Recombination theory and technology and Recombined UHT milk

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Outlines

- Background
- Recombining – theory
- Recombined UHT milk

Descriptions

- Natural milk - white fluid produced by animals and human
  - Oil-in-water emulsion produced by natural emulsification
- Recombined milk – white fluid produced by machanical means
  - Simulation of the natural milk by recombining individual constitutents of the natural milk
  - Requires emulsification

Recombined milk - definition

- FAO/WHO 1973 Codex milk committee
  - Milk product resulting from the combining of milk fat and milk solids-not-fat in one or more of their various forms with or without water. The combination must be made so as to re-establish the product's specified fat to solids-not-fat ratio and solids to water ratio.

Why recombining milk ?

- Unavailability of suffcient local milk
  - Poor infrastructure for procurement and distribution
  - Poor cattle breeds
- Disproportional production of milk around the world – need for export
- Desire to provide adequate human nutrition, especially for infants and young people
- Balancing seasonal demand for milk & milk products
- Desire to develop tailor-made, novel formulations

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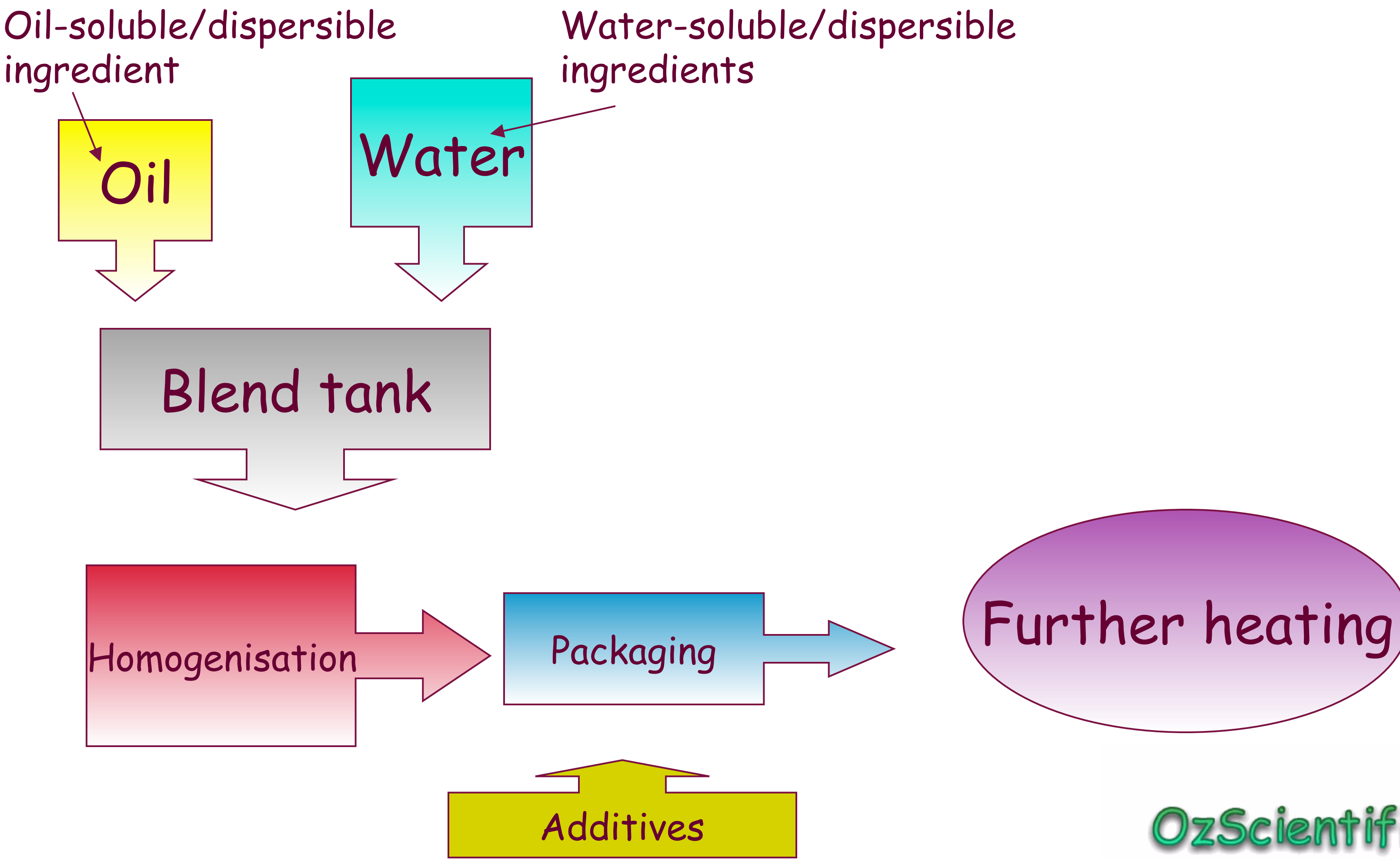
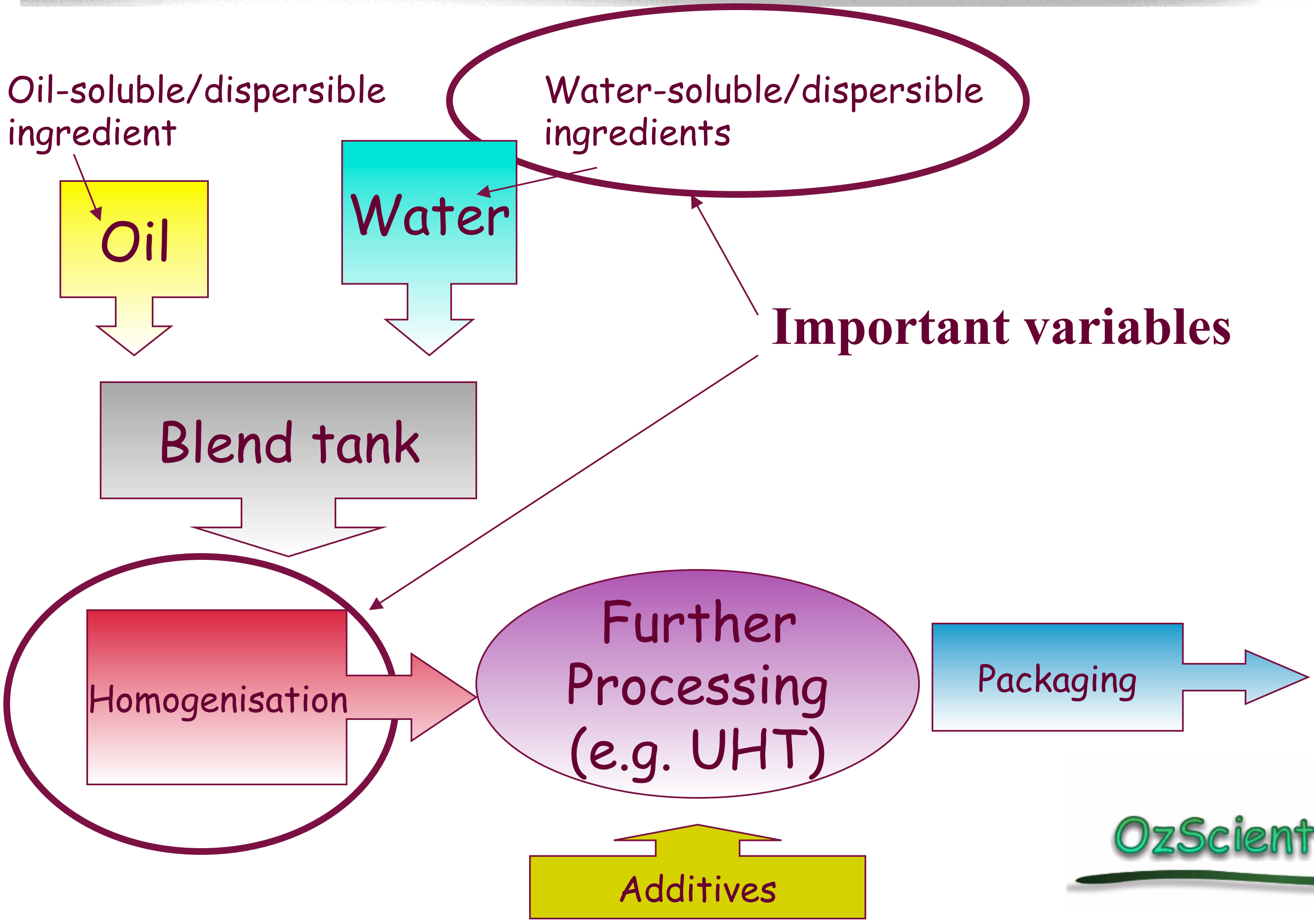
Per capita milk consumption

- Milk producing countries (i.e. New Zealand, Australia, Western Europe,North America)
  - 1000 mL/day
- Developing countries
  - 100 mL/day

