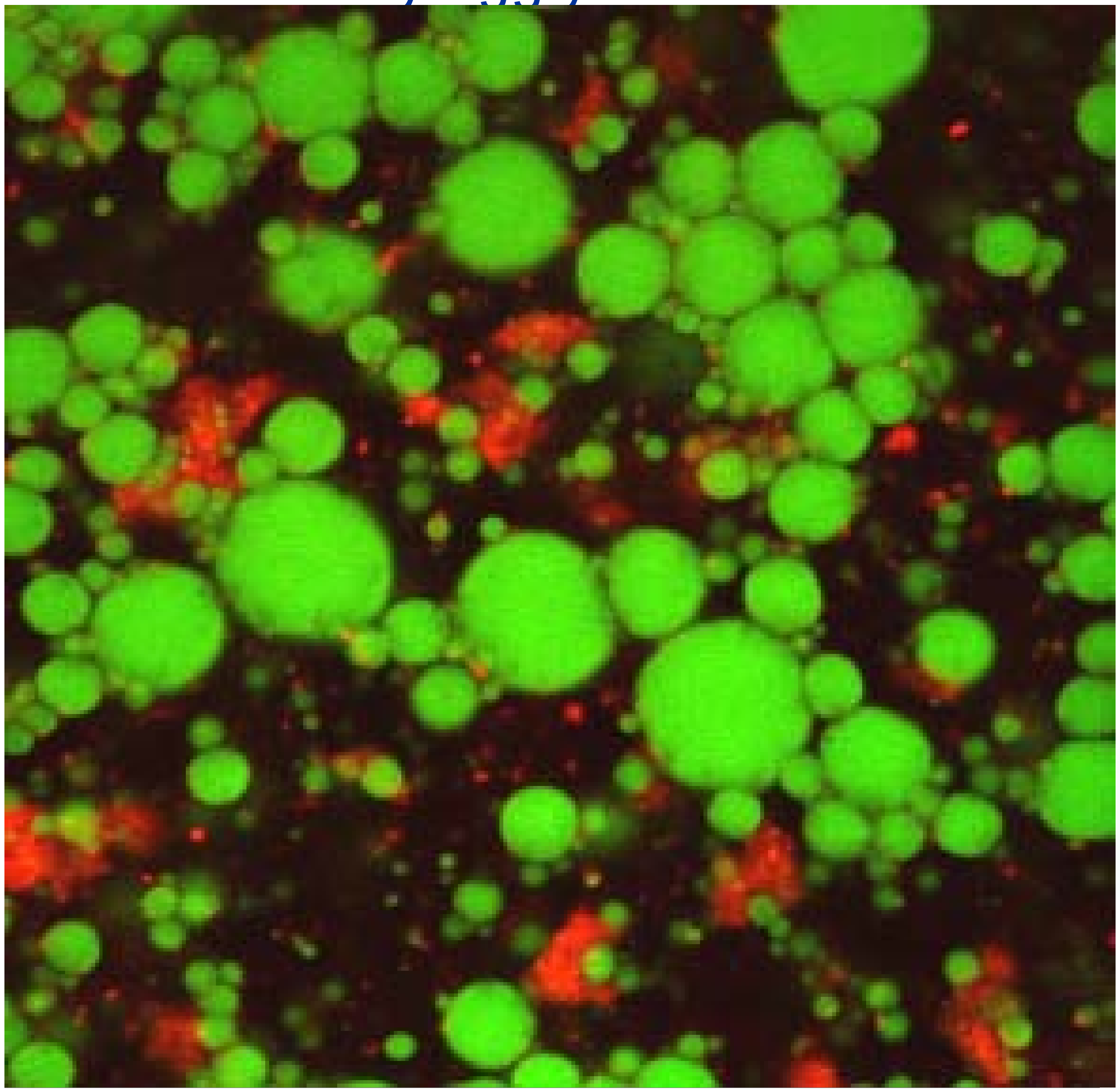
Application of emulsions in the food industry

Dressings

Real Mayonnaise

(Low oil) Mayonnaise

- Mayonnaise is oil in water emulsion, made from (healthy) oils stabilized by egg yolk and flavoured with salt, vinegar and mustard



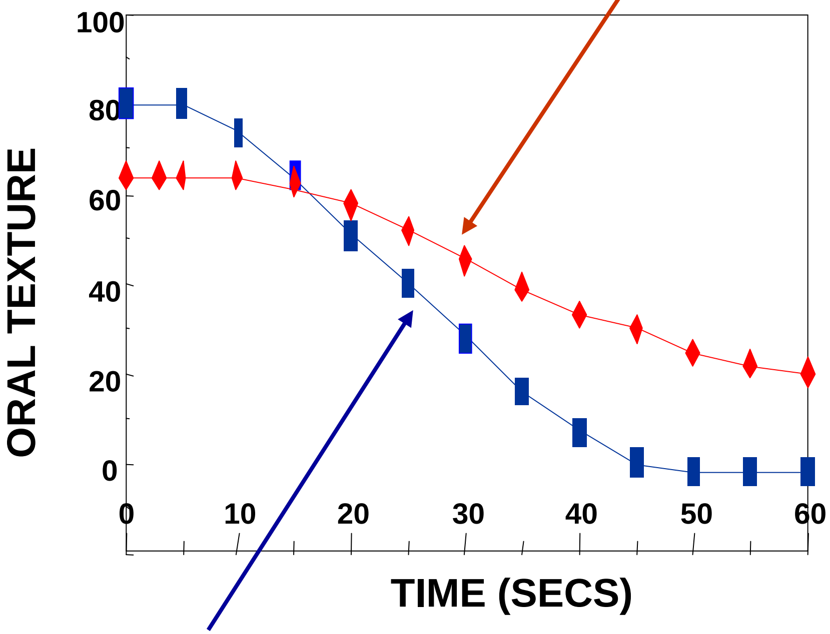
Full Oil Mayo: 70% Oil
Nutritional value per 100 ml:
695 kcal

