‘SOFT’ MATTERS IN FOOD

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Neutrons & Food
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Agenda

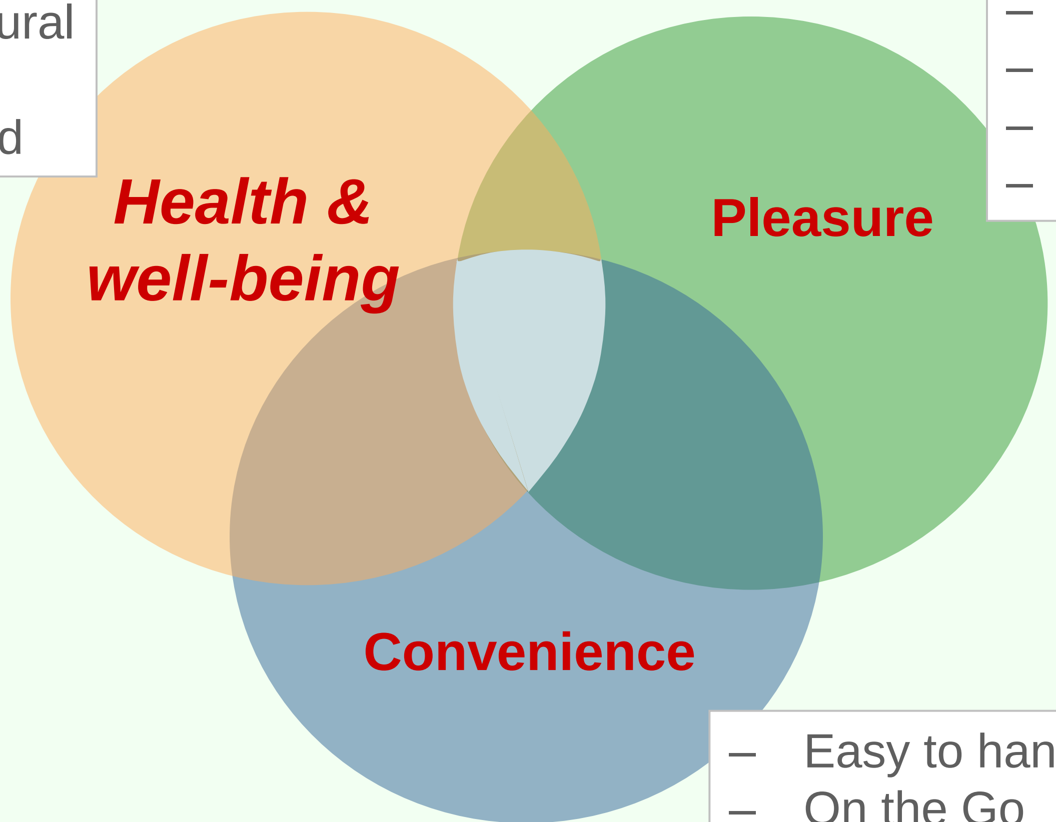
- Current Consumer Trends
- R&D Challenges in Food Industry
- Conclusions, questions to be answered

Good Food, Good Life

Consumer Good Industry Delivering Nutrition, Health and Wellness

3 trends shaping consumer attitudes and behaviours

- Fresh & natural
- Preventive
- Personalized



- « for me »
- Indulgence
- Premiumization
- Luxury

- Easy to handle
- On the Go
- Delivery of solutions

Food as an
Integral Delivery System
for Nutrition, Health & Wellness

The Basis for R&D on Food and Nutrition

From the farm…

…to the table

Focus Change in Food Research

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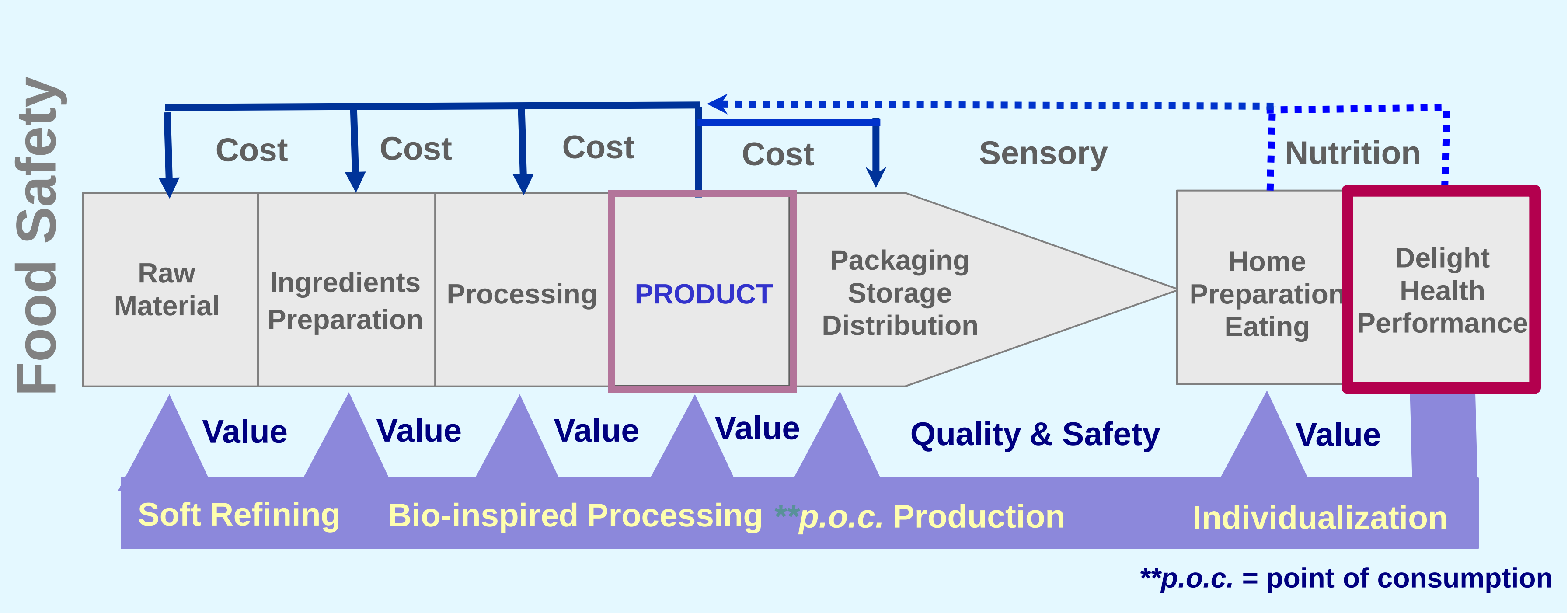
Product-centered / Commodity-driven

"Product matches expectations"