Recombining - emulsion formation



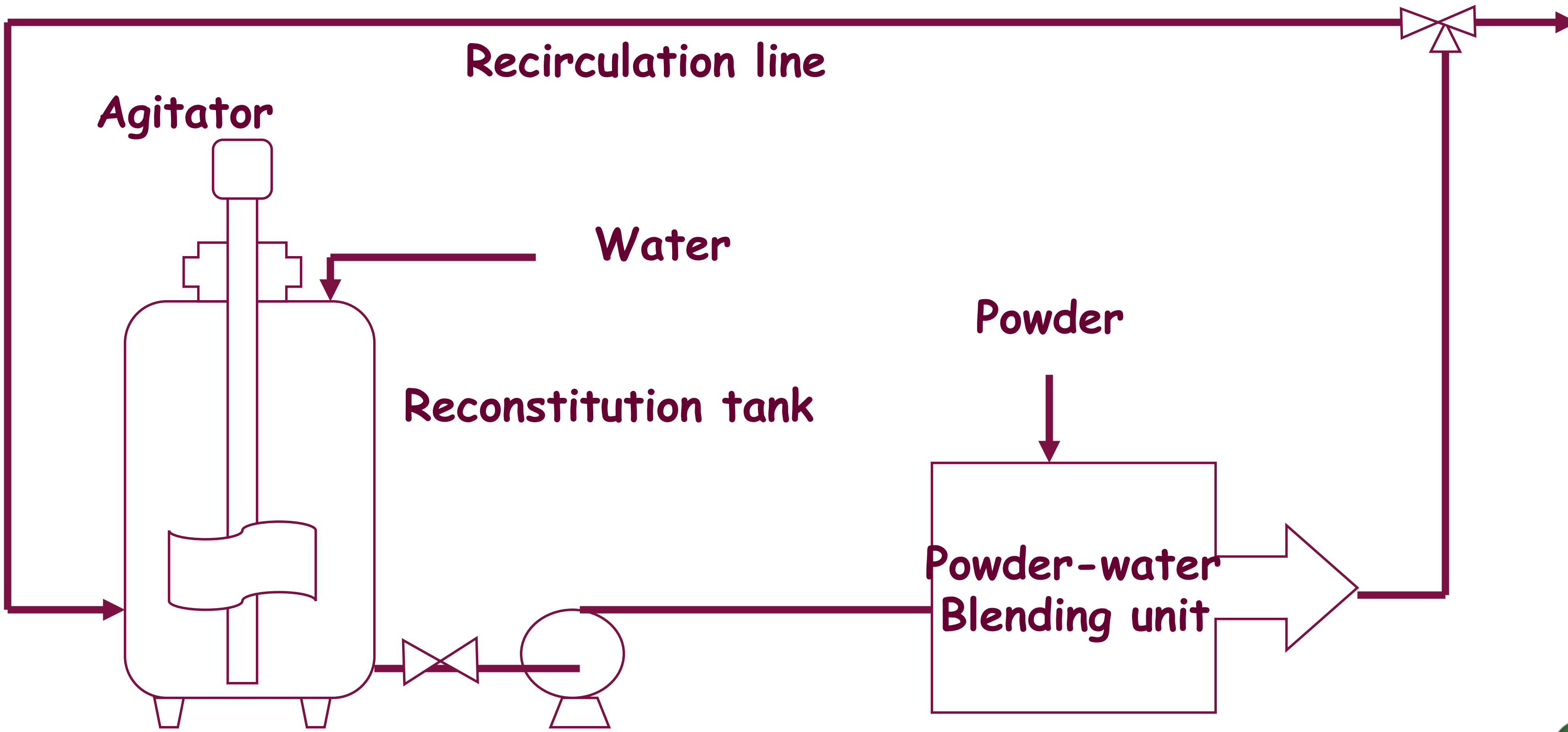
Recombining - emulsion formation



Reconstitution of milk powder

- Proper hydration and dispersion of milk powder essential
- Optimum conditions determined by the type of milk powder used

Simple setup for reconstitution of milk powder



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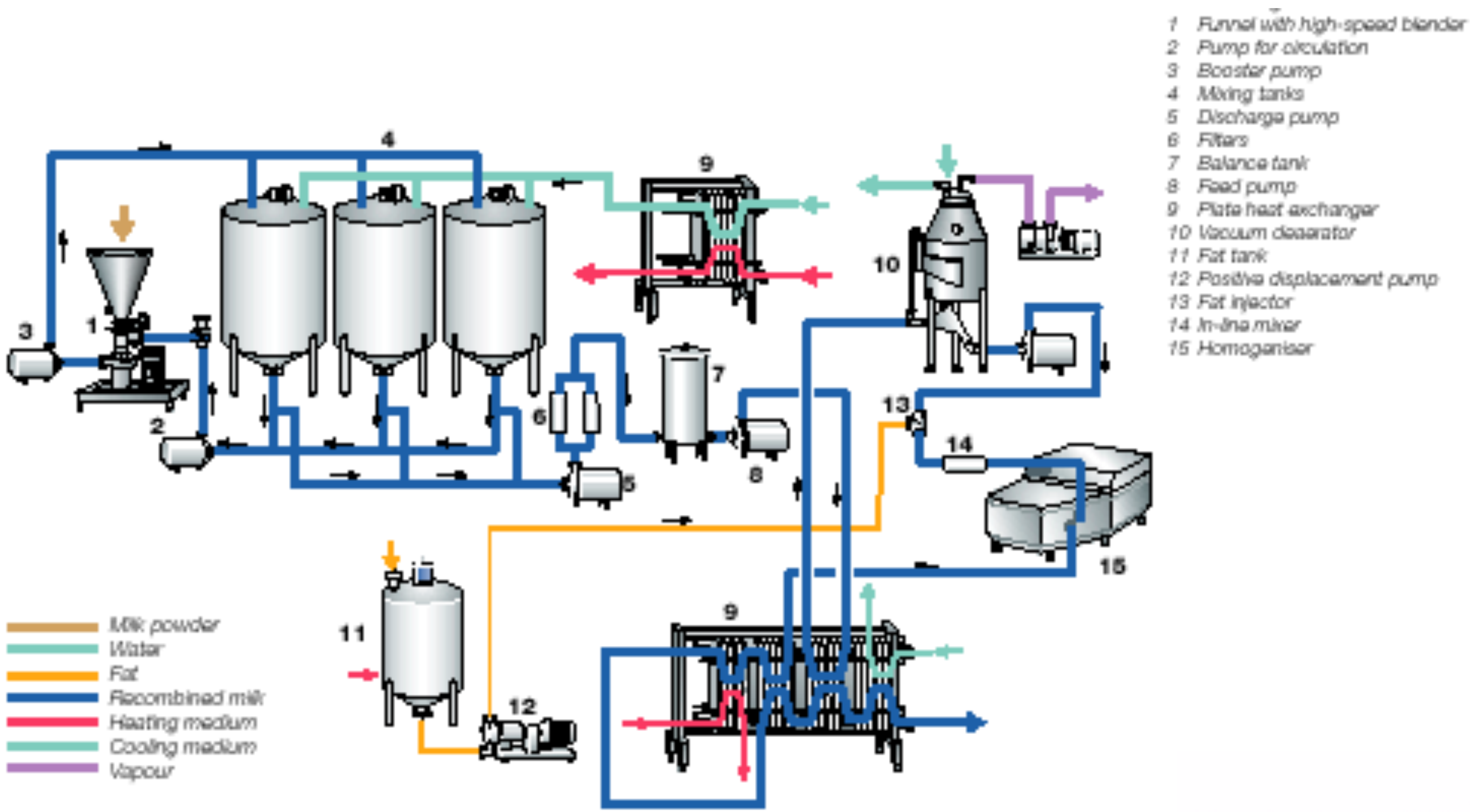
Recombination plat with in-line fat mixing



Dairy Processing Handbook, Tetrapak

Homogenisation

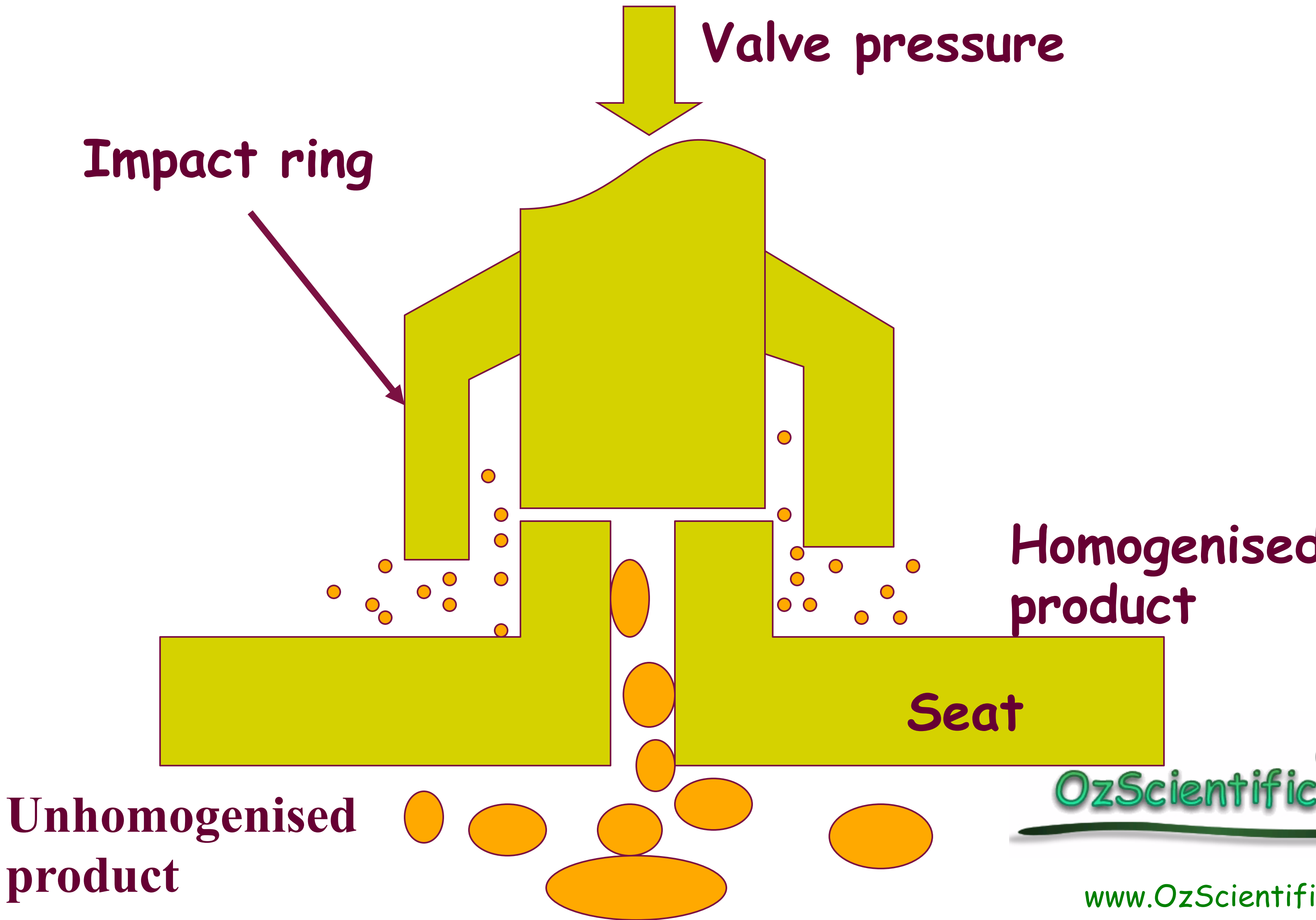
- Heart of the recombining process
- Leads to the formation of fat globules and migration of proteins to the fat globule surface layers
- High pressure valve homogenisers are most common