Low Oil Light: 30% Oil
Nutritional value per 100 ml:
230 kcal

The real issue with low oil mayo

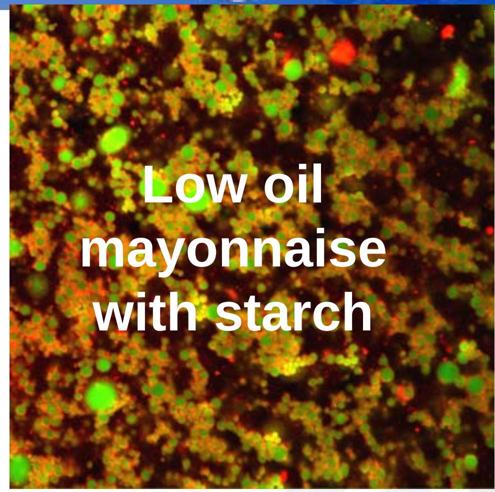
Low oil Mayonnaise

Slow oral breakdown



Full fat Mayonnaise

Fast oral breakdown



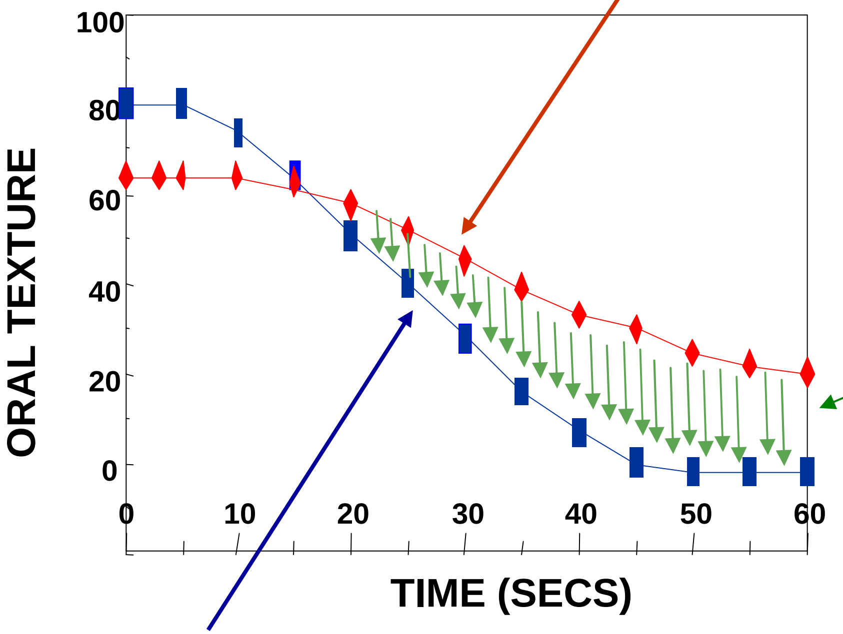
Aim:

structure a low-fat mayonnaise with a low-caloric and **natural structuring** agent while maintaining a fast oral breakdown

And the solution is ...

Low oil Mayonnaise

Slow oral breakdown



Full fat Mayonnaise

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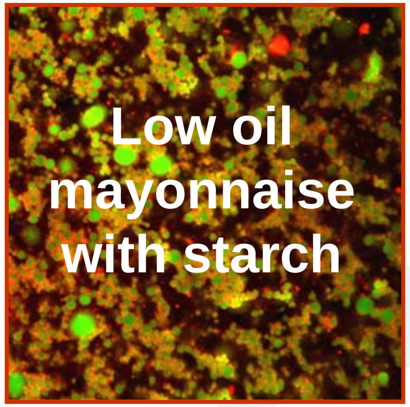
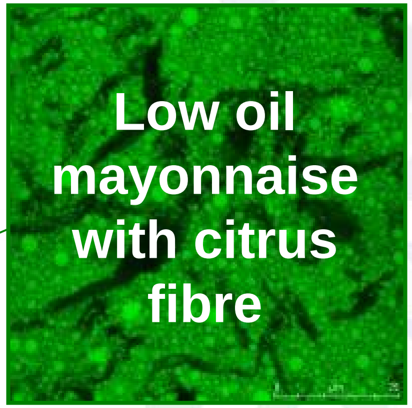