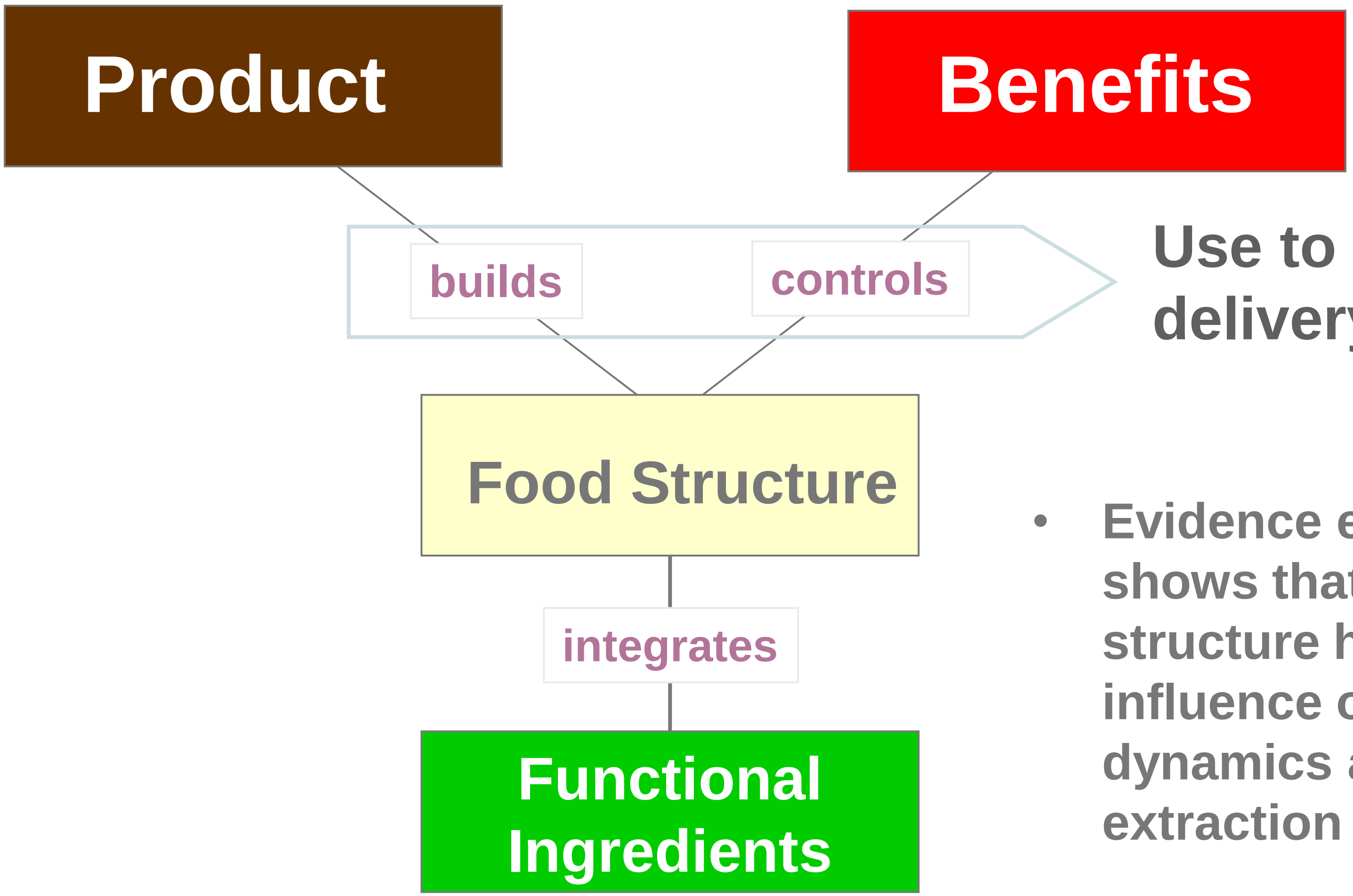


Consumer-centered / Benefit-driven

"Product delivers benefits"

Nestlé Research

Food Structure – in the center



Use to create delivery systems

- Evidence exists that shows that food structure has an influence on digestion dynamics and nutrient extraction yield

‘Soft’ Matters in Food !

Using Soft Condensed Matter physics concepts allows Food Scientists to significantly better understand the main structural elements building up food materials

What is 'Soft Condensed Matter'?

– Materials which are easily **deformable** by external stresses, electric or magnetic fields or thermal fluctuations

– T.A. Witten in Rev. of Modern Physics 1998
'Soft matter occupies a **middle ground between two extremes**: the fluid state and the ideal solid state. It emerges because the thermal fuctuations that dominate the fluid state coexist with the stringent constraints characteristic of the solid state'.

Scattering methods

– P.G. de Gennes in his 1991 Nobel Physics Prize speech
' Behaviour of 'soft' matter' is dominated by one simple fact: they contain **'mesoscopic structures'** with sizes between that of a small molecule ($H_2O \sim 0.3$ nm) and the beaker containing the material'

R&D Challenges in Food Industry

Food Products are Colloidal Systems, i.e. Soft Condensed Matter

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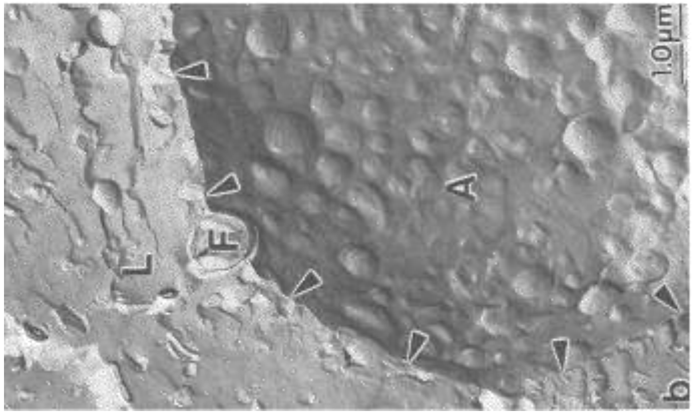
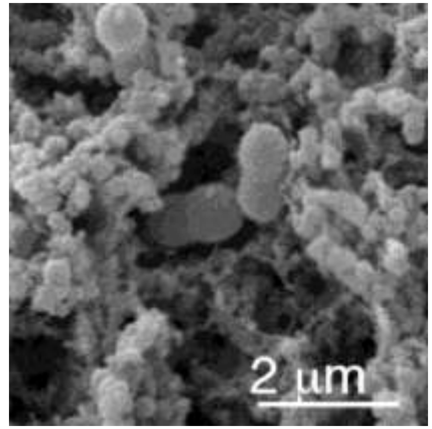
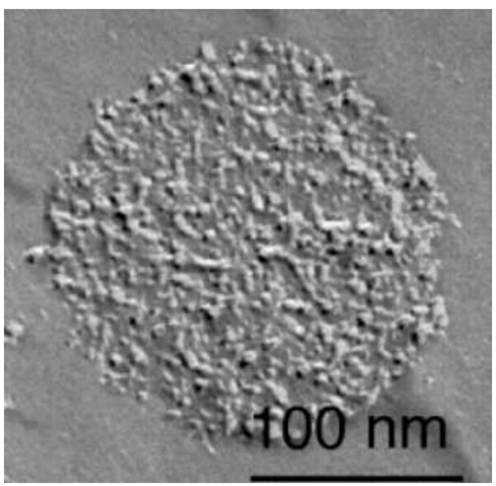


