Specificities of egg yolk in relation with applications and processes

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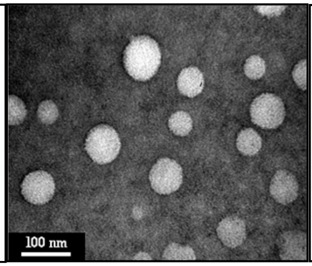
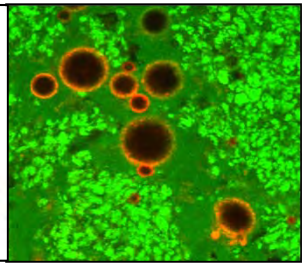
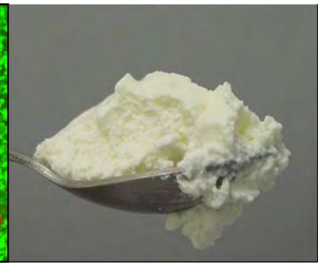
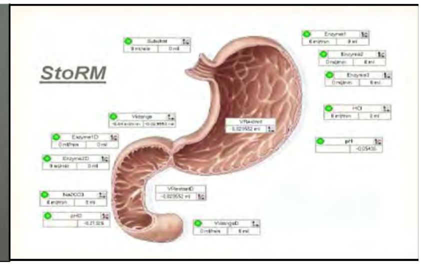
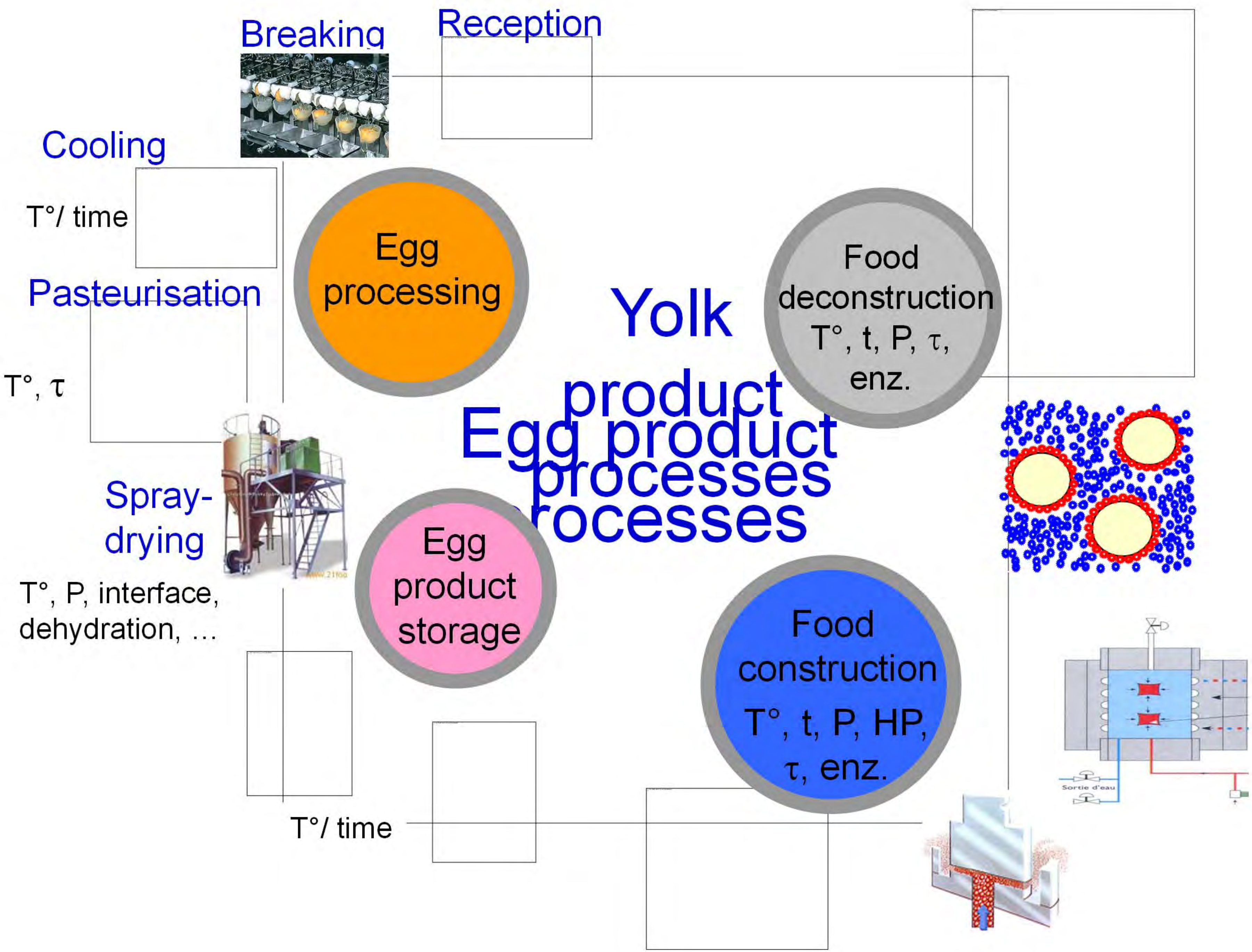


Yolk specificities

- source of nutrients and energy
  → vit., minerals, highly digestible lipids and proteins
- biological activities
- numerous functional properties
  → emulsifying, gelling, colouring, antioxidant …
- natural micro- and nano- structures
  → impact on functional properties
- role of processes on structures and properties ?