Processing

- Two primary processing routes used for real mayonnaise processing

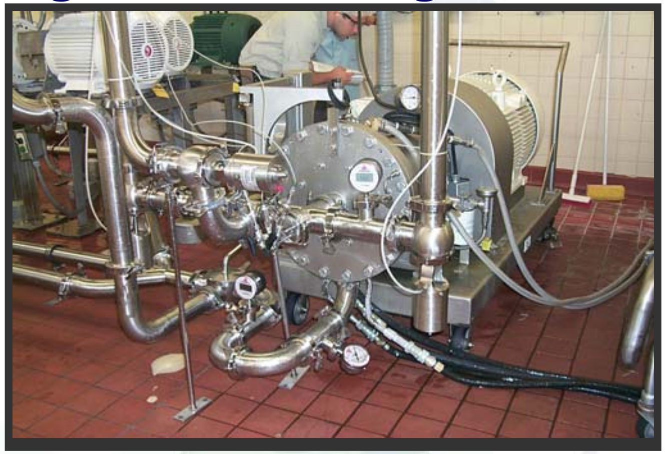
Route 1: Continuous Premix + Continuous Single Pass Milling

Vegetable Oil

Egg Phase

Water/ Vinegar

+

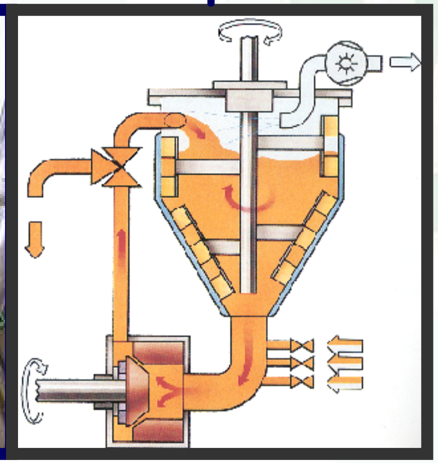


Route 2: Batch Premix and Multi-pass Milling

Vegetable Oil

Egg Phase

Water/ Vinegar



Continuous Processing - Premix

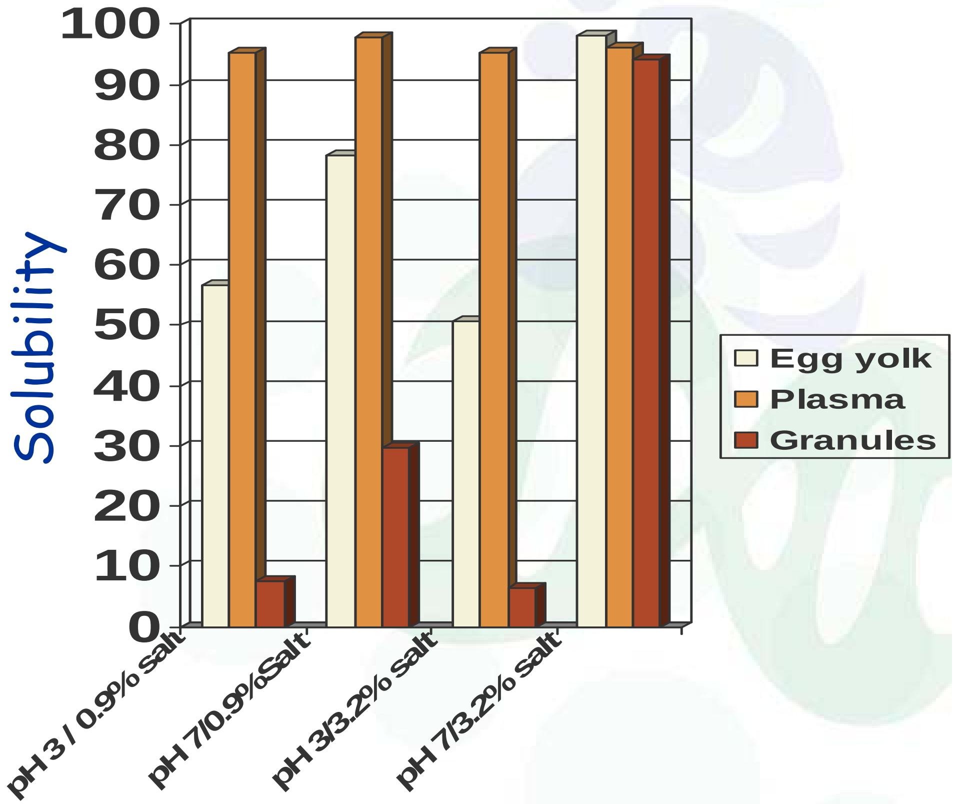
- The manufacturing process of mayonnaise typically requires formation of a pre-emulsion, or "premix"
- Premix is a coarse (~50 μm) densely packed dispersion of oil droplets stabilized by egg yolk protein - this provides a barrier to recoalescence; the other aqueous ingredients surround these droplets as the continuous phase
- The initial procedure used in batching the premix is critical to the kinetics of forming the correct (oil-in-water) emulsion
    - order of addition is critical: egg phase, oil and water vinegar
    - egg phase must have enough water to create the continuous phase.