Air Bubble in Ice cream

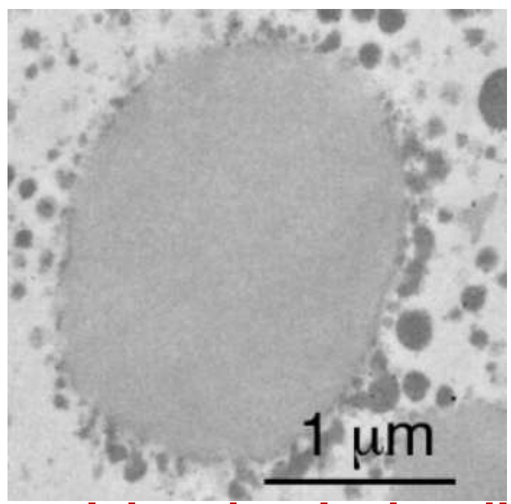


Casein micelle network in Yogurt

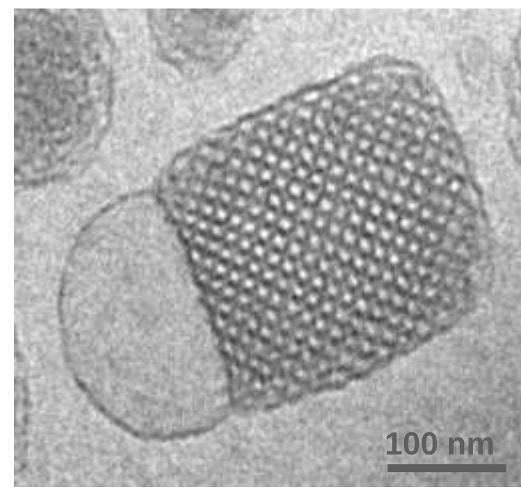
Oil droplet Coffee



Casein micelle in Milk



Emulsion droplet in Milk
Stabilized by Protein



Cubosome as is formed during fat digestion

Milk - A Hierarchically Designed Natural Product

Fat droplet membrane
lipo-protein - bilayer structures

Protein oligomers
Tetramer aggregation

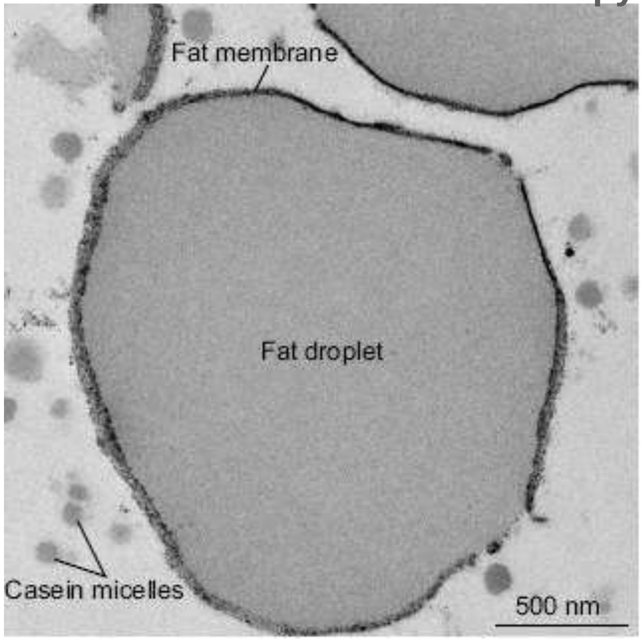
Supramolecular aggregate
Peptide aggregates & Ca phosphate clusters

Lactose molecules
Increase co-solubility of proteins

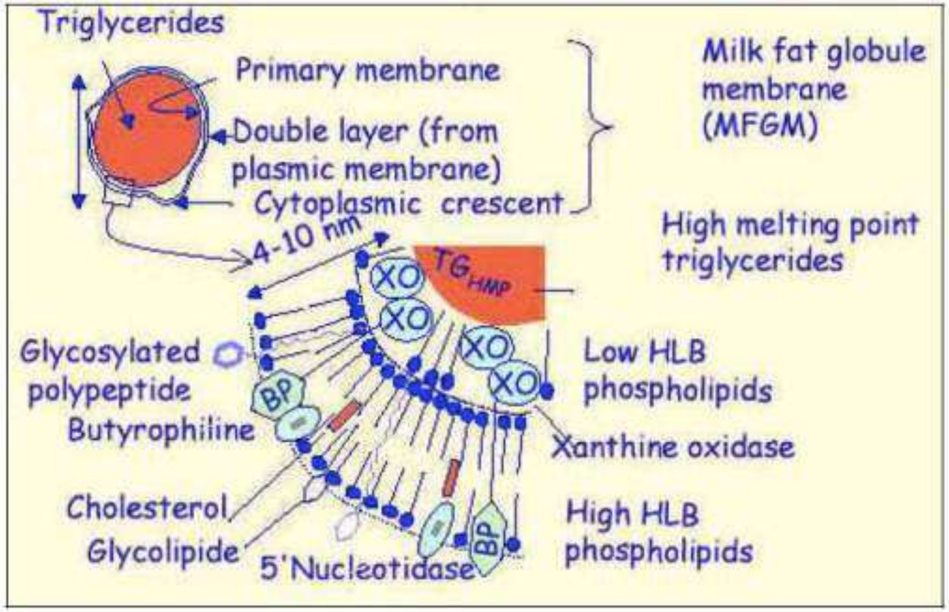
Evolution used hierachical and integrated structures to control digestive dynamics

To digest fat droplets, the membrane has to be firstly "digested" by phospholipases liberating not only the "fuel" but also membrane building blocks, enzymes, bioactive peptides and nutrients.