Homogenising devices

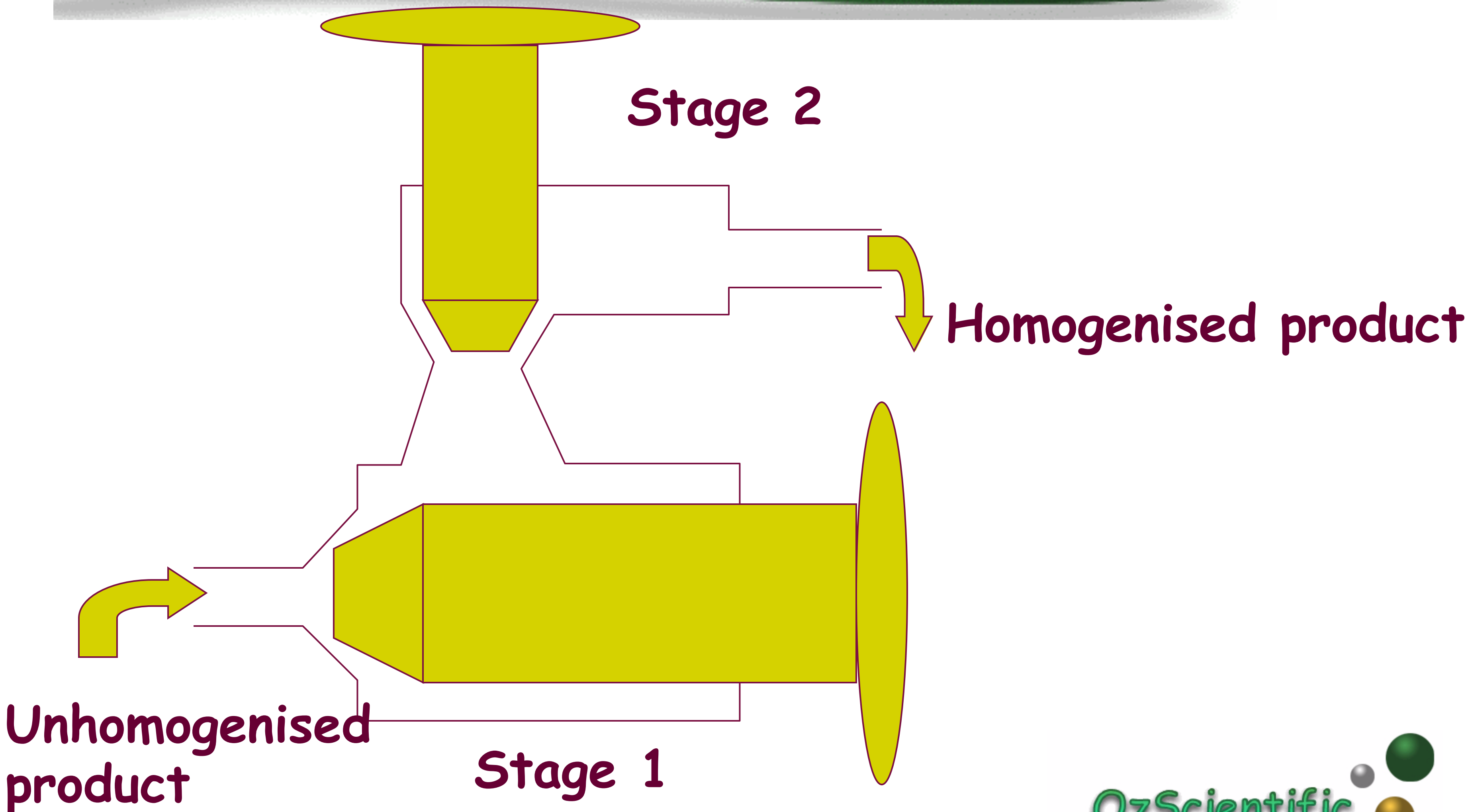
- High-speed blender
- Colloid mills
- **High-pressure valve homogeniser**
- Ultrasonic homogeniser
- Microfludiser
- Membrane-based homogeniser

Homogeniser

Homogenising valve



Two-stage homogeniser



Homogenisation efficiency

$$E_H = \frac{\Delta E_{min}}{\Delta E_{total}} \times 100$$

E_H – homogenisation efficiency

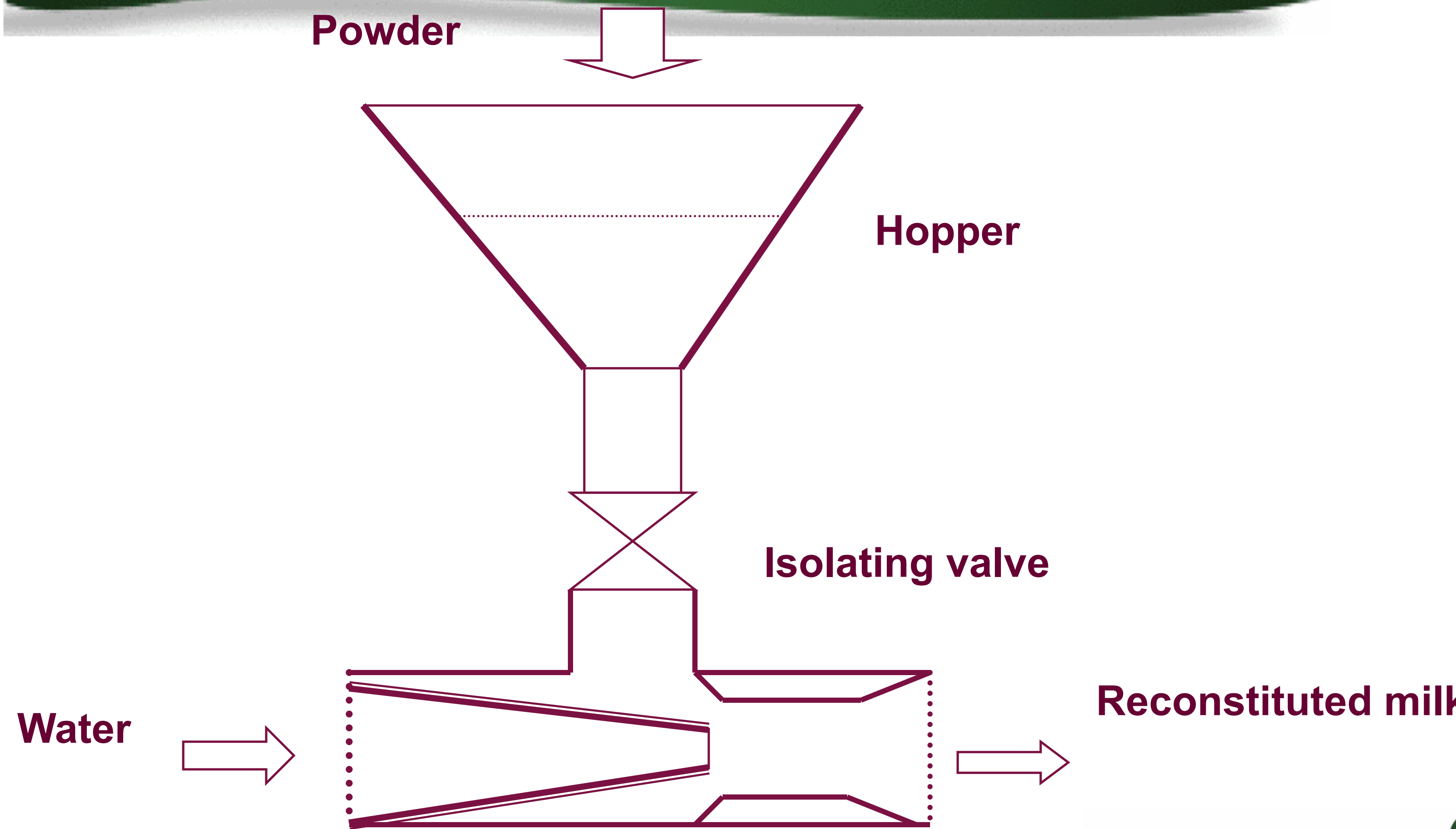
ΔE_{min} – Minimum amount of energy theoretically required to form emulsion = $\Delta A\gamma$ (interfacial area and interfacial tension)