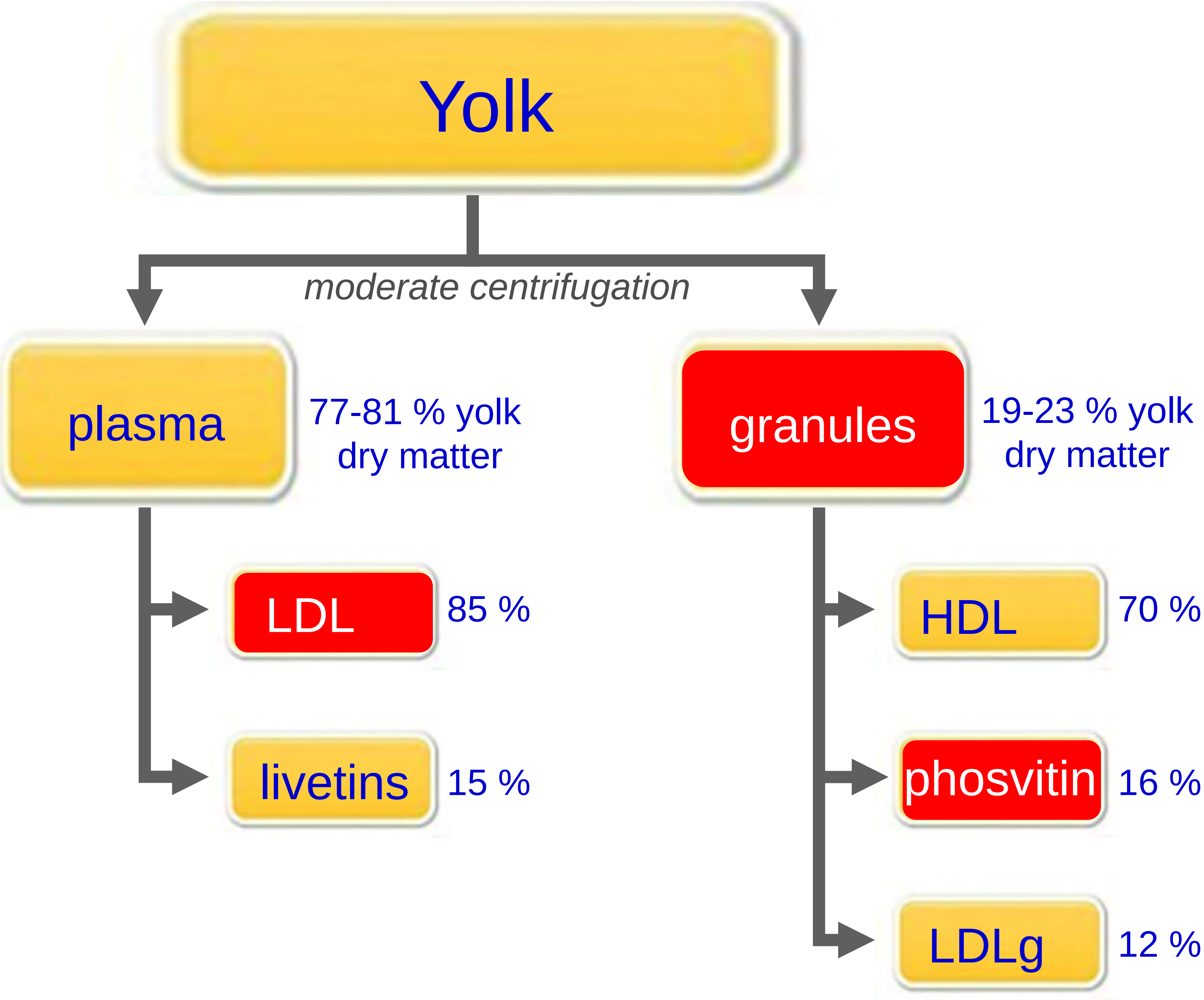

Breaking
Reception
Cooling
T°/ time
Pasteurisation
T°, τ
Spray-drying
T°, P, interface, dehydration, …
T°/ time
Egg processing
Egg product storage
Yolk product processes
Egg product processes
Food deconstruction
T°, t, P, τ, enz.
Food construction
T°, t, P, HP, τ, enz.
Sortie d'eau