Transmission Electron microscopy

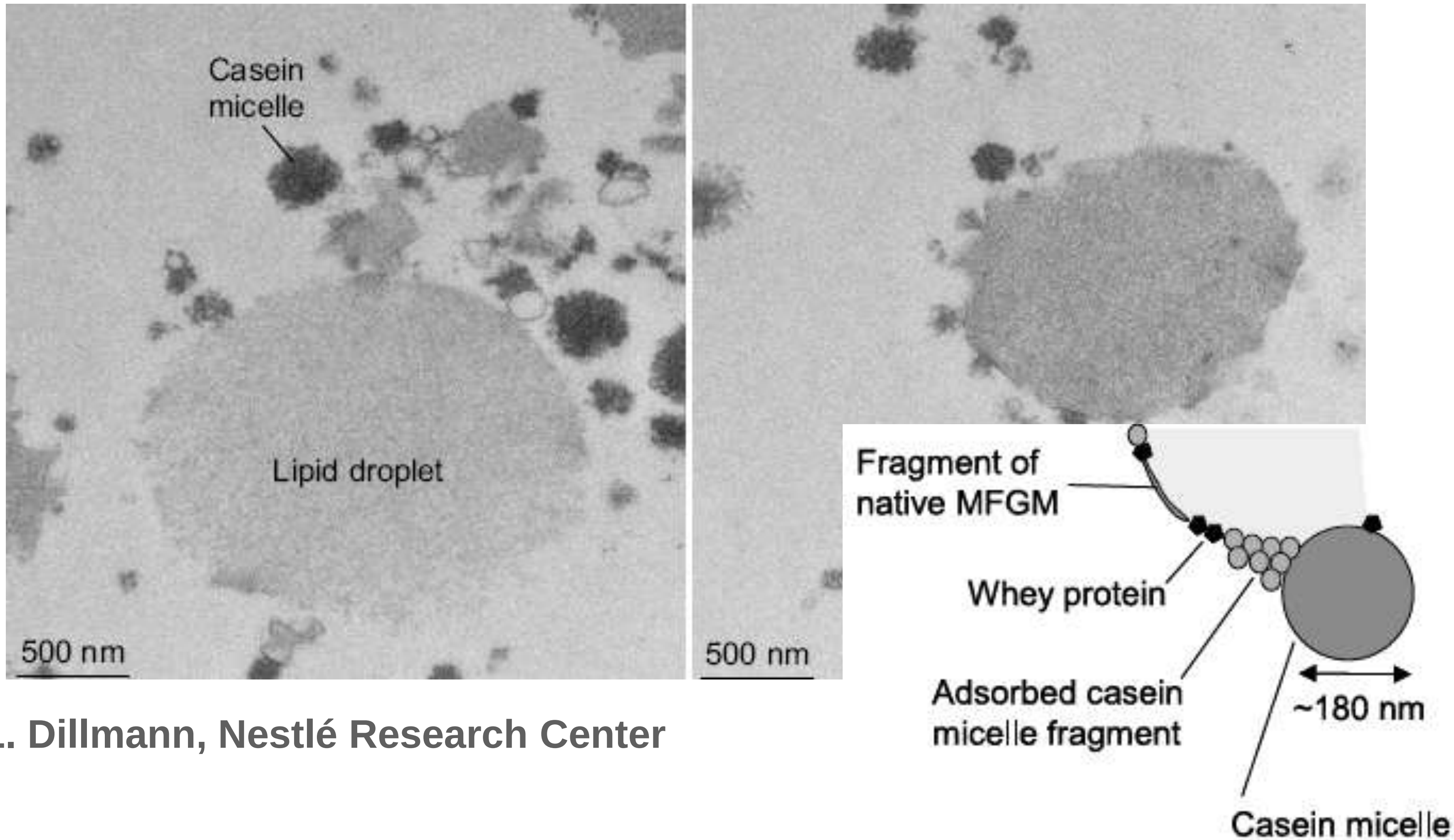


Raw cow milk



Complex bio-membrane around fat globule

Homogenized & Pasteurized Milk
Transmission Electron microscopy



M.-L. Dillmann, Nestlé Research Center

Structure evolution as function of the lipophilicity of ‘oily’ ingredients

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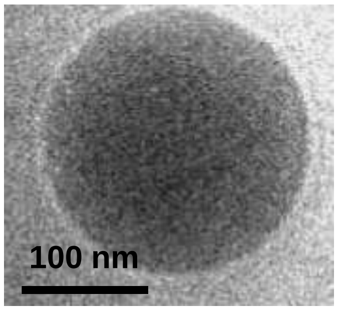
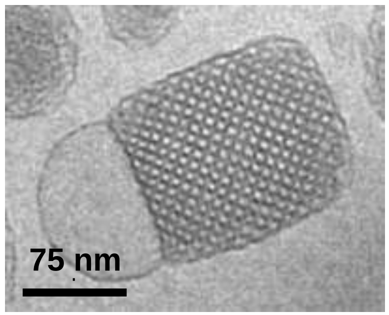
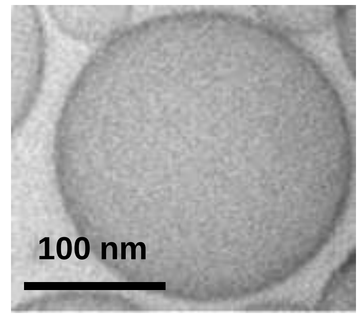
Oil droplet



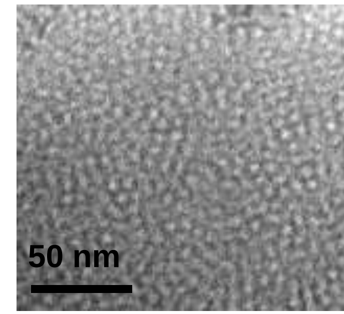
Cubic Phase



Vesicle



Micelle

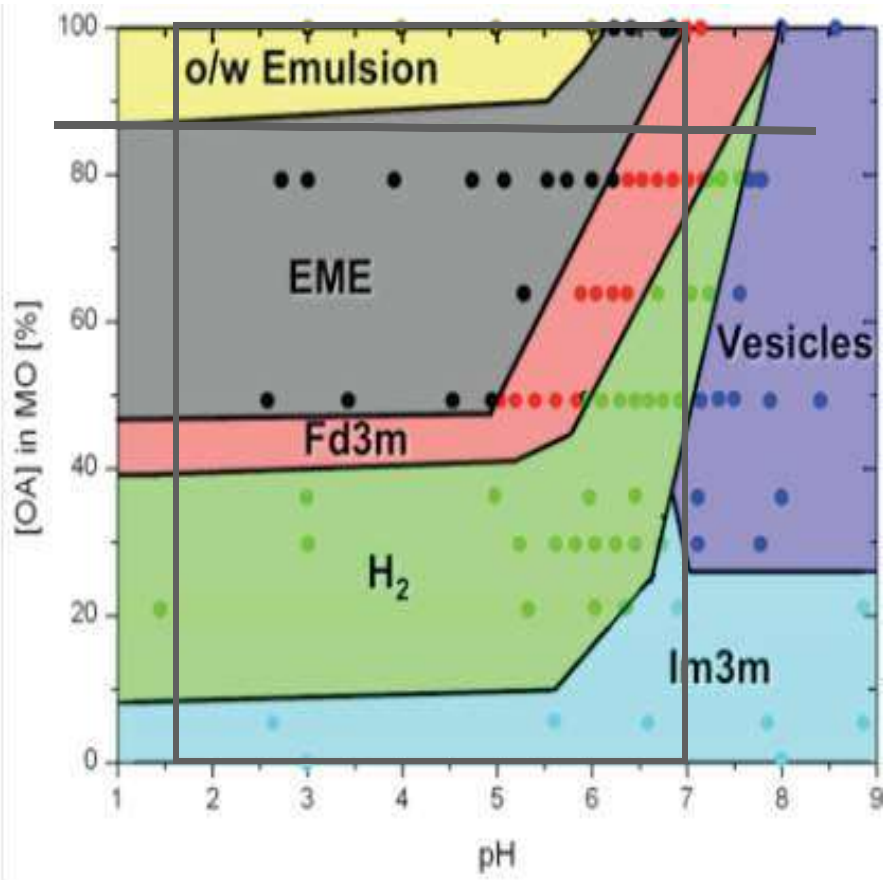


Increase hydrophilicity of lipophilic molecules

- Making oil molecules more hydrophilic and amphiphilic self-assembly structures are formed (surfactants)
- Zoo of self-assembly structures can be formed by changing nature of the hydrophilic/lipophilic balance (HLB) of surfactants
- Are these structures also formed during Digestion of oil dropletys by lipases

Phase diagram: Oleic acid-Monoglyceride (in PBS buffer with bile acids)

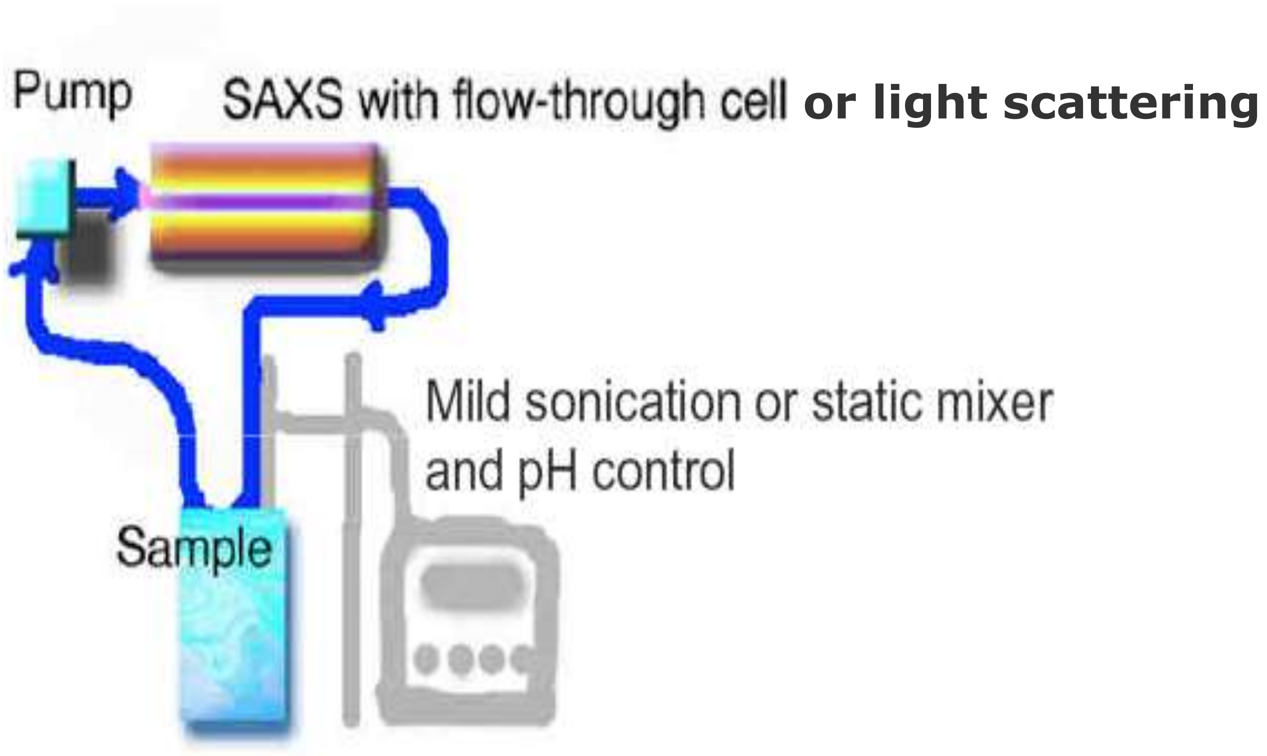
SAXS Experiments



- Oleic acid and mononoglycerides can form a variety of different self-assembly structures
- Influence of pH is due to Oleic acid deprotonation
- Final digestion of oil is expected to produce a ratio 2:1 oleic acid-monoglyceride → reversed microemulsion (EME), reversed micellar cubic phase (Fd3m),reversed hexagonal phase (H2), vesicles.