ΔE_{total} – Actual amount of enegy expended during homogenisation

Types of powder-water blending systems

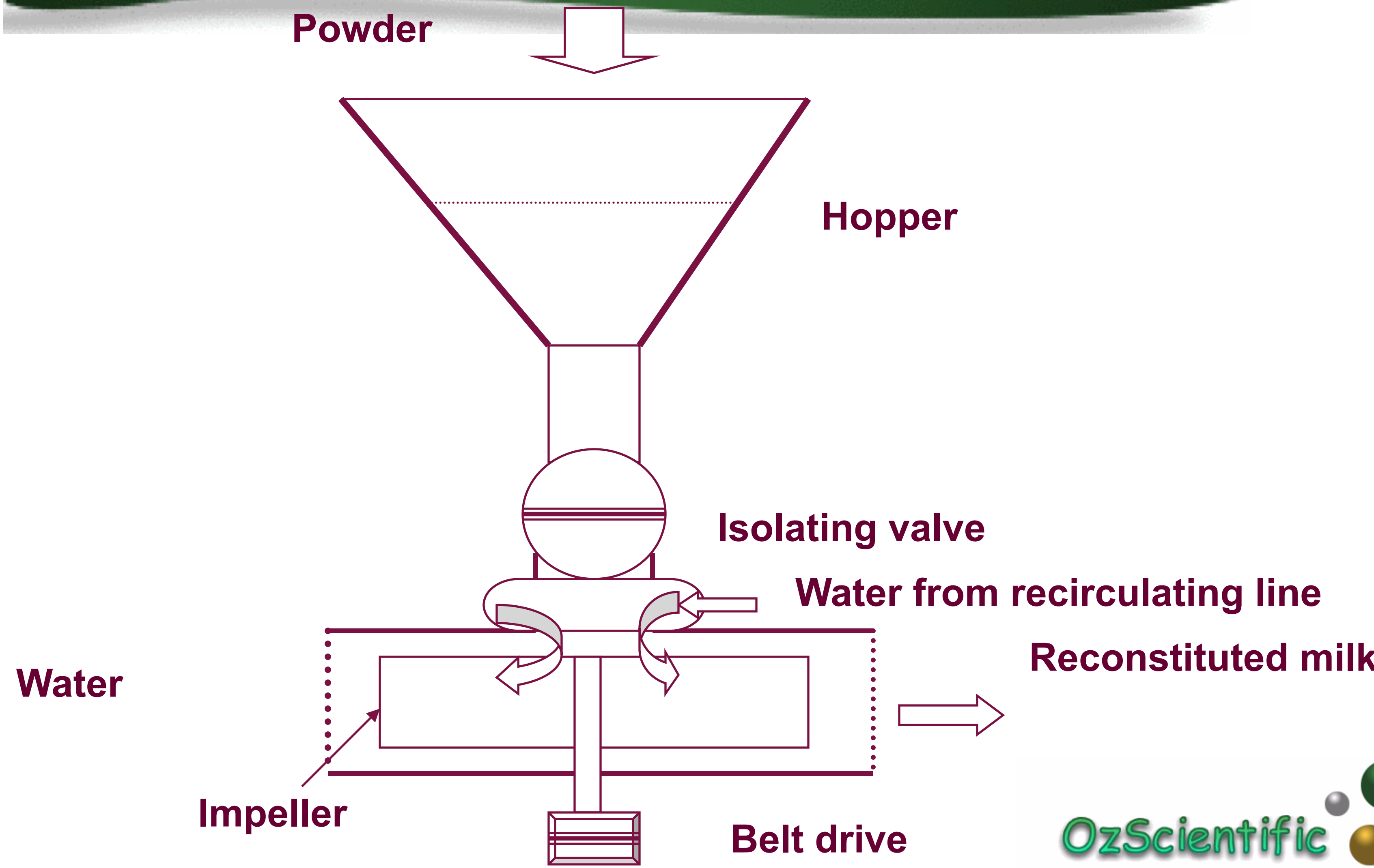
- Venturi blender
- Tri-blender
- Centrifugal blender