- Yolk constituents and structures

- Yolk constituent adsorption at interfaces

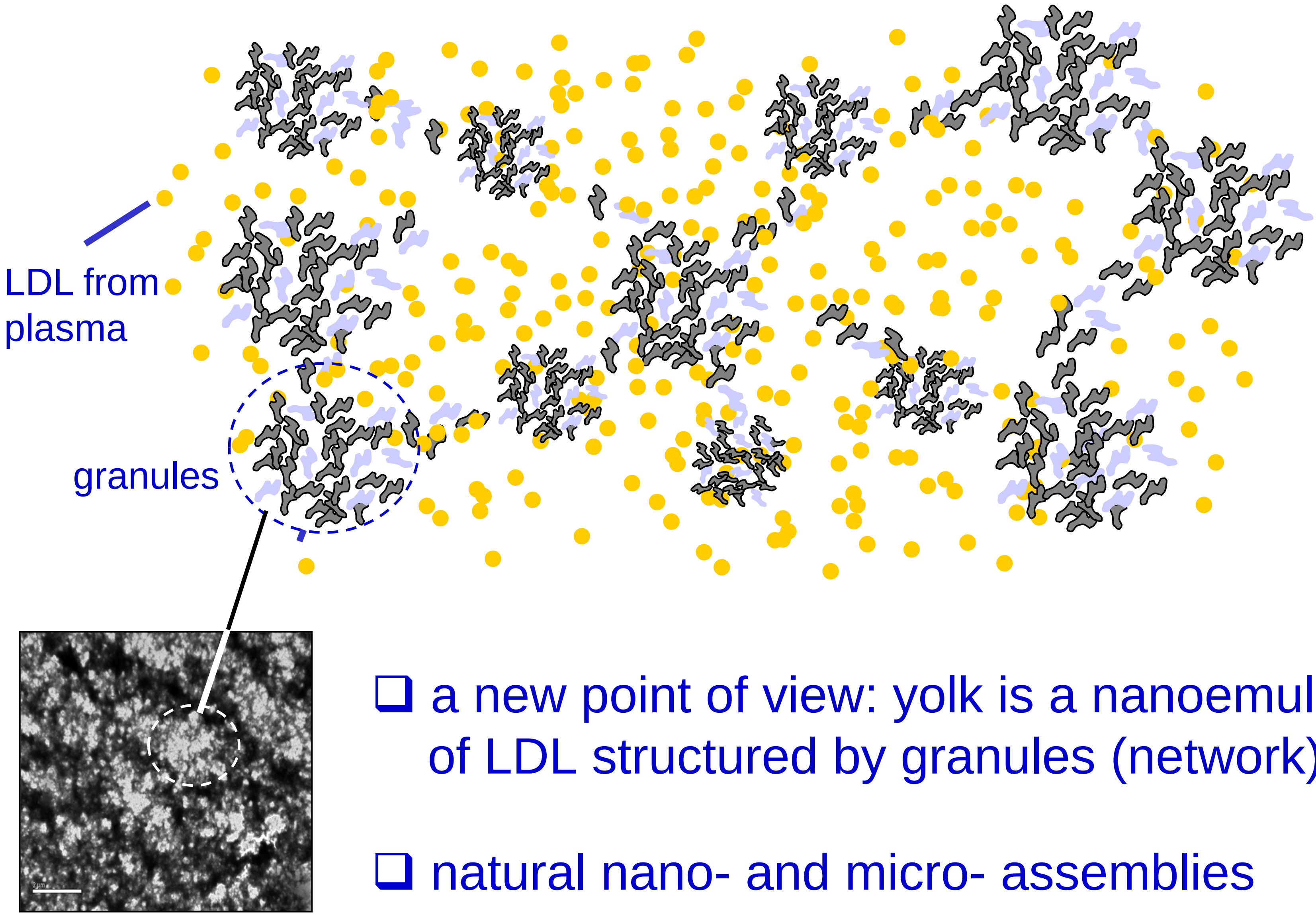
- Impact of various processes on structures and functionalities

Yolk constituents and structures



Yolk
moderate centrifugation
plasma
77-81 % yolk dry matter
granules
19-23 % yolk dry matter
LDL
85 %
livetins
15 %
HDL
70 %
phosvitin
16 %
LDLg
12 %