Premix Residence Time

The longer the premix residence time, the softer and smoother the finished mayonnaise

Solubility of Yolk and yolk components in solution as a function of pH and salt levels

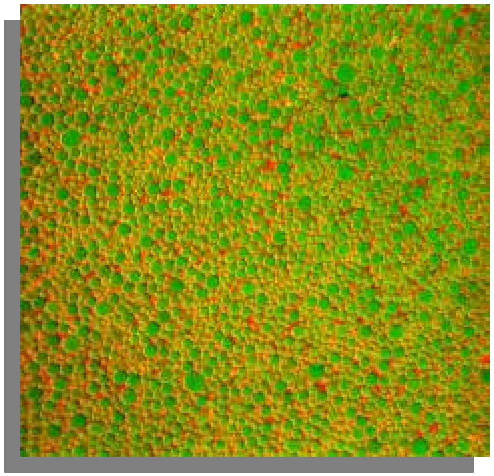
- **Egg yolk granule** phase solubility is very **sensitive** to both **salt** level and **pH**
  - long residence premix times result in low plummets - low pH causes granules to precipitate



Continuous Processing

Single-Pass Milling

- Final emulsification is accomplished in a milling equipment via the application of a high concentration of energy into a small volume of premix within the annular space of the mill
- The average oil droplet size is in the order of 2-8 μm depending on type of milling device
  - typical average residence times of product within the mill are in the order of 10 msec
  - typical average volumes of product within the mill are in the order of 10 cc



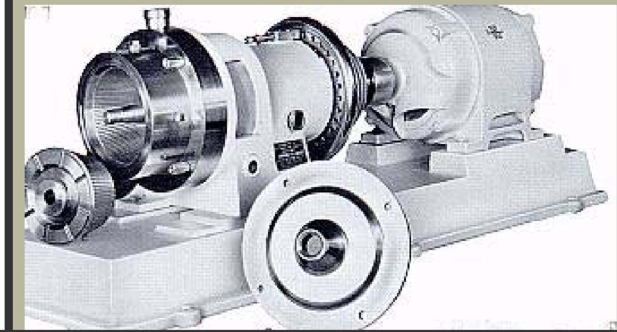
Continuous Processing

Single-Pass Milling

- Typical in-line milling equipment used for real mayonnaise

Charlotte® Colloid Mill Sanitary SD

- gap = 0.007 - 0.010” (key control parameter)
- 3500 - 3600 rpm (usually fixed)
- sizes: SD2, SD5, SD20, SD40
  - SD 40 has a 40 horse-power motor



Ross in-line high shear mixer X-series

- gap: 0.045 - 0.075” (usually fixed)
- 3400 - 6000 rpm (key control parameter)
- sizes: 3”, 6”, 9”, 12” and 15” (rotor diameter)
  - e.g 15” has 250 horse-power motor


Fryma Koruma Modular In-line Colloid Homogenizer (Romaco)



Margarine

Unilever Food and Health Research Institute

What is a margarine?

Margarine is a water-in-oil emulsion
It contains dairy powders, salt, flavours to get a good tasteand other ingredients for functionality

Fatlevels: 80/70% - 60% - 40% - (20) - (0)

Packaging: tubs and wrappers

Application: spreading, cooking, baking

History of margarines

- 1869 Mege Mourier Patent
- 1902 Hydrogenation
- 1930 Cooling drum
- 1950 Surface scraped heat exchanger
- 1955 Tubmargarines
- 1963/4 Becel/halvarines
- 1969 Melanges
- 1980 Protein halvarines
- 1989 Very low fat spreads
- 1993 Zero fat spreads
- 1998 Margarines with sterols

QUALITY of Margarines depends on

- Ingredients
- Blend
- Processing
- Packing
- Temperature
  - storage
  - distribution

Formulation and processing of margarine

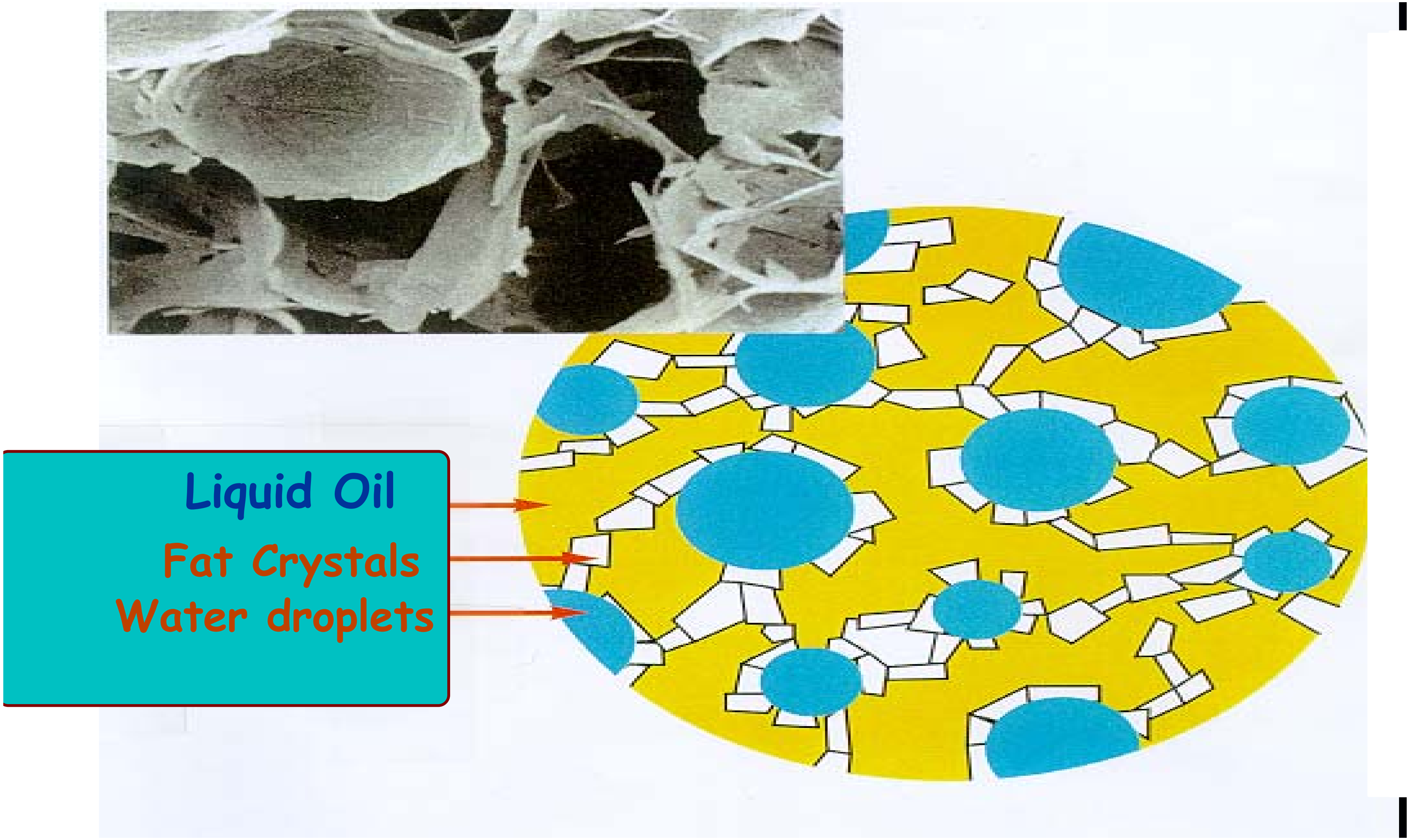
Ingredients
-oil
-**hardstock**
-water + salt
-(**thickener/gelling agents)**
- **proteins**
- **emulsifier**
- colour + flavours
- preservative+acid