PhD S. Salentinig University of Graz, Austria

Experimental design: Digestion of Oil followed by Small Angle X-ray Scattering



- Online investigation of Triolein digestion using Time resolved SAXS.
- Influence of lipase, pH and bile salts on formed structures during digestion and kinetics can be measured.

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Self-Assembly Structures are formed inside the Oil Droplets During Lipase Digestion

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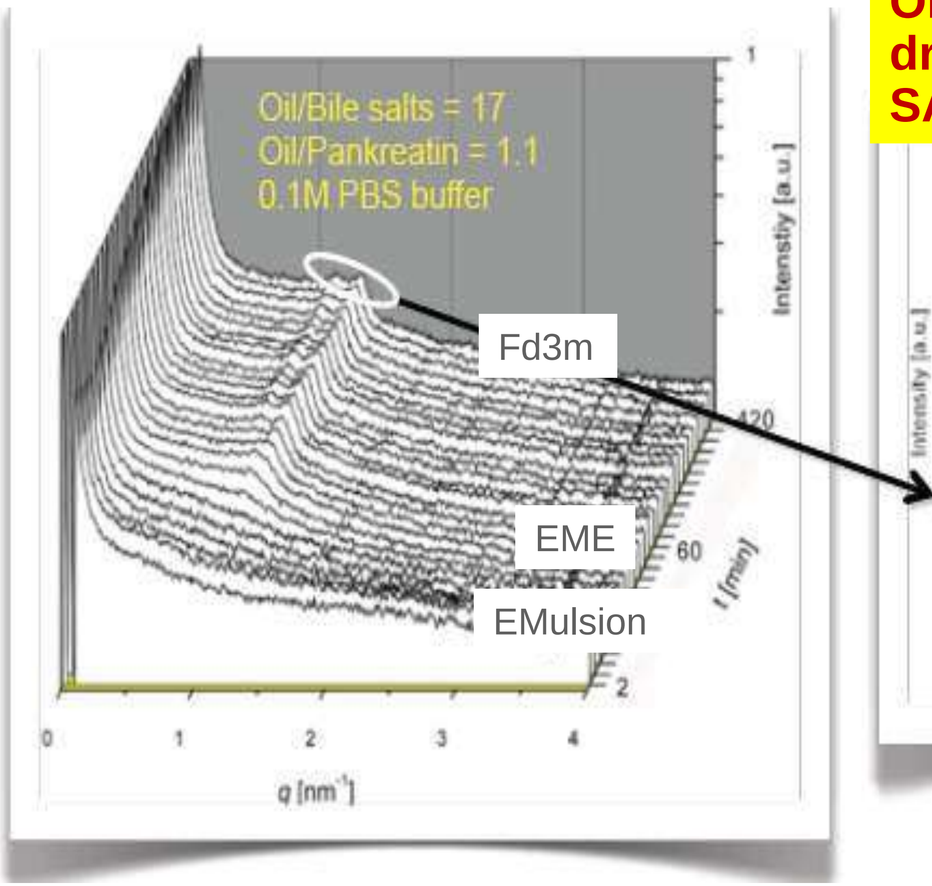
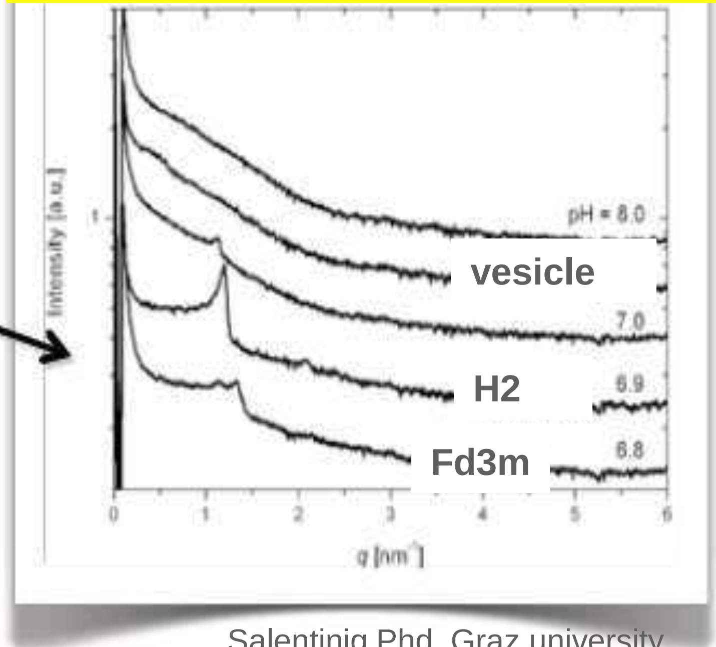
Online investigation of Triolein droplet digestion using Time resolved SAXS.





Salentinig Phd, Graz university

- Various self-assembled structures are formed during digestion, i.e, not only vesicles and micelles
- Self-assembly structures (i.e., interface) are formed inside oil droplets; water and hydrophilic components (e.g. bile salts, lipase) are transported inside the oil droplets enabling digestion of triglycerides inside the oil droplets.

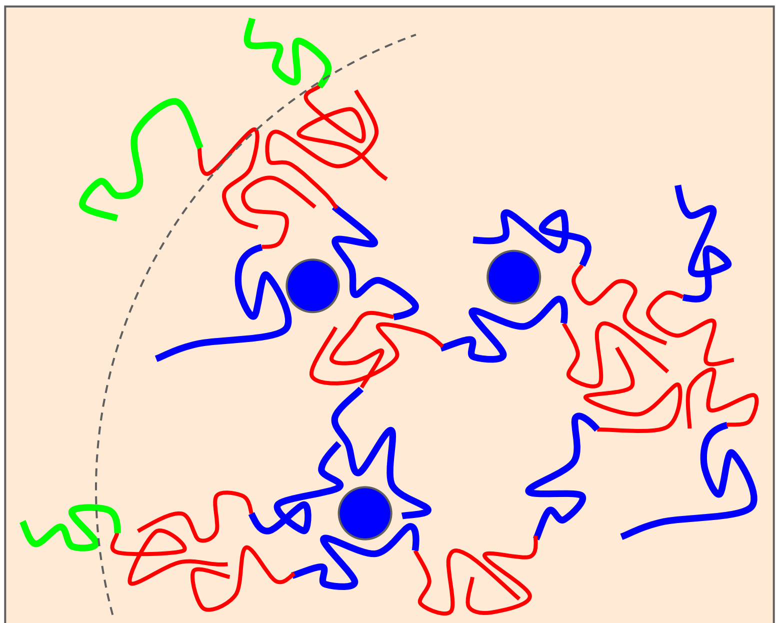
PhD S. Salentinig University of Graz, Austria