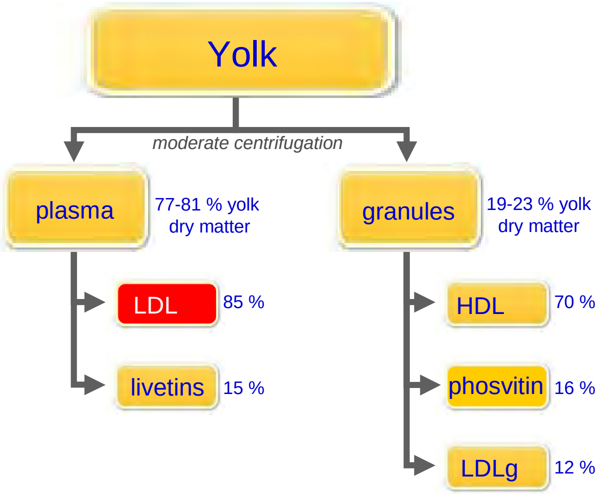
Yolk: a multi-scale structure

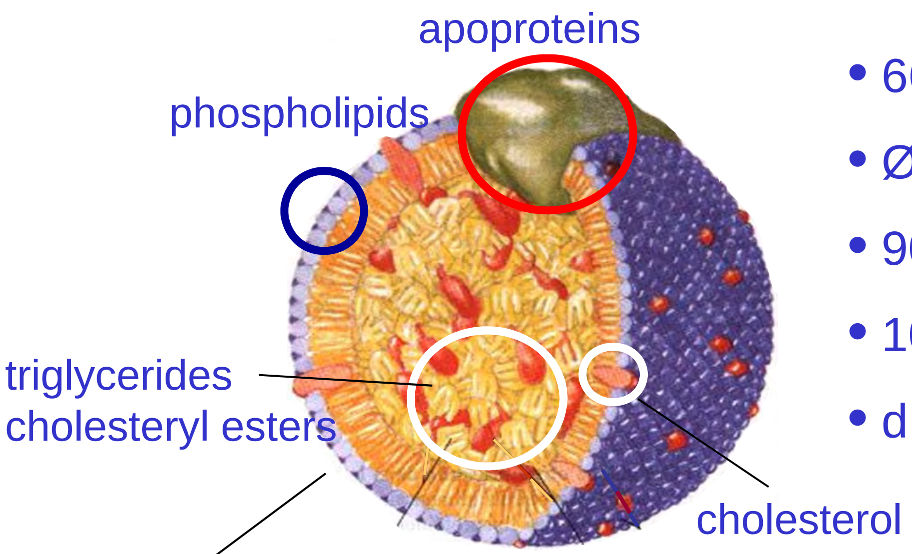


- a new point of view: yolk is a nanoemulsion of LDL structured by granules (network)