Processing
- temperature profile
- shear applied

→ **Microstructure** →

Product quality
-**spreadability**
- **firmness**
- **stability**
-appearance attributes:yellow and glossy
-mouthfeel attributes:dissolvable, **melting,** powdery, salt, sour, fatty.

Structure of Margarine

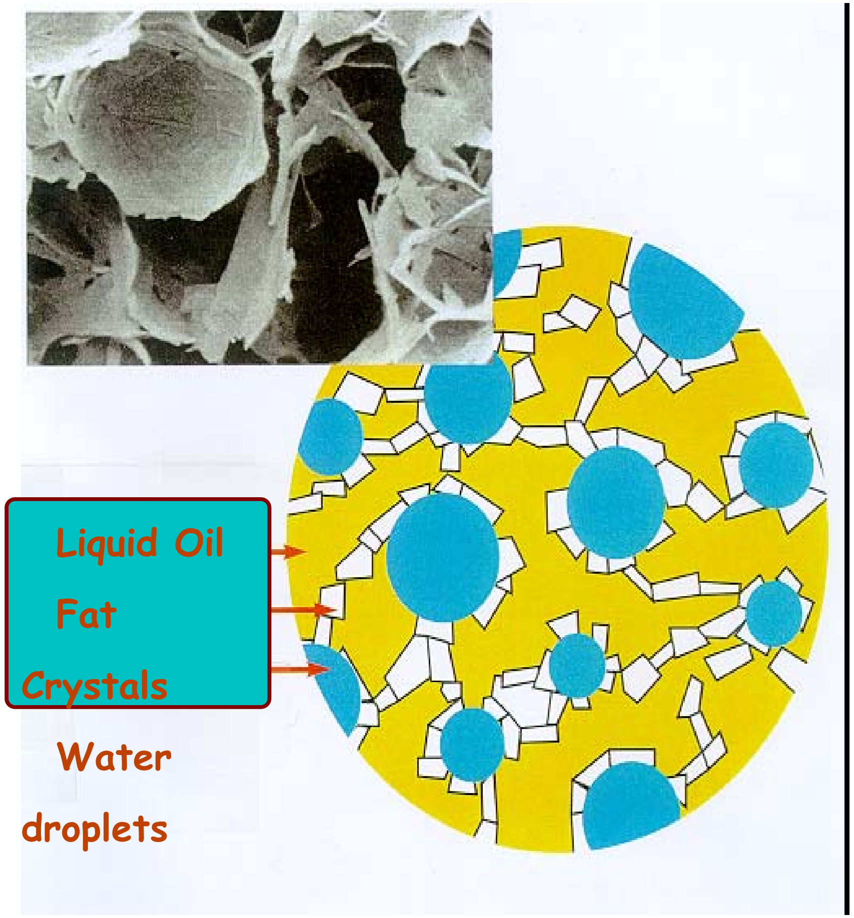


Manufacturing of margarines

Process tools

* Oil refining and modification
* Blending
* Ingredient preparation
* Emulsion preparation
* Margarine processing
* Packaging
* Storage/Distribution