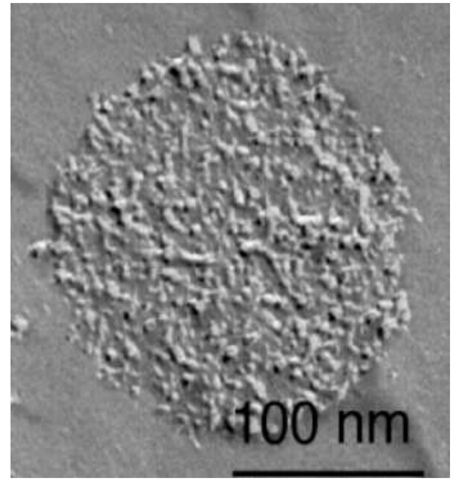
Nestlé Research

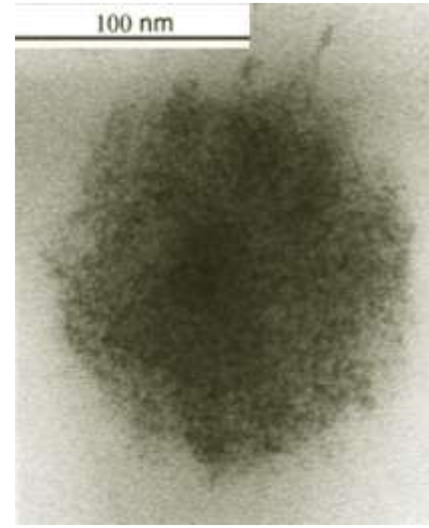
Casein Micelles - Adhesive Colloids

Casein micelles:
Self assembled particles
with pH-dependent charge density
but mainly sterically stabilized

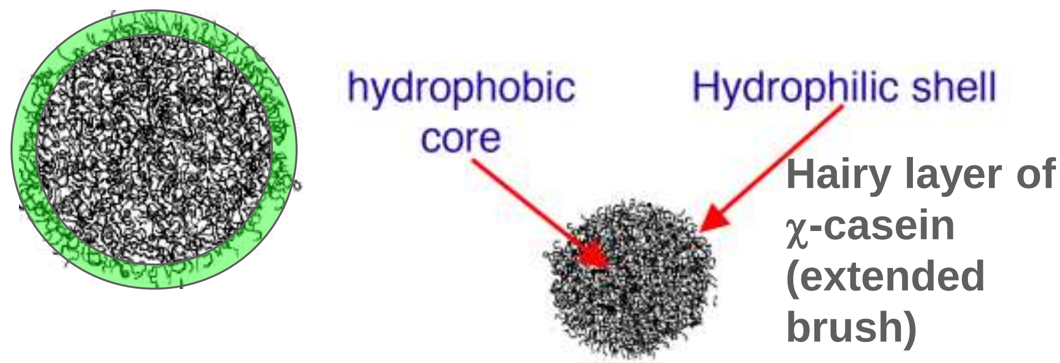
Dual binding model of casein micelles
D.S. Horne, *Int. Dairy J.* **8** (1998) 171







D.J. McMahon, W.R. McManus
J. Dairy Sci. **81**, 2985 (1998)



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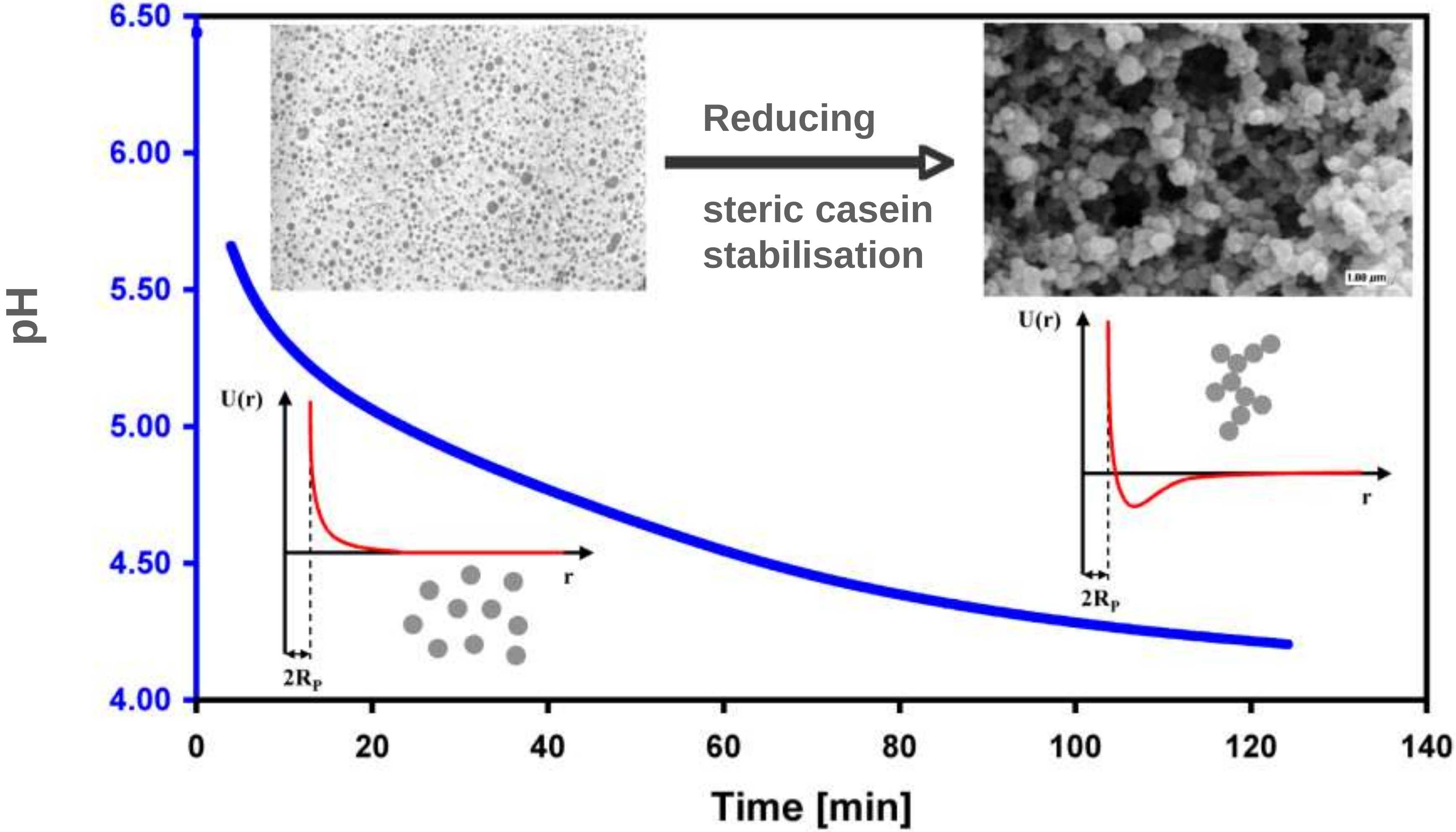
Acid-induced Casein Micelle Aggregation:
The yoghurt making process