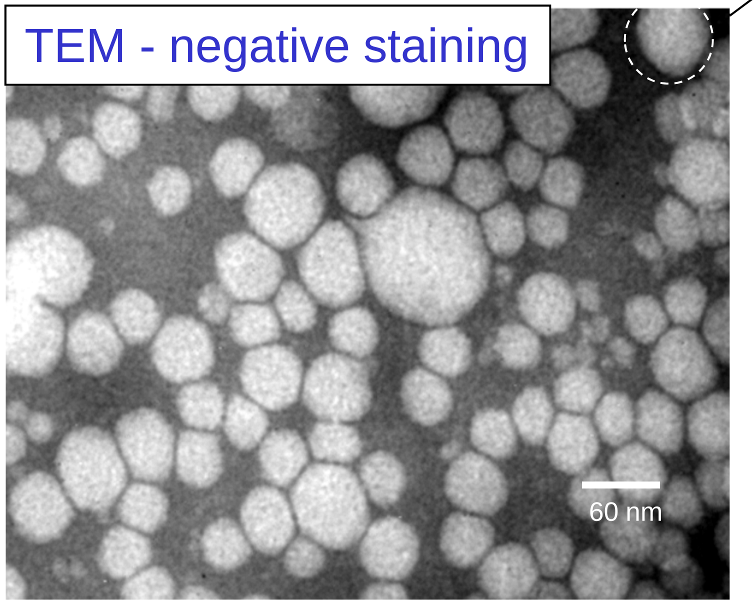
- natural nano- and micro- assemblies

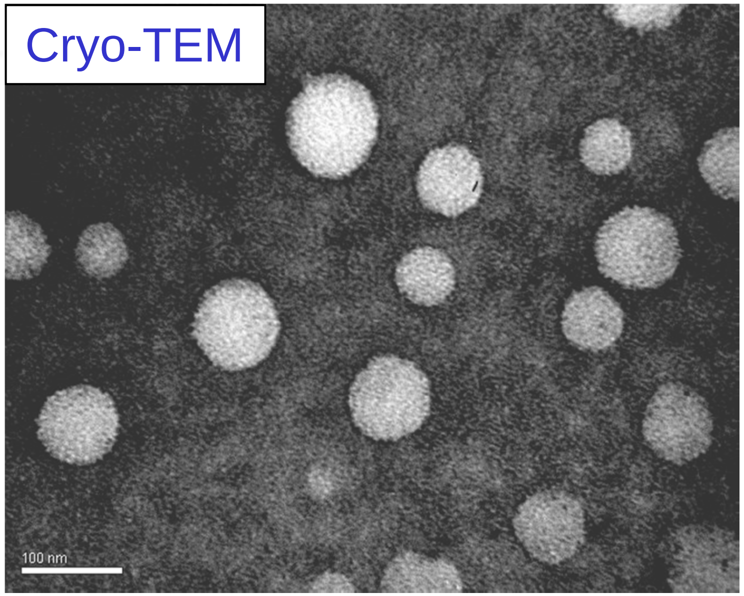
LDL nanostructure





- 66% yolk DM
- Ø 17-60 nm
- 90% lipids
- 10% proteins
- d = 0.98 g/cm^3

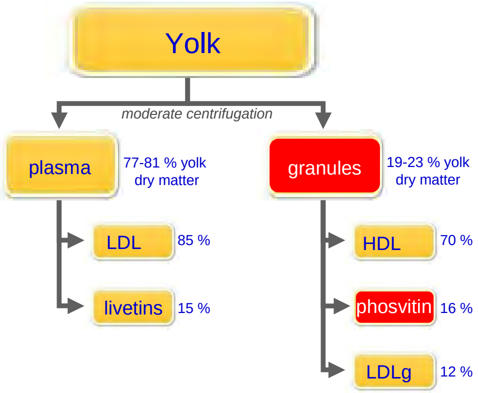


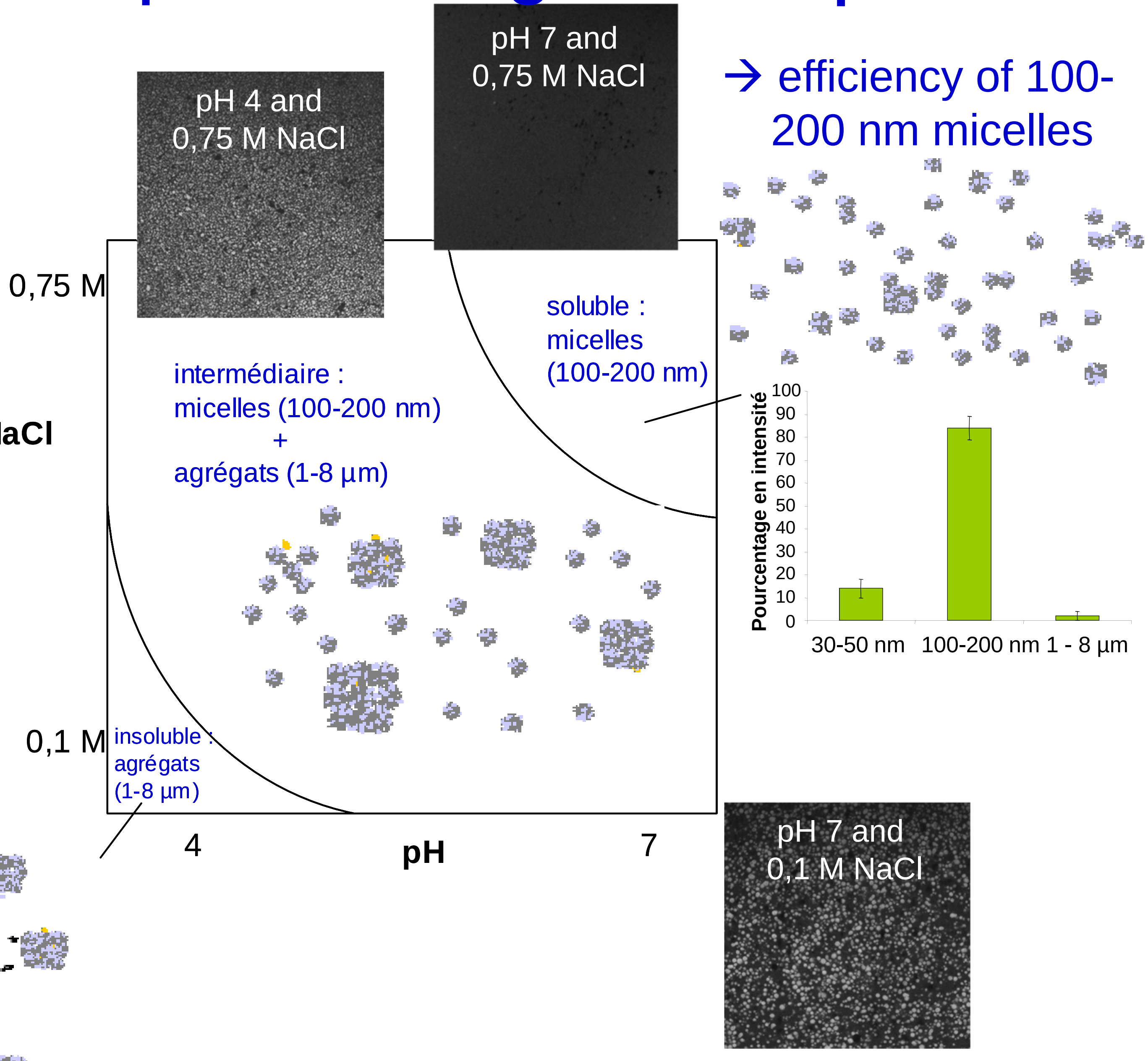


→ soluble nanoemulsions