Venturi blender

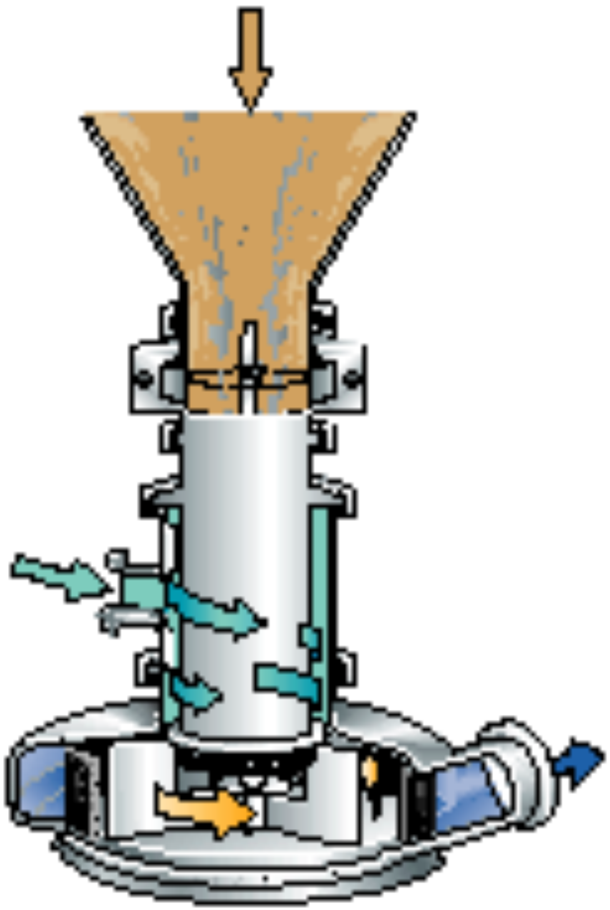


Tri-blender

Centrifugal blender



High-speed blender for reconstitution of milk powder



Dairy Processing Handbook, Tetra Pak

Ingredients in recombined milk

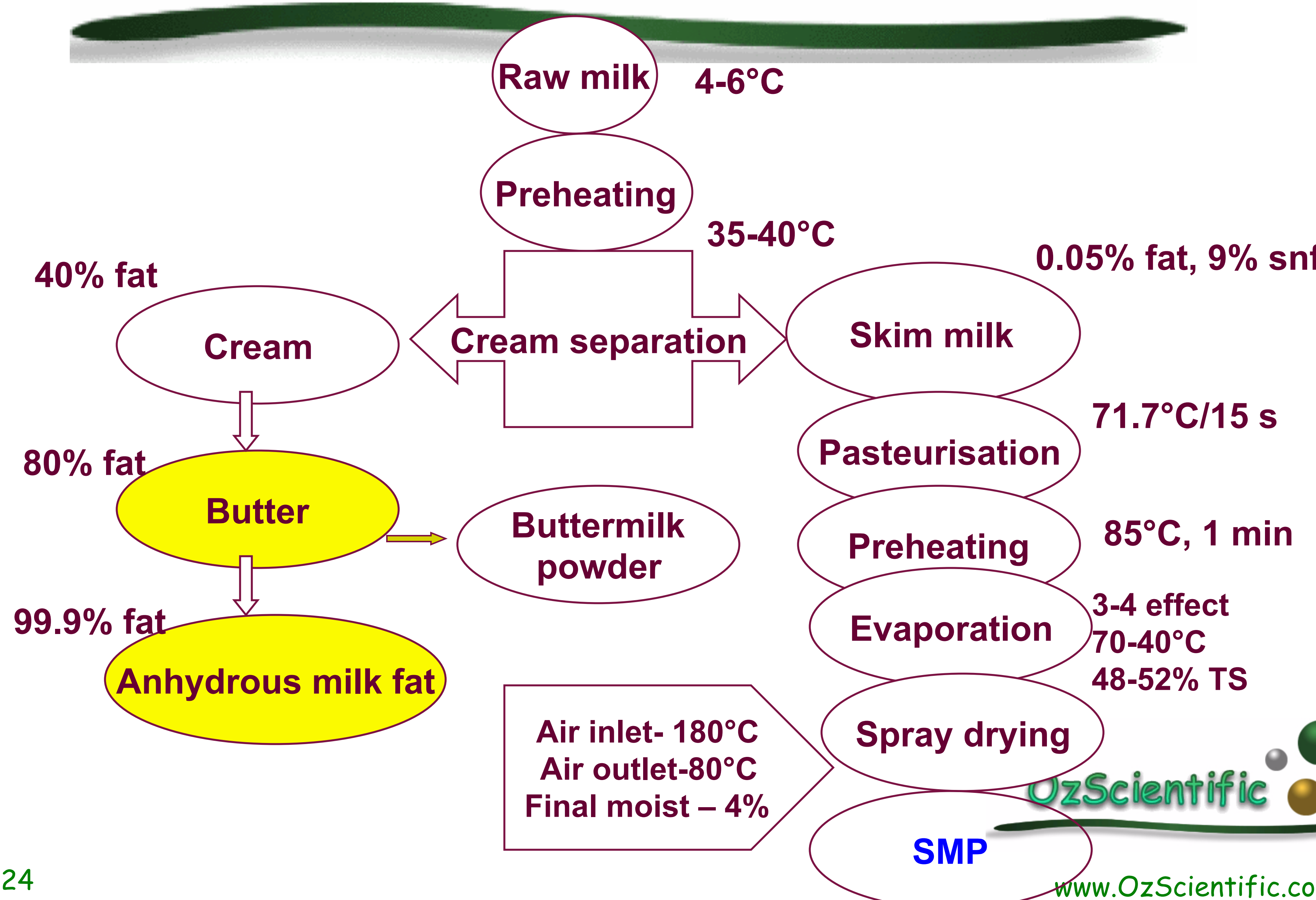
Basic ingredients

- Skim milk powder
- Anhydrous milk fat
- Water

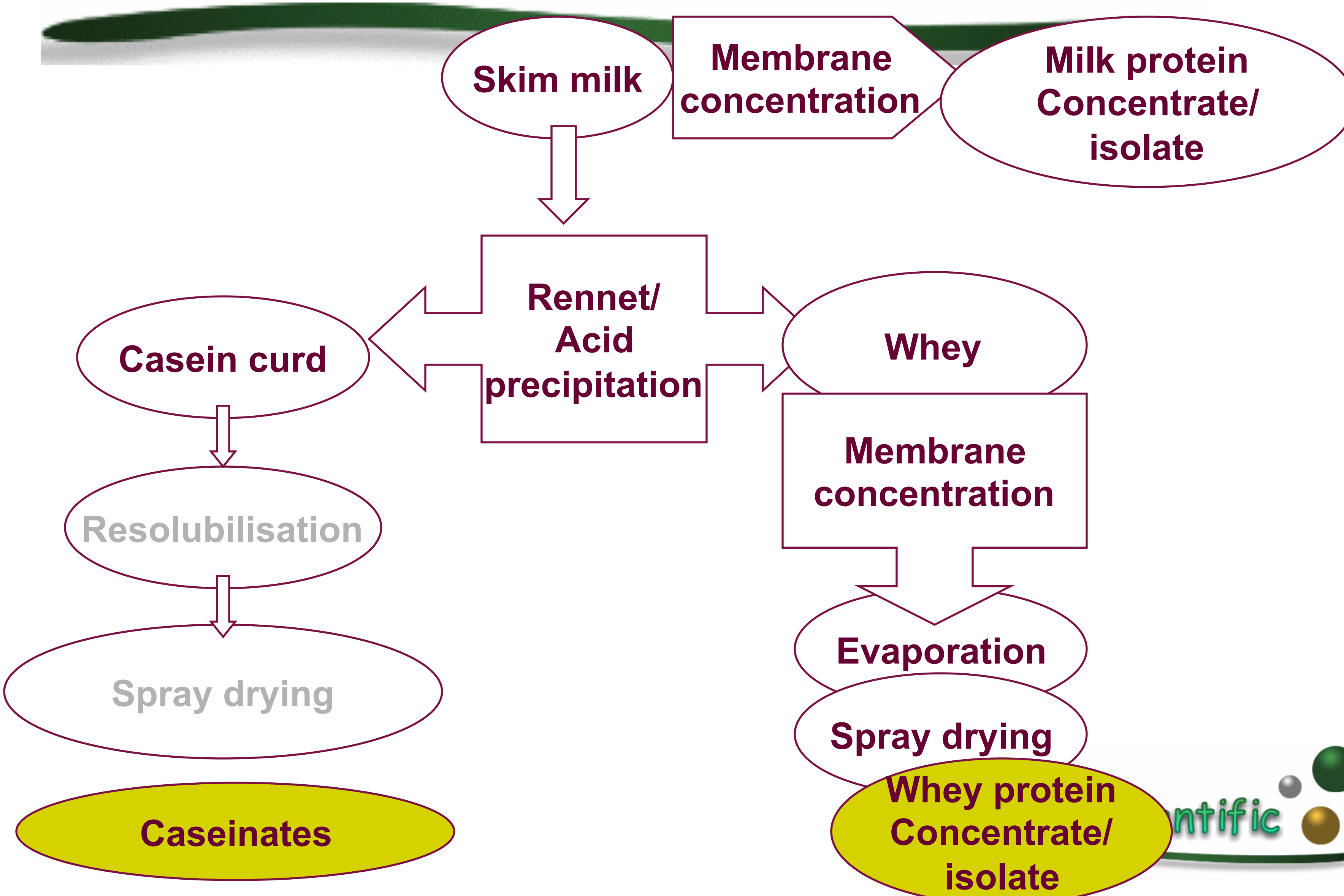
Other ingredients

- Whole milk powder
- Butter milk powder
- Milk protein concentrate/isolate
- Caseinate
- Whey protein concentrate/isolate
- Lactose
- Emulsifiers & stabilisers

Manufacture of SMP, AMF & BMP



Manufacture of milk protein concentrates



Selective Chemical Composition of Milk Powders

Attribute	SMP	WMP	BMP
Moisture (%)	4.0	4.0	4.0
Fat, (%)	max 1.0	min 26	5.0
Total protein (N*6.38, %)	35	28	35
Lactose (%)	50	38	48
Calcium (%)	1.2	1.2	
Potassium (%)	1.6	1.2	
Phosphorus (%)	1.0	1.0	

Selective Chemical Composition and Physico-Chemical Attributes of Milk Protein Products

Attribute	Milk protein concentrate	Sodium caseinate	Whey protein concentrate
Moisture (%)	4.0	4.0	4.0
Total protein (N*6.38, %)	82.5	92	83.5
Casein (%)	66.0	92.0	0
Whey protein (%)	16.5	0	83.5
Calcium (%)	2.20	0.01	0.06
Potassium (%)	0.01	0.005	0.05
Phosphorus (%)	1.40	0.80	0.18
Protein state	Casein micelles, soluble whey protein	Soluble aggregates of casein	Soluble whey proteins

Classification of skim milk powder

SMP type	Extra low-heat	Low-heat	Medium-heat	Medium-high-heat	High-heat
WPNI	-	>6	5.9-4.5	4.4-1.5	<1.4

Caution: Such classifications can be misleading

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Emulsion formation, structure and stability

- During homogenisation, fat globules with sub-micron size are formed
- Milk proteins migrate to the newly formed fat globule surfaces
- Capability to form a stable emulsion is determined by the ability of the protein to unfold at the fat-water interface
- Protein load affects the stability of emulsion towards heating and storage

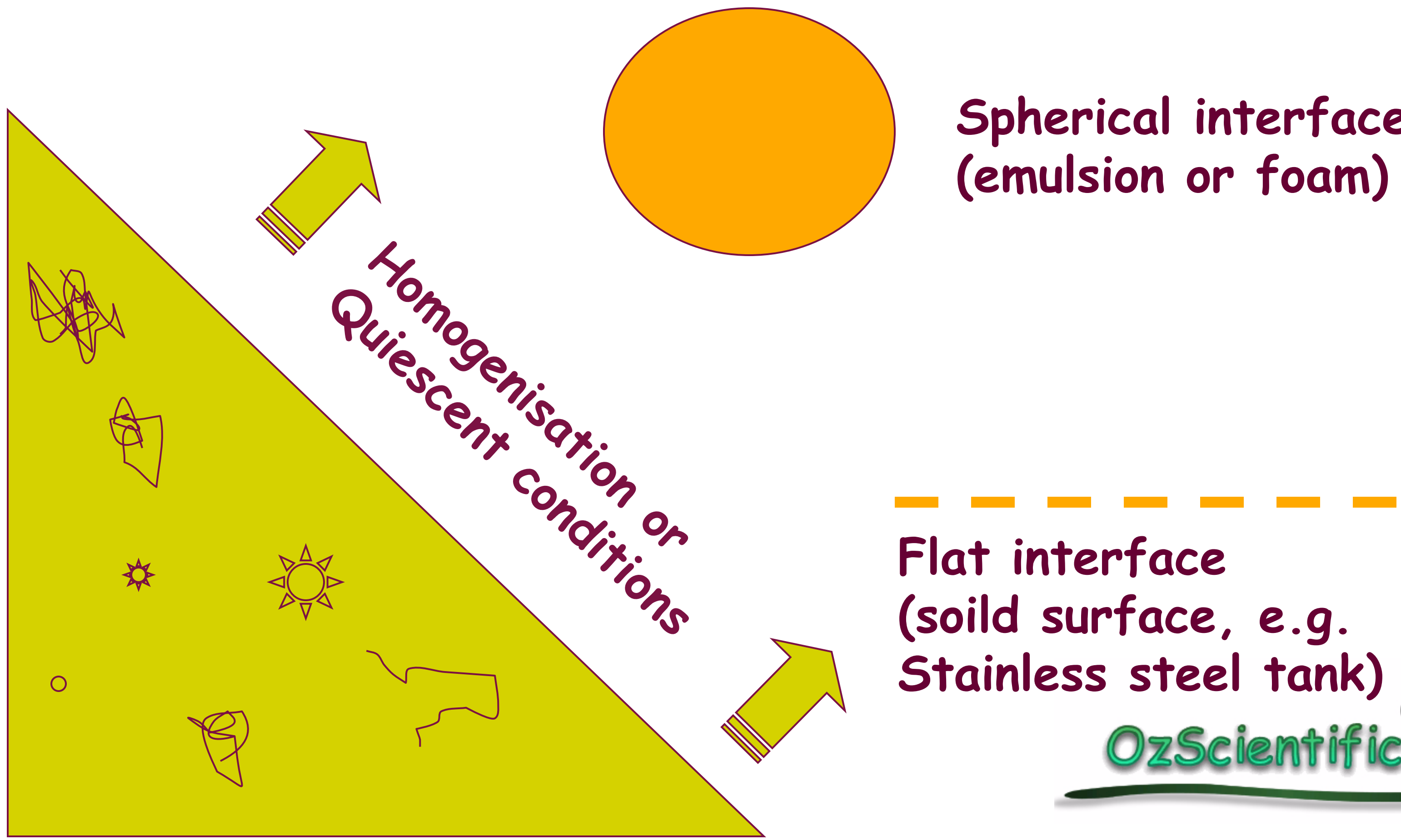
Milk protein – the functional ingredient in milk powder and protein concentrate

- Proteins are surface active due to their amphiphilic nature
- Aggregation state of protein affects the stable emulsion formation
- Two major proteins: casein and whey proteins

Physico-chemical properties of milk proteins

CASEIN	WHEY PROTEIN
•Strong hydrophobic regions •Low cysteine •High ester phosphates •Little or no secondary structure •Unstable in acidic conditions •Micelles in native form •Random coil in dissociated form	•Balance in hydrophobic and hydrophilic residues •Contains cysteine and cystine •Globular, much helical •No ester phosphate •Easily heat denatured •Stable in mild acidic conditions •Present as soluble aggregates (<10 nm)

Protein adsorption



Protein load

$$\Gamma = \frac{\text{Protein at the oil droplet surface (mg)}}{\text{Total droplet surface area } (m^2)}$$

Protein load at recombined milk oil-water interface

Protein	Protein load (mg/m^2)
α_s-Casein	3-4.2
β-Casein	1-1.75
κ-Casein	4.2
Casein micelle	20
Sodium caseinate	2.2-2.6
Skim milk powder	10-23
β-Lactoglobulin	1.7