Ph.D P. Aichinger, Nestlé Research

Influence of Milk Processing

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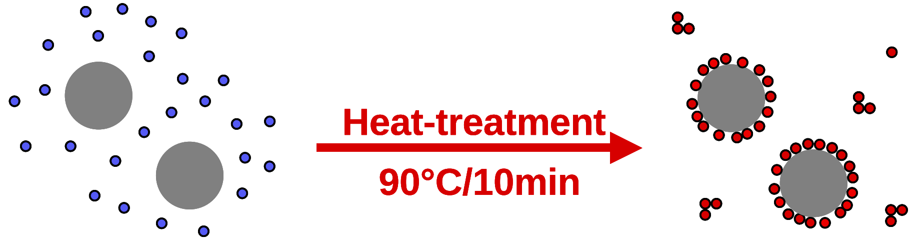
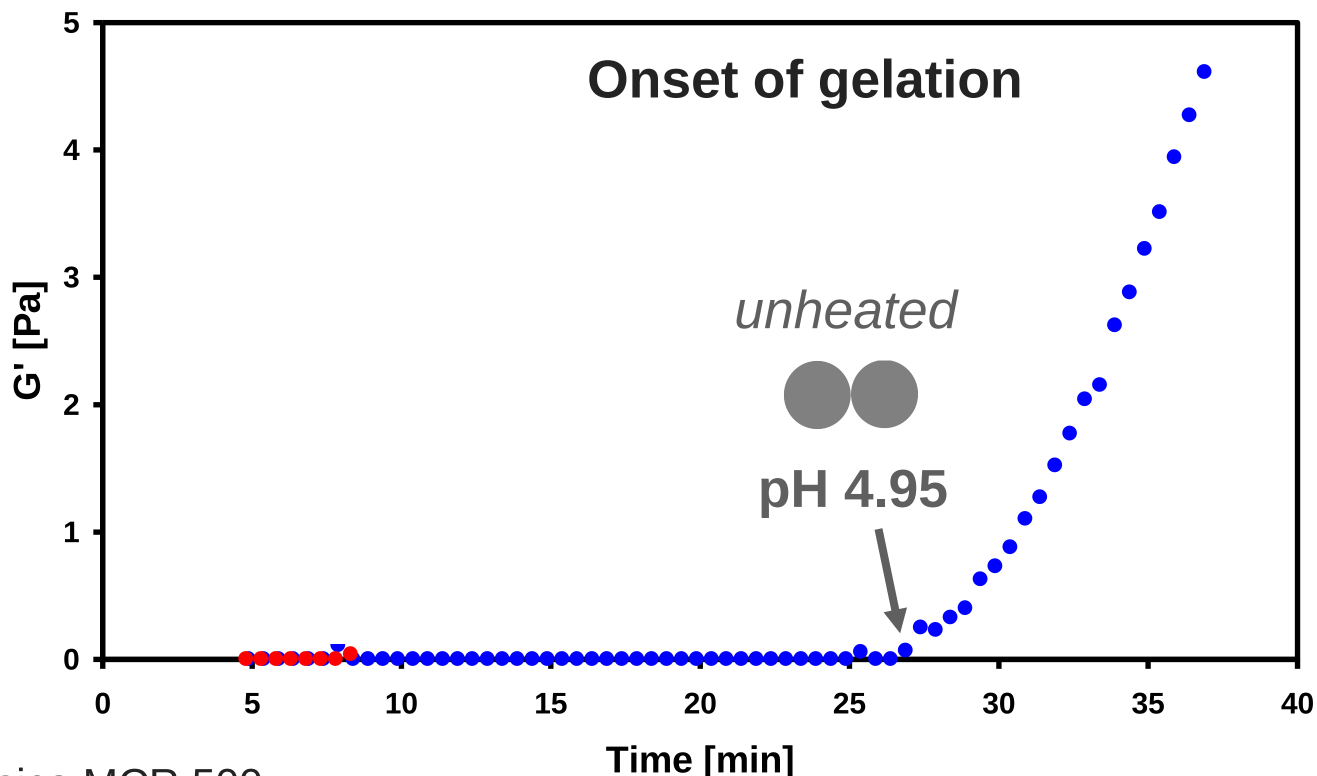




Paar Physica MCR 500, CC27, 0.1Hz, 0.04% strain

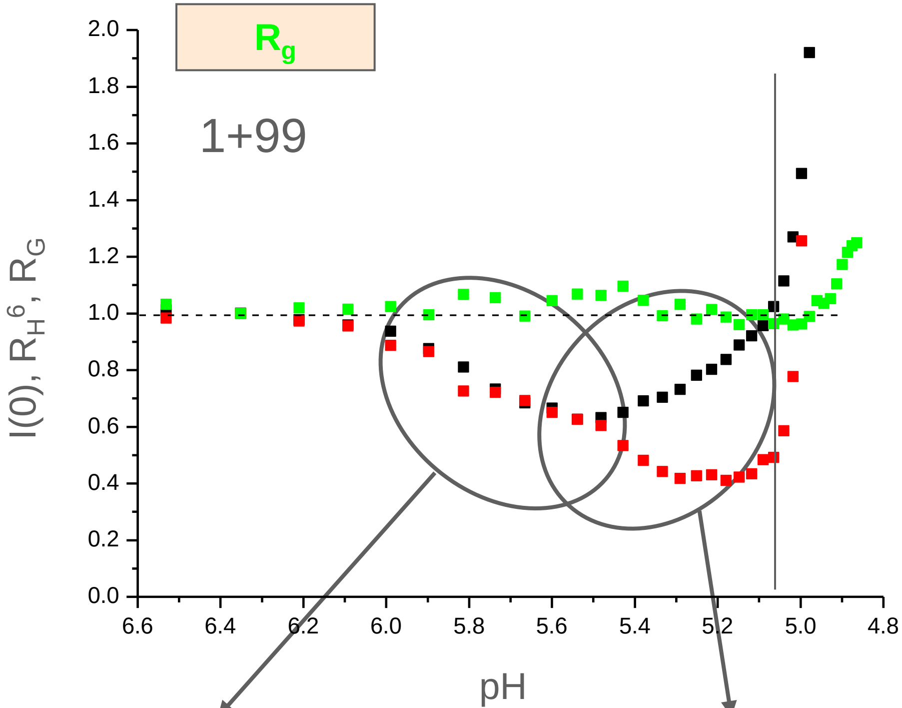
Gelation conditions: 40° C, 3% GDL

Multi-angle 3D time resolved static and dynamic LS

Mass

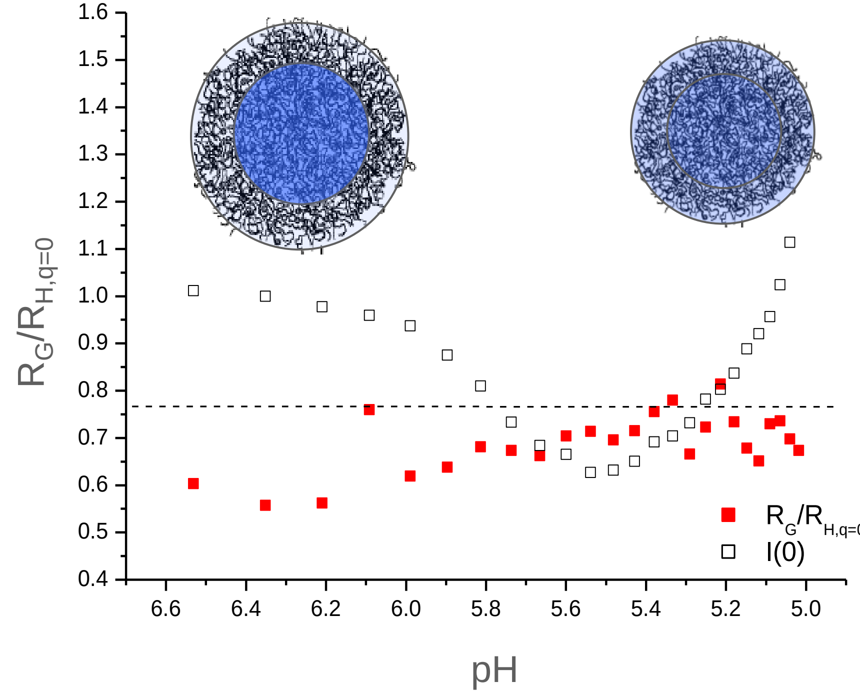
size

R_g



Decrease in size and mass

Increase in mass
Size is still decreasing



Interpretation:
Casein micelles are getting smaller and more homogeneous with a higher average density

C. Moitzi

UNIVERSITAS FRIBURGENSIS

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Emulsion resistance to acid-induced Precipitation