Martinet et al., 2003, Colloids and Surfaces B: Biointerfaces, 31, 185-194

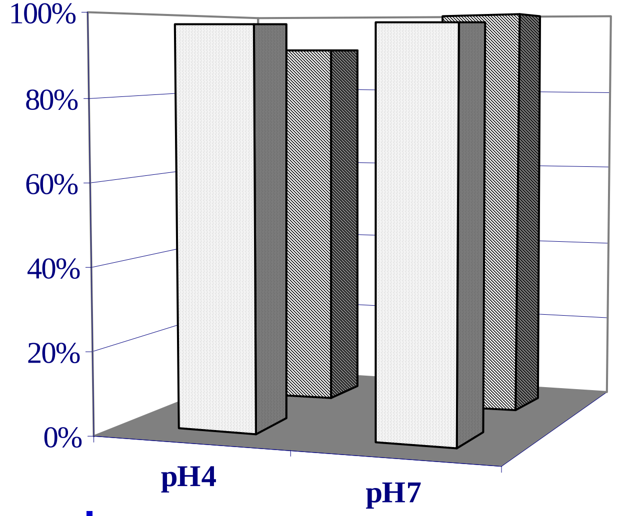
Granules: phase diagram vs pH/salts



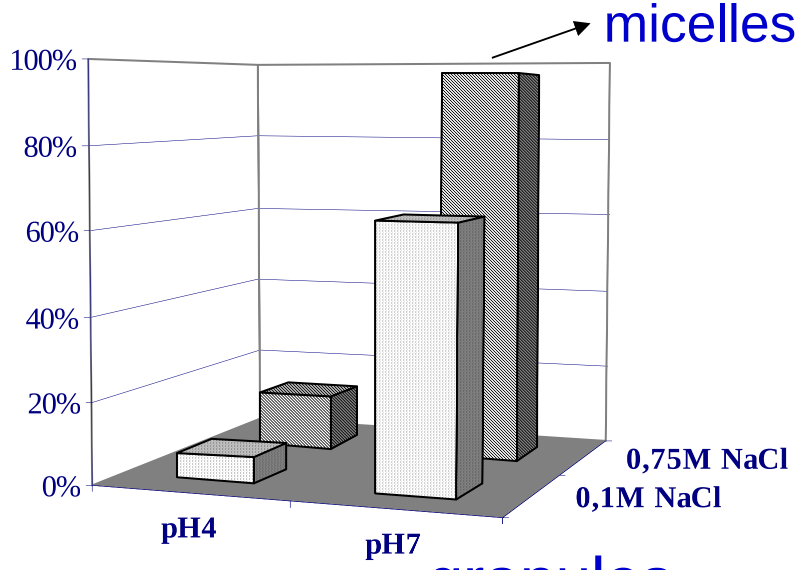


Sirvente et al., 2007, J. Agric. Food Chem., 55, 9537–9544

Protein solubility

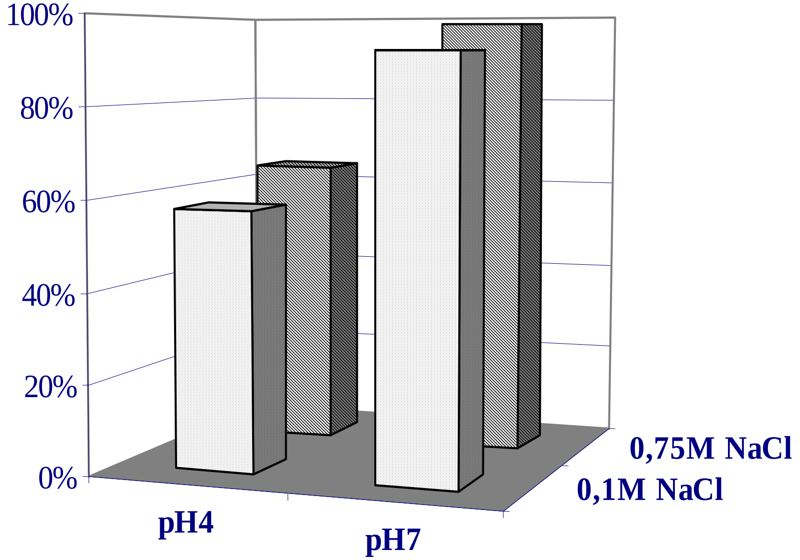


plasma