Making Margarine
Structure of Margarine

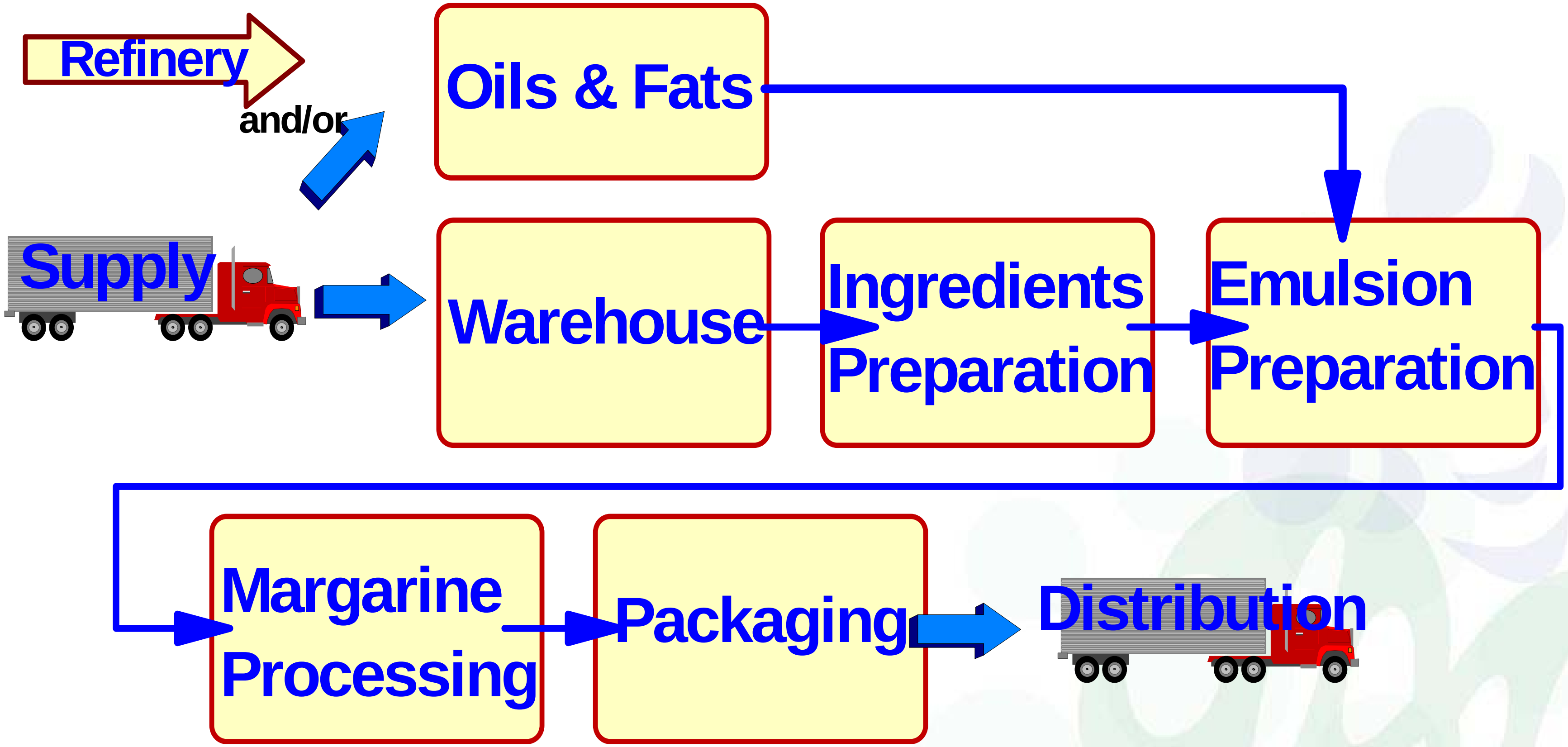


What To Do ?