Factors affecting protein load

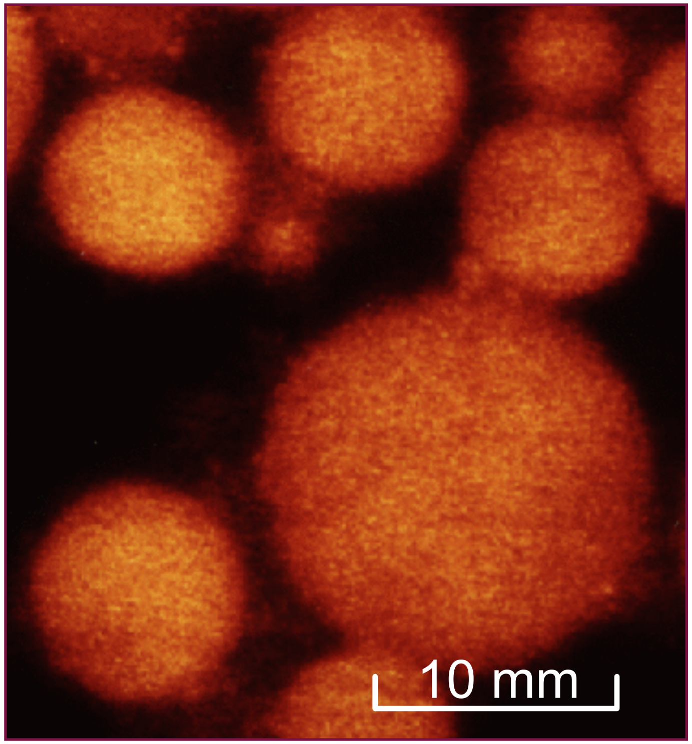
- Volume of oil
- Protein concentration
- Homogenisation temperature
- Homogenisation pressure
- Aggregation state of protein
- Pre-treatment of protein, i.e. Hydrolysis or cross-linking

Types of protein adsorption

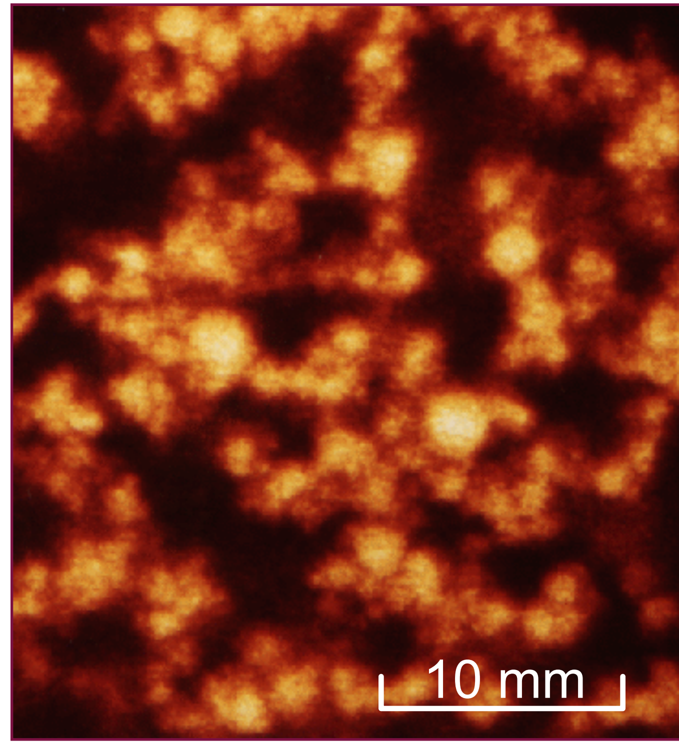
- Reversible and irreversible adsorption
- Competitive adsorption

Fat globules in recombined milk

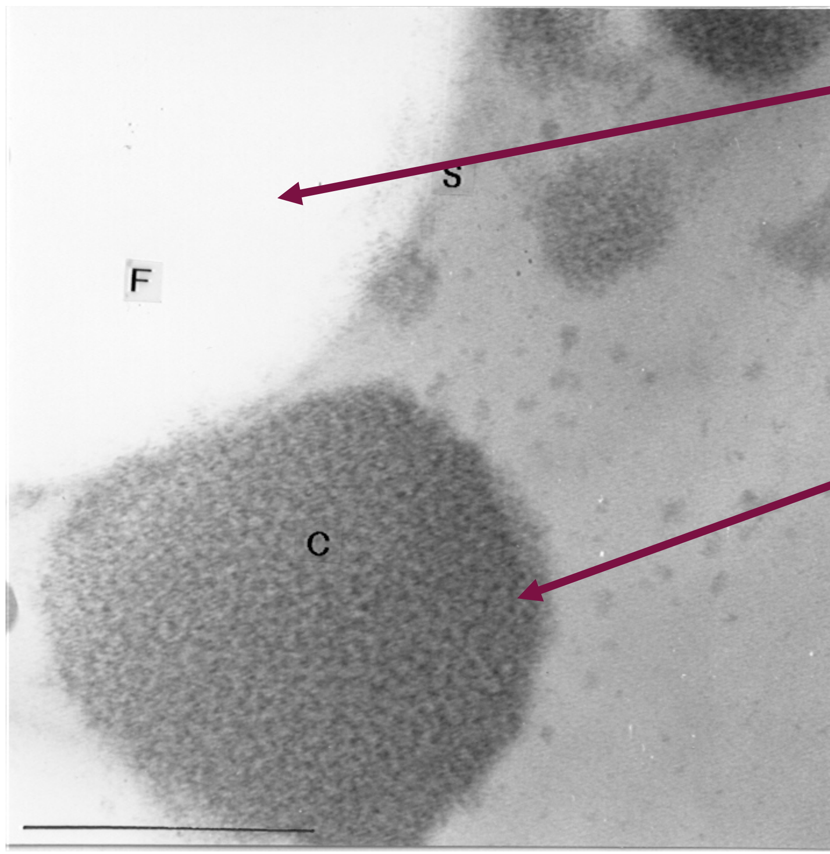
Natural milk



Recombined
(homogenized milk)



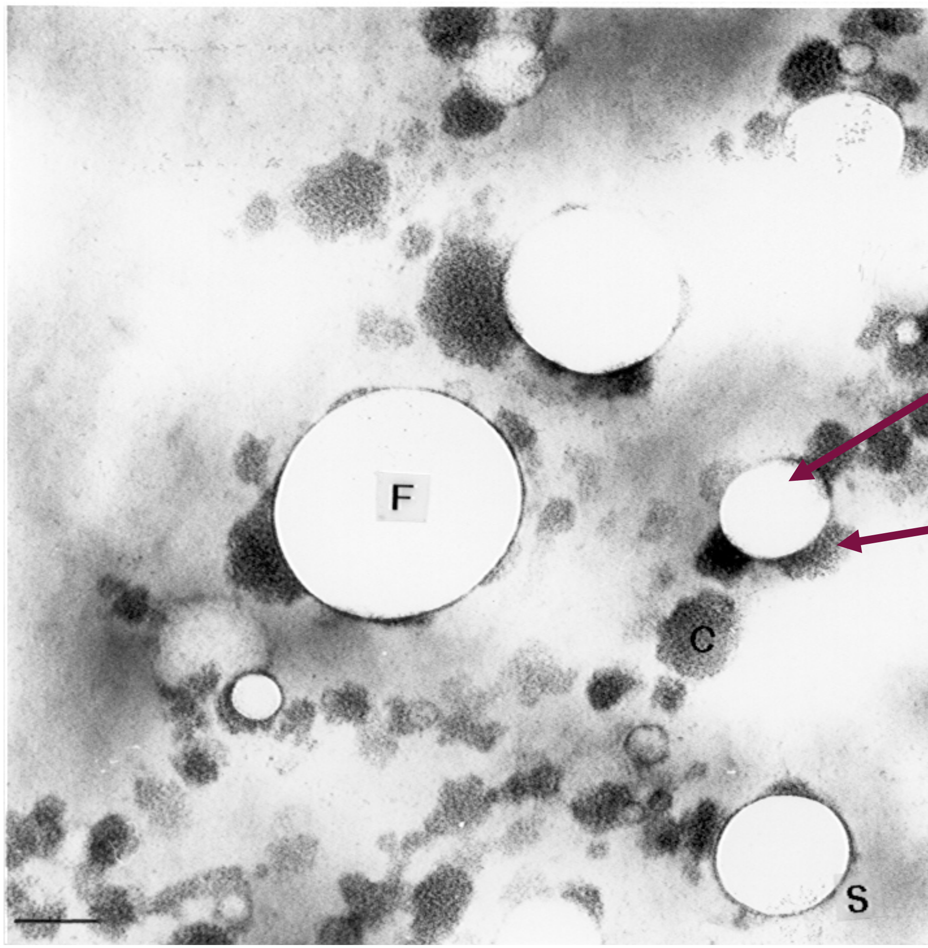
Recombined milk - casein micelles and whey proteins at oil-water interface



200 nm

Sharma (1993)

TEM of recombined milk



Sharma (1993)

Emulsion destabilisation in recombined milk

- Thermodynamically unstable
- Mechanisms of destabilisation: aggregation, flocculation, coalescence and creaming