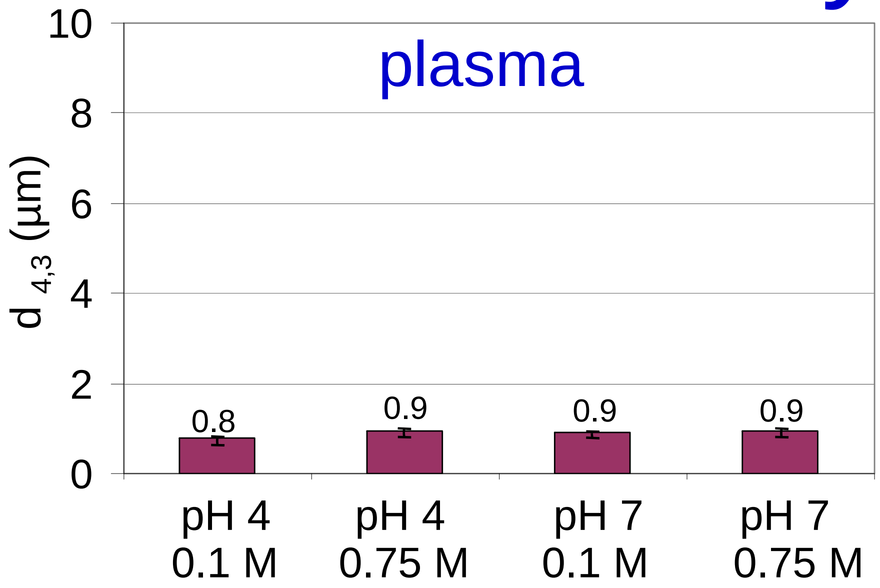
granules

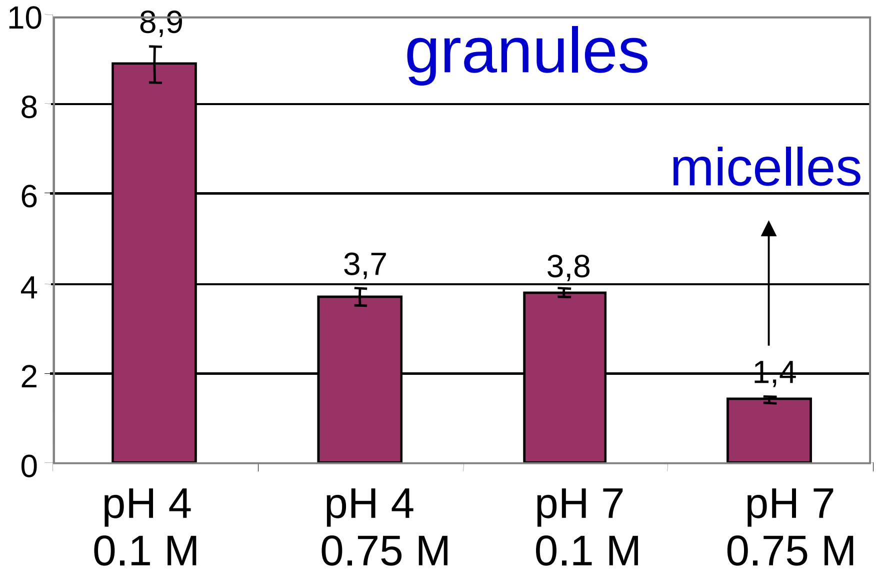
yolk



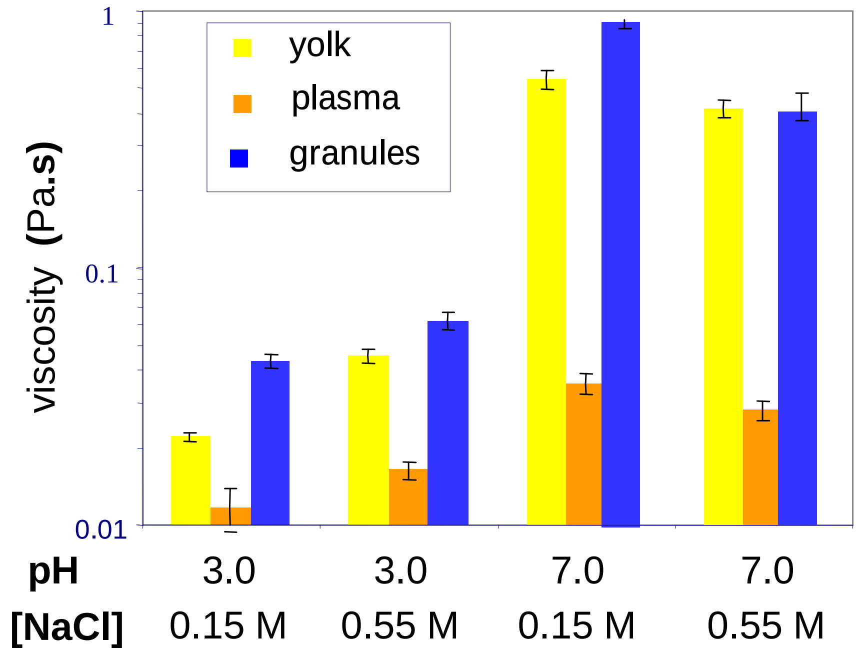
Ledenmat et al., 2000, Food Hydrocolloids, 14, 539–549

Emulsifying properties





	Plasma proteins	Granules proteins
Yolk	52	48
pH3 / 0.15 M	61	39
pH3 / 0.55 M	63	37
pH7 / 0.15 M	47	53
pH7 / 0.55 M	49	51