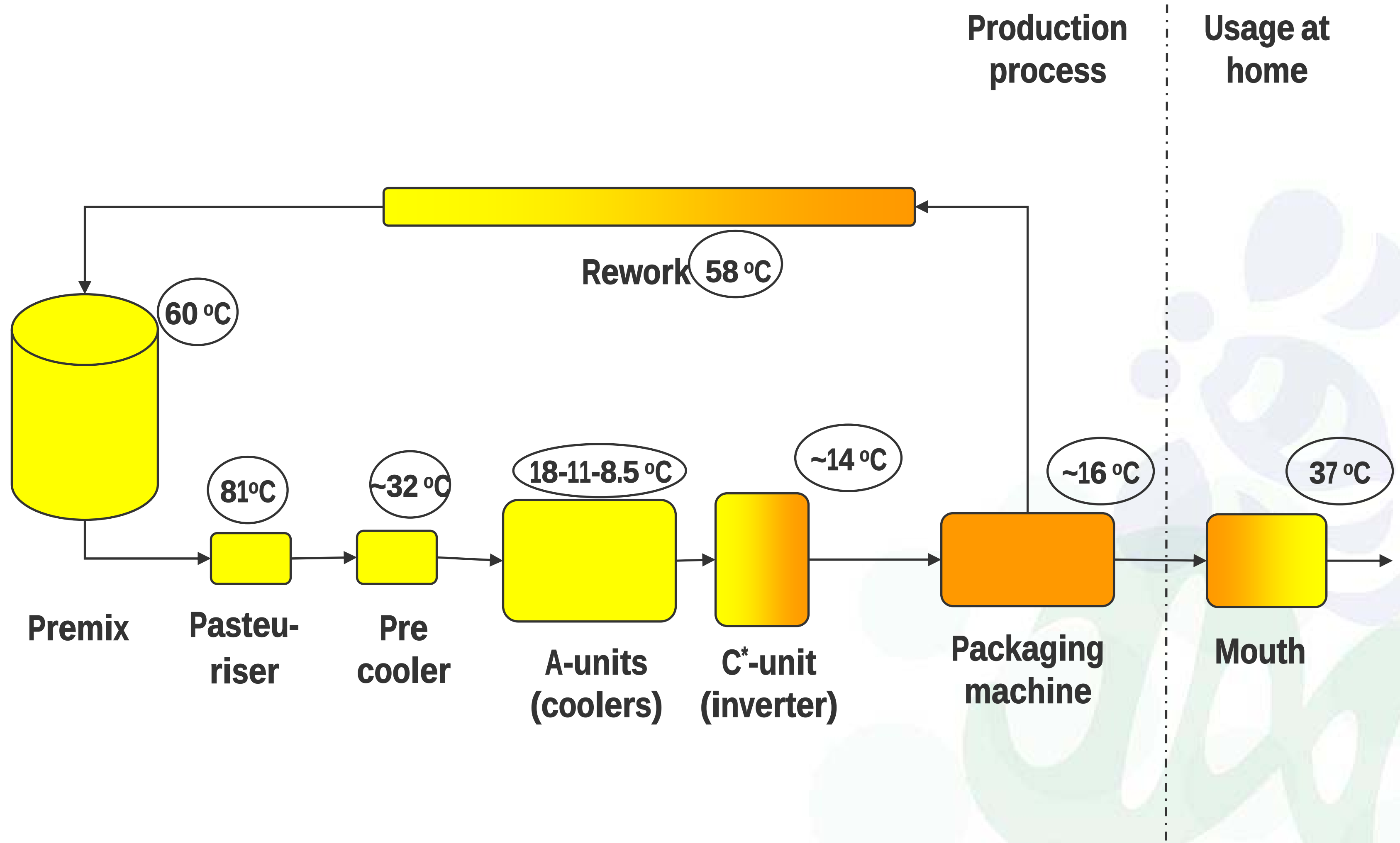
- Mix all Ingredients incl oils/fats
- Create Crystals
- Manipulate Crystals
- Create Water Droplets

Making Margarine

Basic Flow Diagram



Spreads production: process line



Function of A,B,C-unit

	A-unit	C-unit	B-unit
Function	Cooling	Crystallisation	Crystallisation in rest
	Crystallisation	Working	Working by sieve plates
	Emulsification		
Parameters	Cooling area	Residence time	Residence time
	Annular space	Rpm	Sieve plate(s)
	Rpm / knives	Pins (type/no)	Place
	Coolant temp.		