Colloidal forces important for emulsion stability

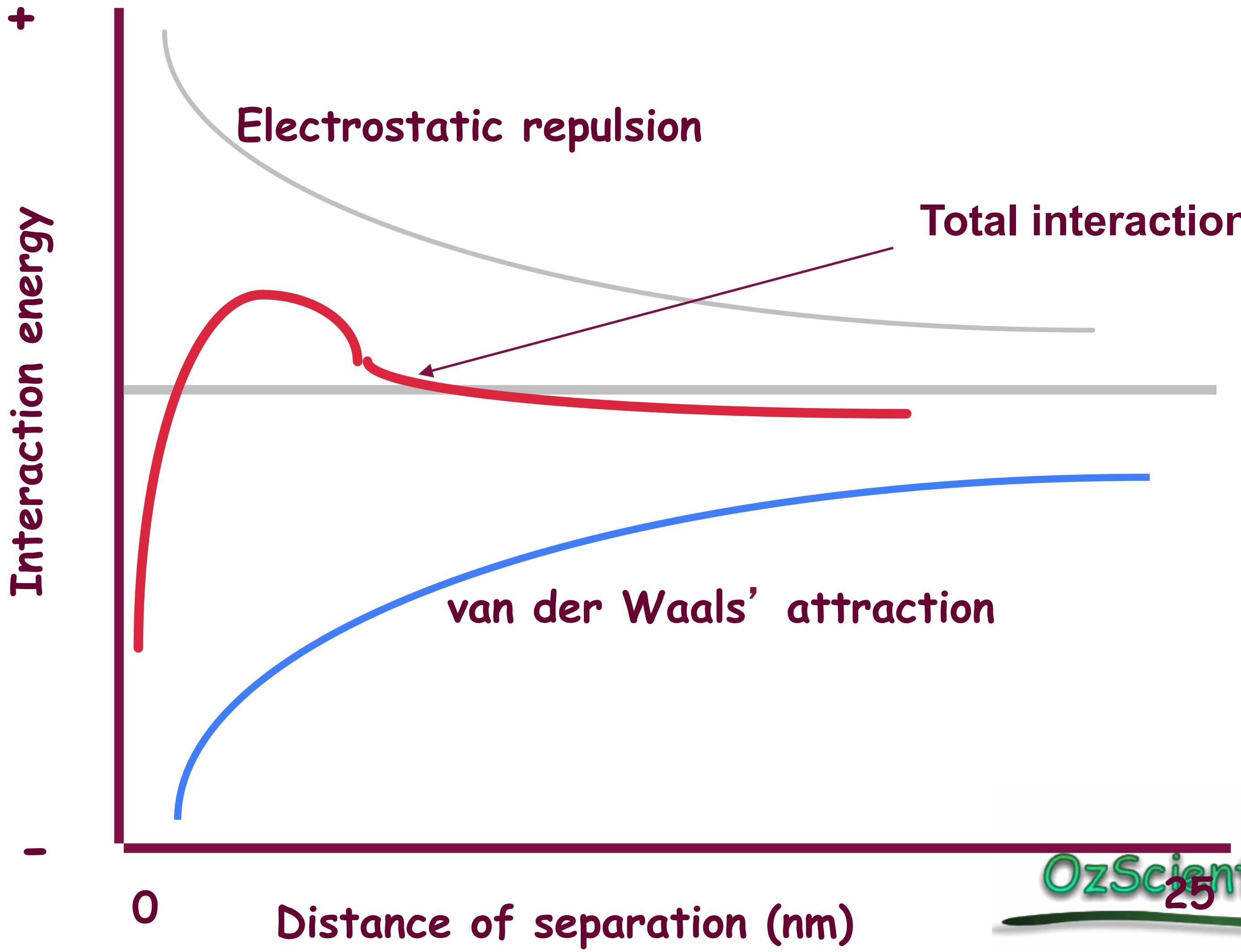
Type of force	Character	Origin	Influenced by
van der Waals	Attraction	Permanent & fluctuating dipoles	Refractive index Dielectric constant
Electrostatic	Repulsion	Surface charge	Ionic strength, pH
Steric	Repulsion	Adsorbed polymers	Polymer coverage & solubility
Bridging	Attraction	Adsorbed polymers	Polymer coverage
Depletion	Attraction	Non-adsorbed polymers Micelles	Molecular weight Polymer polydispersity
Polyelectrolytes	Repulsion or attraction	Adsorbed polyelectrolytes	Ionic strength, polyelectrolyte coverage

Colloidal forces important for emulsion stability

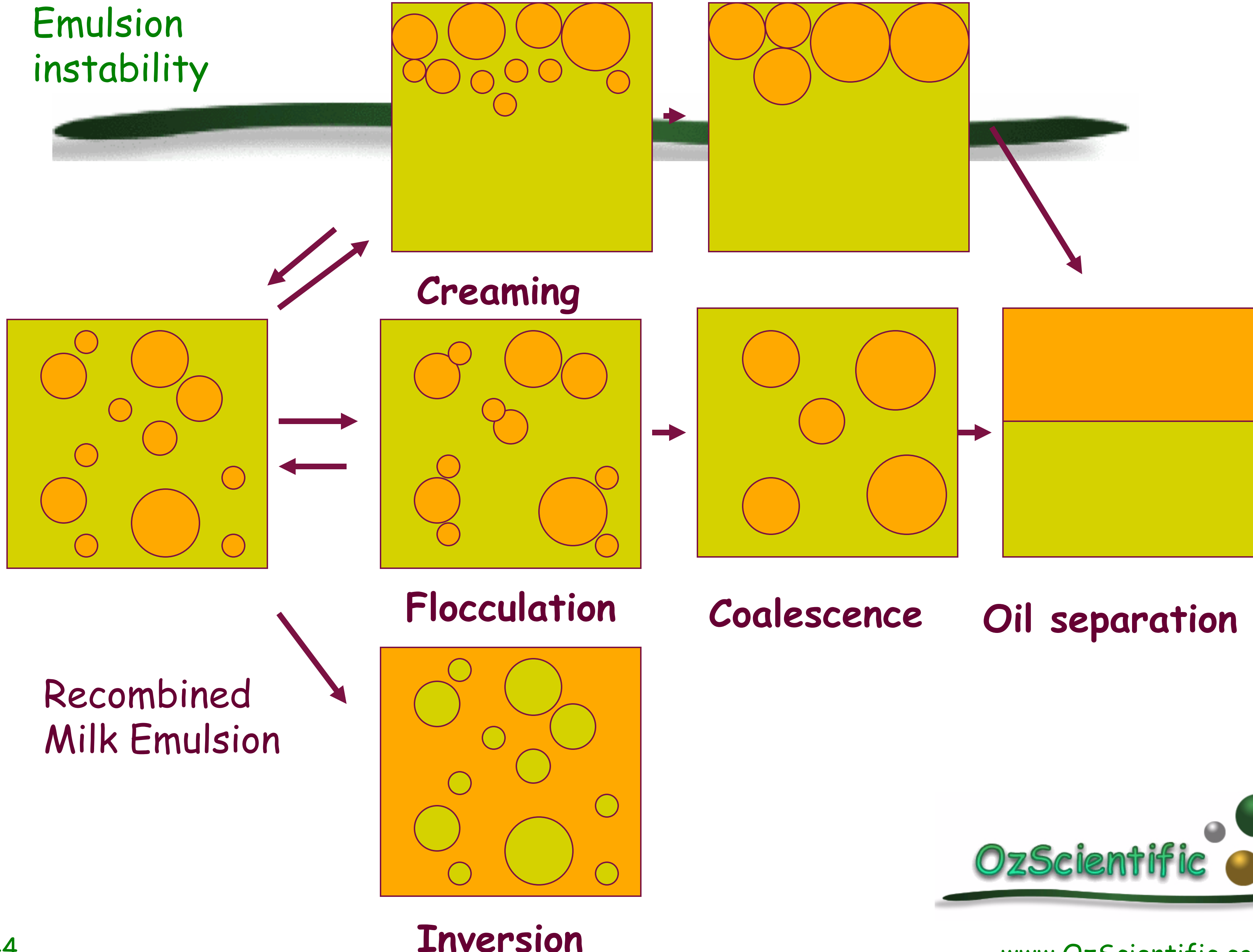
Type of force	Character	Origin	Influenced by
Hydrophobic	Attraction	Water-water affinity	Solvent properties, surface hydrophobicity
Hydration	Repulsion	Dehydration of polar group	Emulsifier head group, crystallinity
Protrusion	Repulsion	Reduction in movement of emulsifiers normal to the interface	Fluidity of the layer, head-group size, Oil/water interfacial tension

Bergenstahl A & Claesson PM (1997) Surface forces in emulsion. In Food Emulsions (Friberg S & Larsson K, eds), pp 57-109, Marcel Dekker, NY