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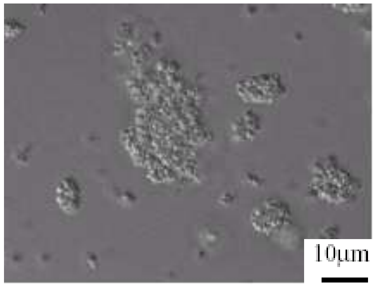
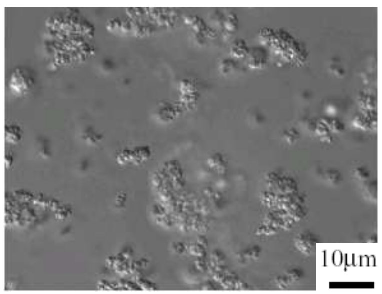
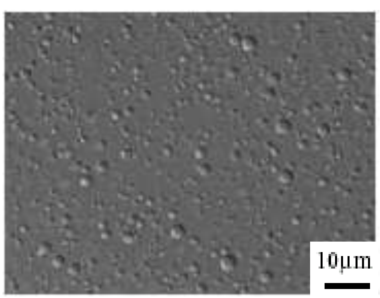


No DS

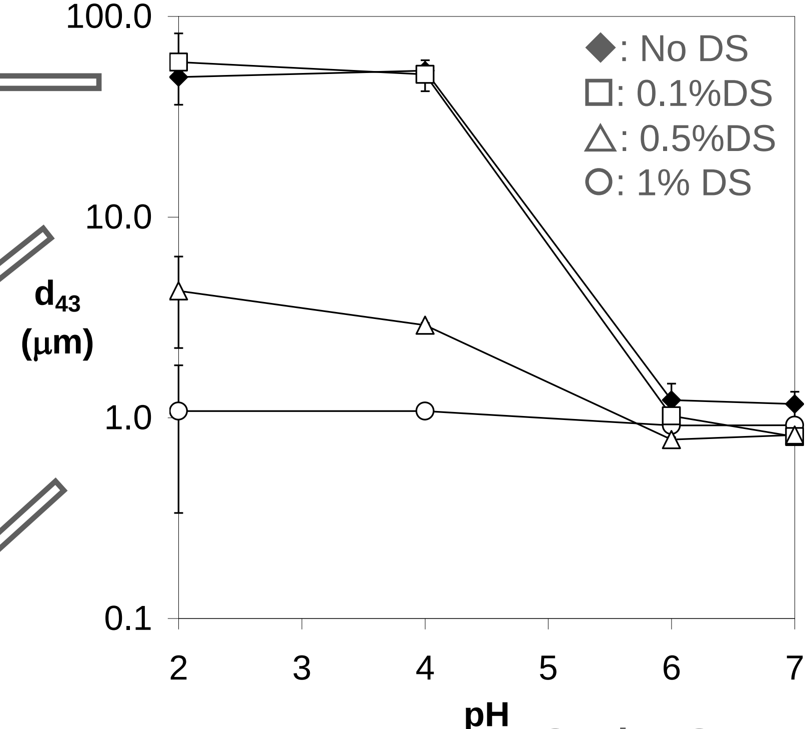


0.1%DS



1% DS

Mixed emulsions



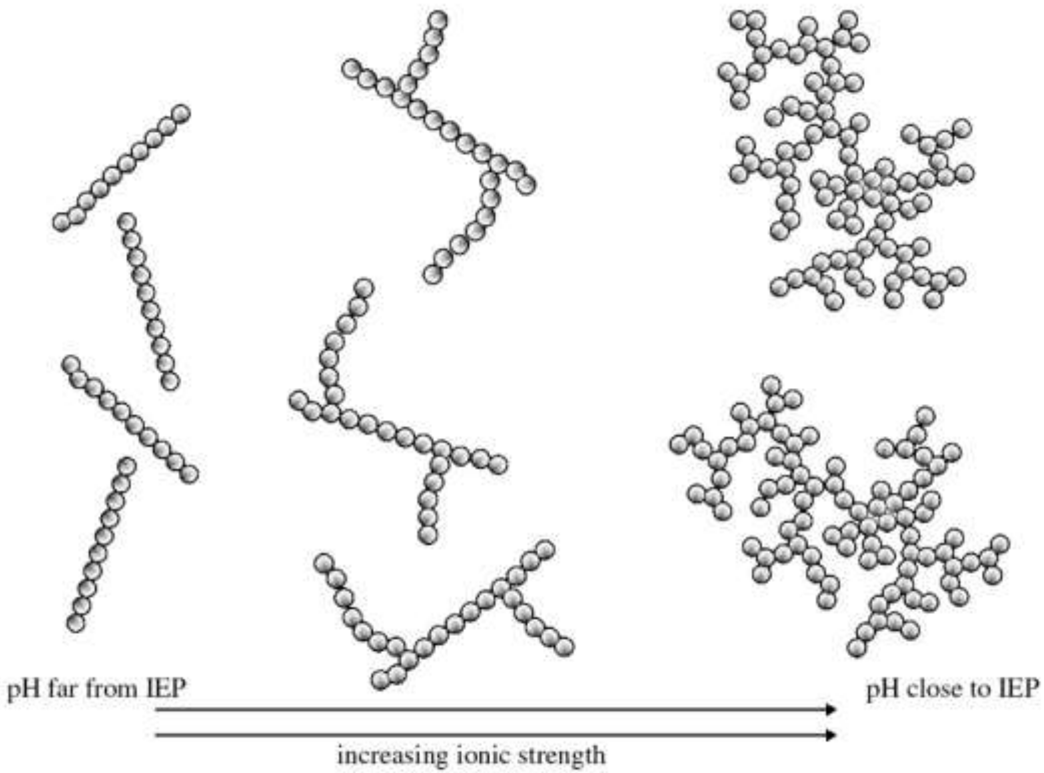
Static LS
Malvern Mastersizer

Adsorbed CN-DS complexes protect the emulsion from acid-induced precipitation when ≥ 1%DS

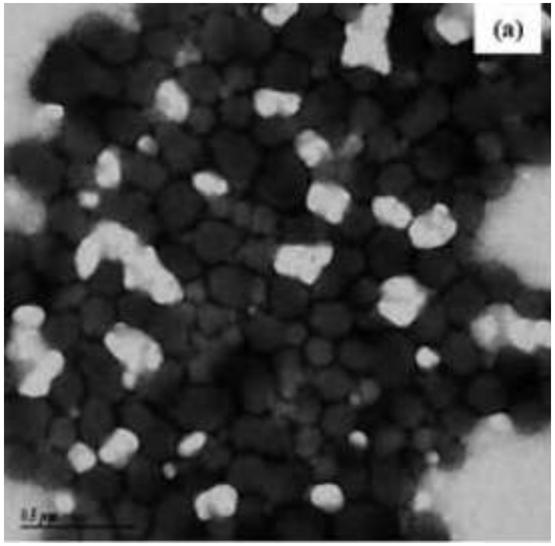
Nestlé Research

Ph.D L. Jourdain

Whey Protein aggregation, Microgels



E.v.d. Linden, P.Venema, COCIS (2007)



Schmitt et al. Soft Matter 2010

Negative-staining TEM micrograph from a freshly prepared 4 wt% WPM dispersion. Scale bar is 0.5 μm.

Protein structures formed by heat-denatured whey proteins as a function of the ionic strength and difference between the iso-electric point (IEP) of the protein and the pH of the solution.

Some Concluding Remarks

Soft Condensed Matter Physics concepts help to understand behaviour of Food Raw Materials and their corresponding processed end products

Knowing equilibrium conditions and kinetics of structure (de-structure) formation is essential

Future functional food colloids will be developed in the context of Foods as an integral delivery system

Using Scattering Methods will significantly help to investigate the multi-structural principles (on different length scales using mixtures of different molecules)

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- C. Moitzi, A, Stradner P. Schurtenberger et al. (University of Fribourg, CH)

What to do now with my new inventions?

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