Strength of the crystal network

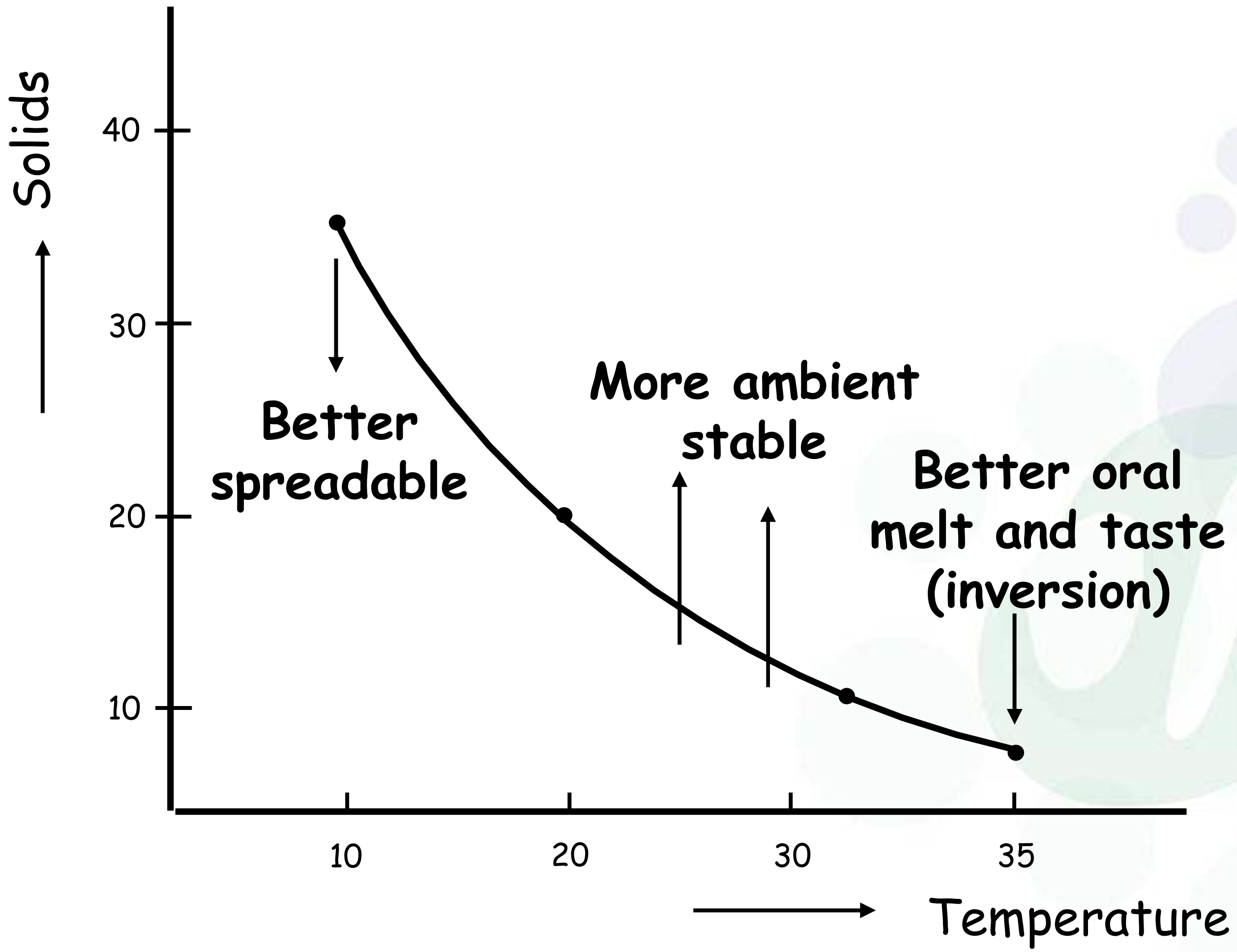
Depends on

- amount of crystals
  - temperature
  - SFC of the fatblend
- type of triglycerides
- working

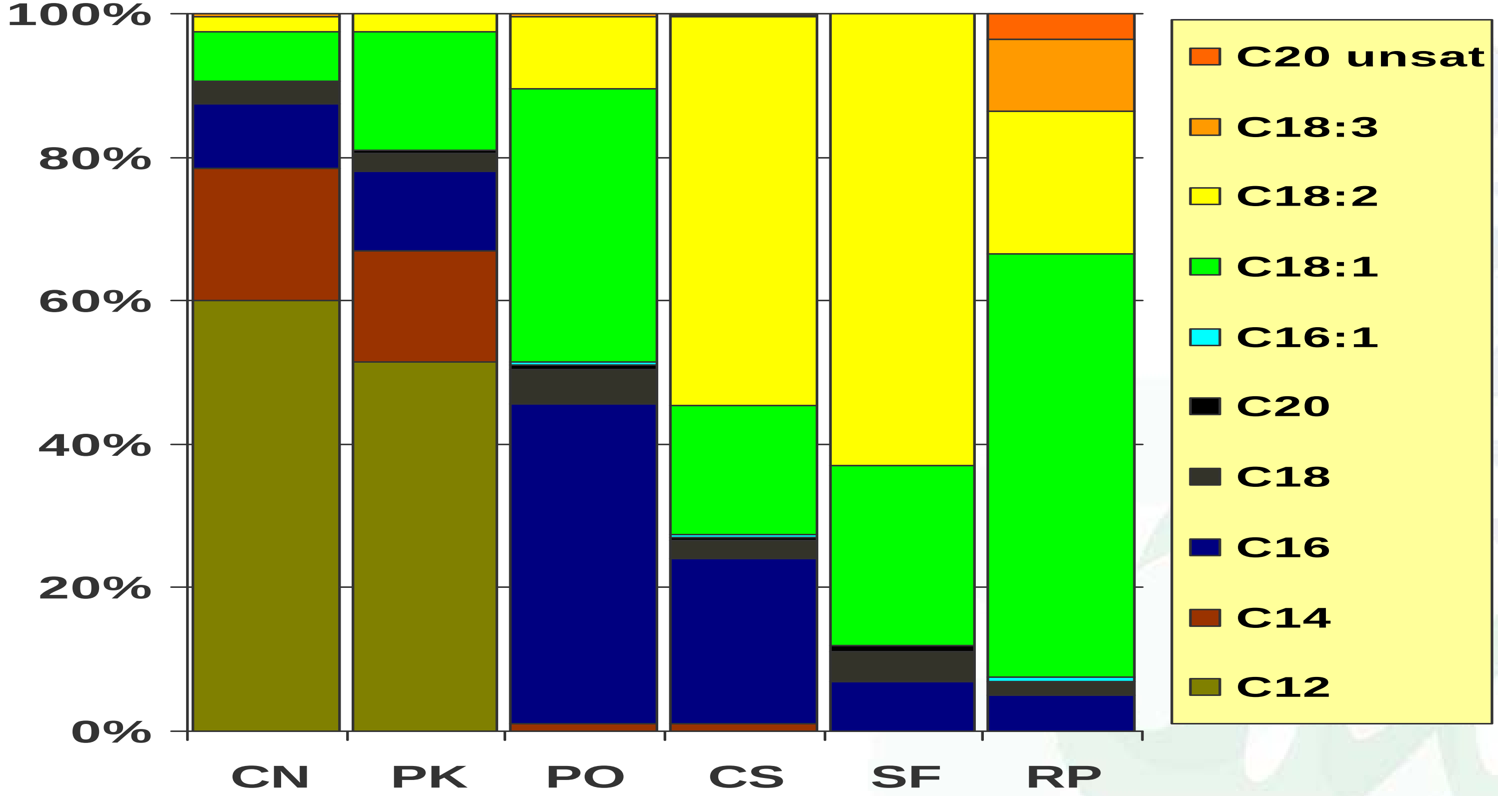
DIFFERENCE IN NETWORK

- at packing or filling on the line
- after storage or at use

How to influence consumer requirements by the solid fat content



Fatty acid distribution of major oils



SFC t control hardness and oral properties