DLVO Theory for colloidal stability



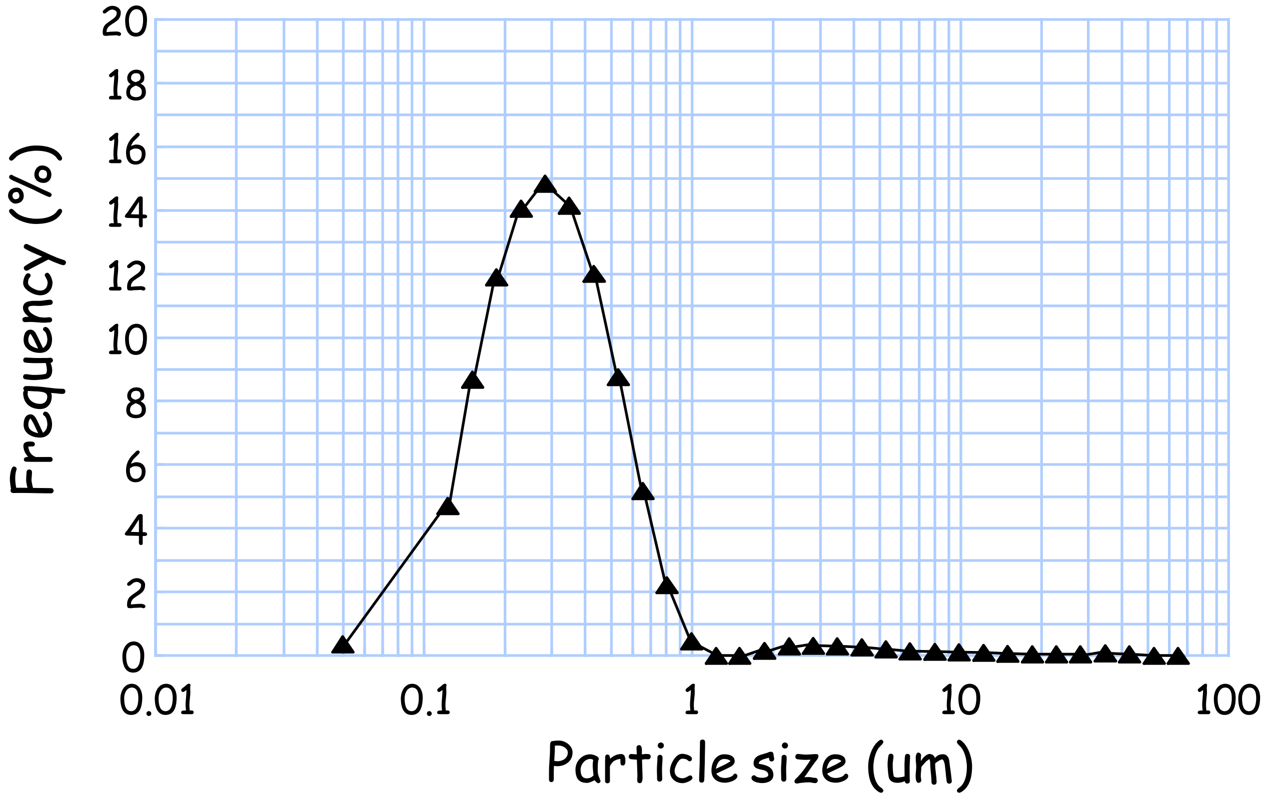
Emulsion instability



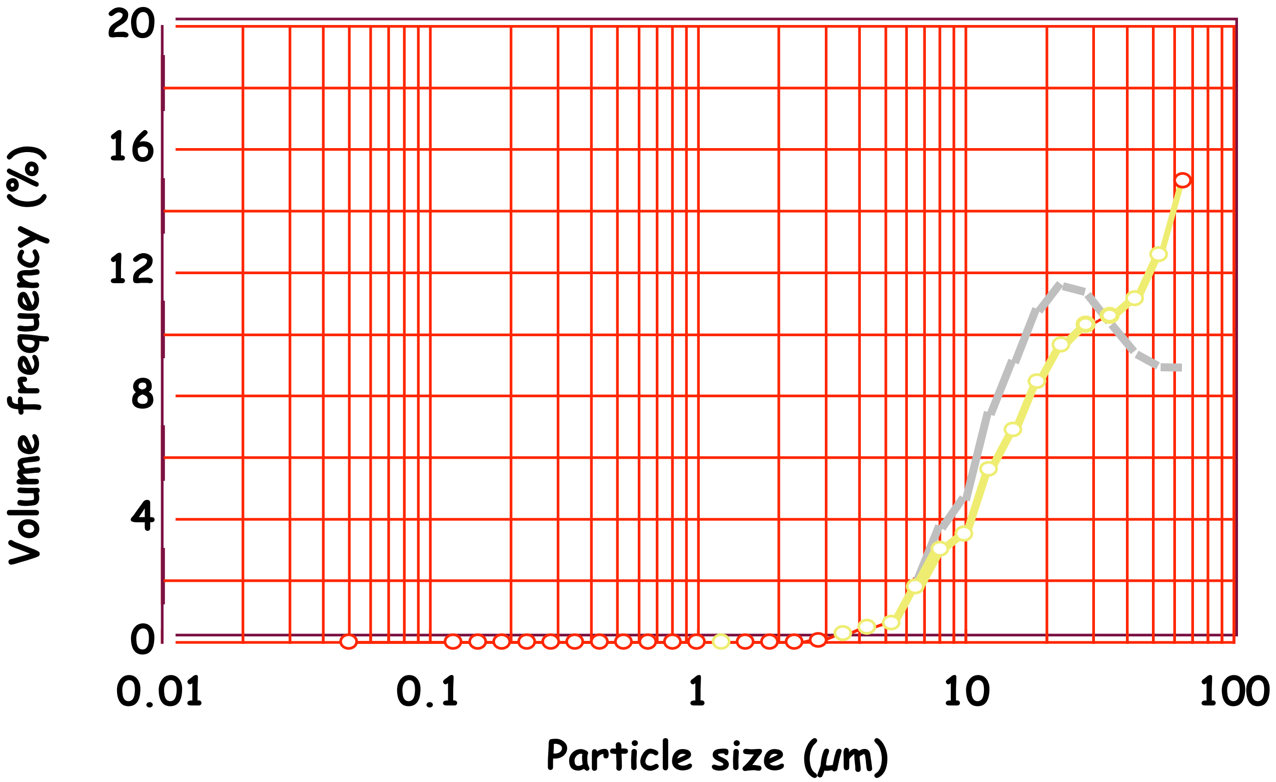
Characterisation of emulsions

- Emulsifying properties of proteins
  - Emulsifying activity
  - Emulsion capacity
  - Surface hydrophobicity
- Emulsion stability
  - Emulsion droplet size
  - Protein load
  - Creaming and oil separation
  - Heat stability
- Emulsion rheology
- Emulsion microstructure

Particle size distribution – A stable emulsion



Particle size distribution - unstable emulsion



Recombined milk products

- Pasteurised milk
- **UHT milk**
- Evaporated milk
- Sweetened condensed milk
- Cheese
- Yoghurt
- Ice cream
- Many formulated emulsion products..

Guide to powder selection

Recombined Dairy Product	Heat Treatment of Powder	Desirable Functional Attributes
Milk (Pasteurised)	Low	Lack of cooked flavour
UHT Milk	Low – medium	Heat stability
Evaporated Milk	High	Heat stability
Sweetened Condensed Milk	Medium	Viscosity
Cheese	Low	Rennetability

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Guide to powder selection

Product	Heat Treatment of Powder	Desirable Functional Attributes
Yoghurt	Low*	Water binding, viscosity, gelation
Ice-cream	Low-medium	Foaming, whipping, emulsifying
Confectionery	High	Water binding, emulsifying, foaming, whipping, heat stability
Bakery	High	Water binding, emulsifying, foaming, whipping, gelling
Chocolate	High	High "free-fat",

* High heat powder can be used if the yoghurt milk is not given a high heat treatment at the recombination plant

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Recombined UHT Milk

Typical Formulation:

8.5% MSNF, 3.5% fat

Ingredients:

Whole milk powder

Skim milk powder, fat, emulsifier, stabiliser

Processing:

UHT

UHT recombined sweetened milk

Anhydrous milk fat	3.6
SNF	8.5
Sugar	3.5
Vanilla	0.1
Stabilizer	0.2
Water	84.1

UHT recombined concentrated milk

- Also known as UHT recombined evaporated milk
  - Can be manufactured using standard UHT equipment
  - Alternative to canned evaporated milk
  - Less expensive to manufacture than canned evaporated milk

UHT milk: important requirements

Powder usable

- Skim milk powder, whole milk powder, buttermilk powder

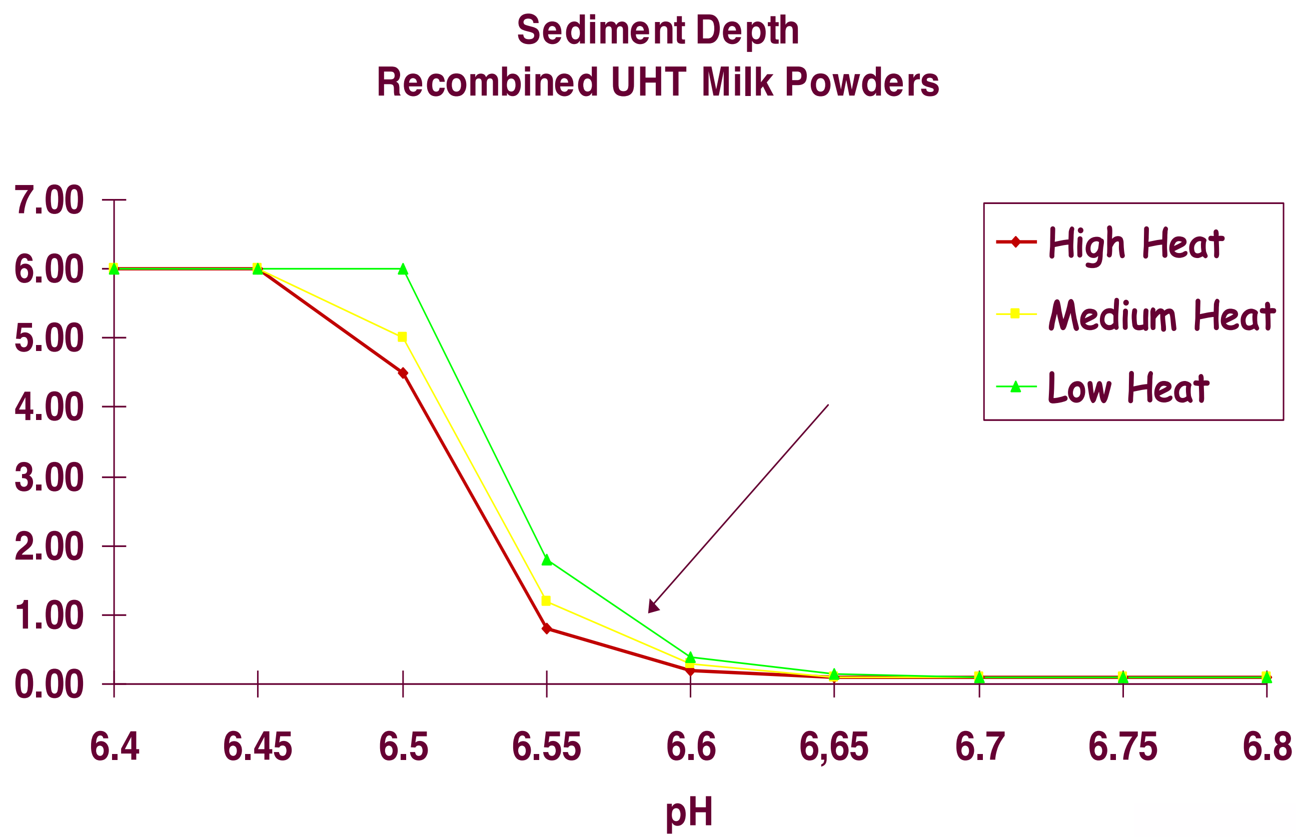
Requirements

- Heat classification: low, medium
- Reconstitutability
- Microbial standard
- Emulsifying capacity
- Emulsion stability
- Flavour quality
- Level of heat stable enzymes

Recombined UHT milk

- Issues
  - Flavour
  - Age gelation
    - Caused by the action of enzymes from Psychrotrophic bacteria
    - Most rapid at 26C
  - Sedimentation
    - Protein denaturation and aggregation (heat instability) – pH affects the sedimentation

Effect of pH on stability of recombined milks to UHT processing



Thank you

- OzScientific offers innovative ingredient solutions for functional & bioactive food ingredients
  - Business intelligence: Market intelligence, Strategic analysis and Innovation management
  - Ingredient innovations: Development & commercialisation of ingredients & formulations
  - Ingredient knowledge: Scientific and technical reviews

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