Highlights

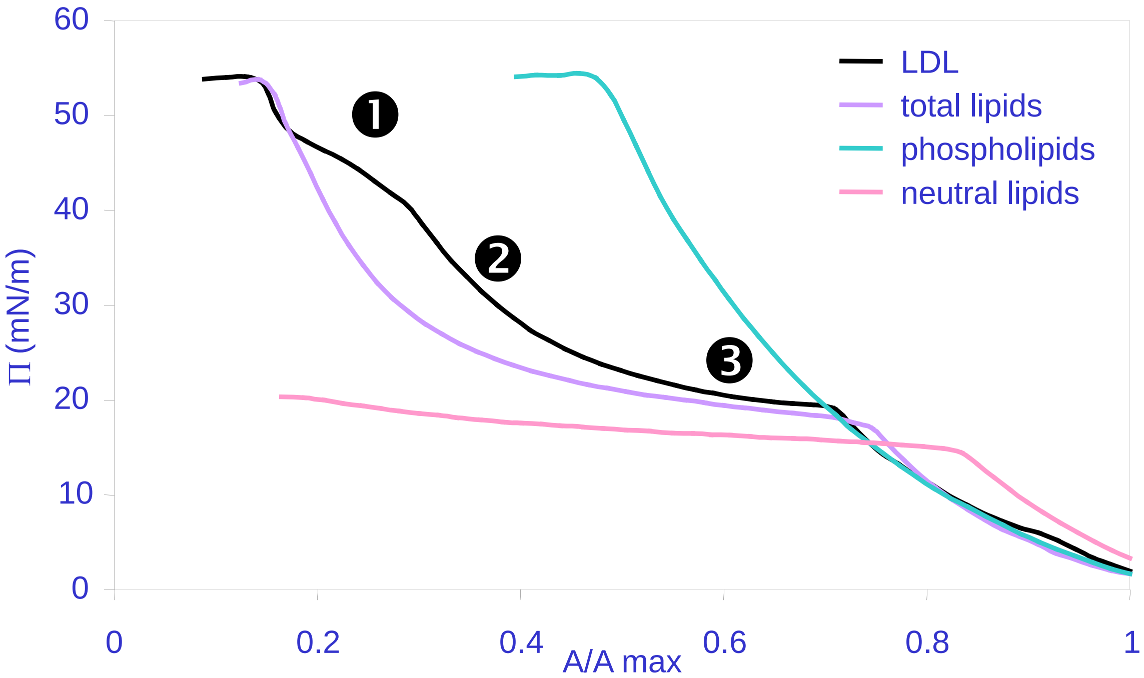
- ❑ yolk structures are governed by natural nano- (LDL) and micro- to nano- (granules) assemblies with specific properties
  - → when soluble granules are in form of micelles

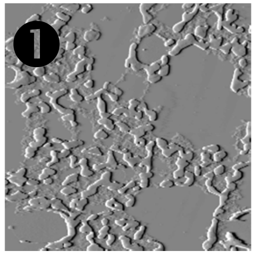
- ❑ $\forall$ conditions, plasma constituents are more efficient than granules to stabilise oil-in-water emulsions
  - → granules constituents contribute to the rheological behaviour of yolk and yolk emulsions
  - →competition between granules constituents and LDL at the interface: main contribution of LDL but pH-Γ/2 dependent

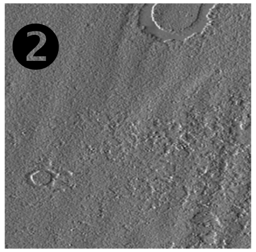
Yolk constituent adsorption at interfaces

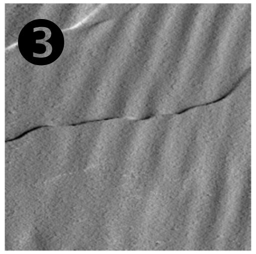
LDL at an interface

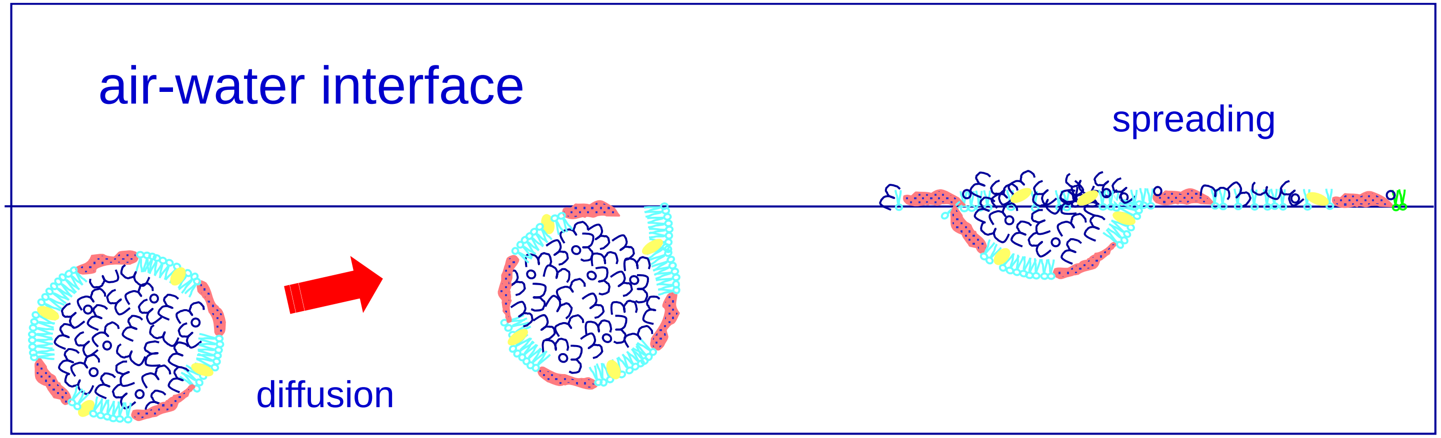
pH 7





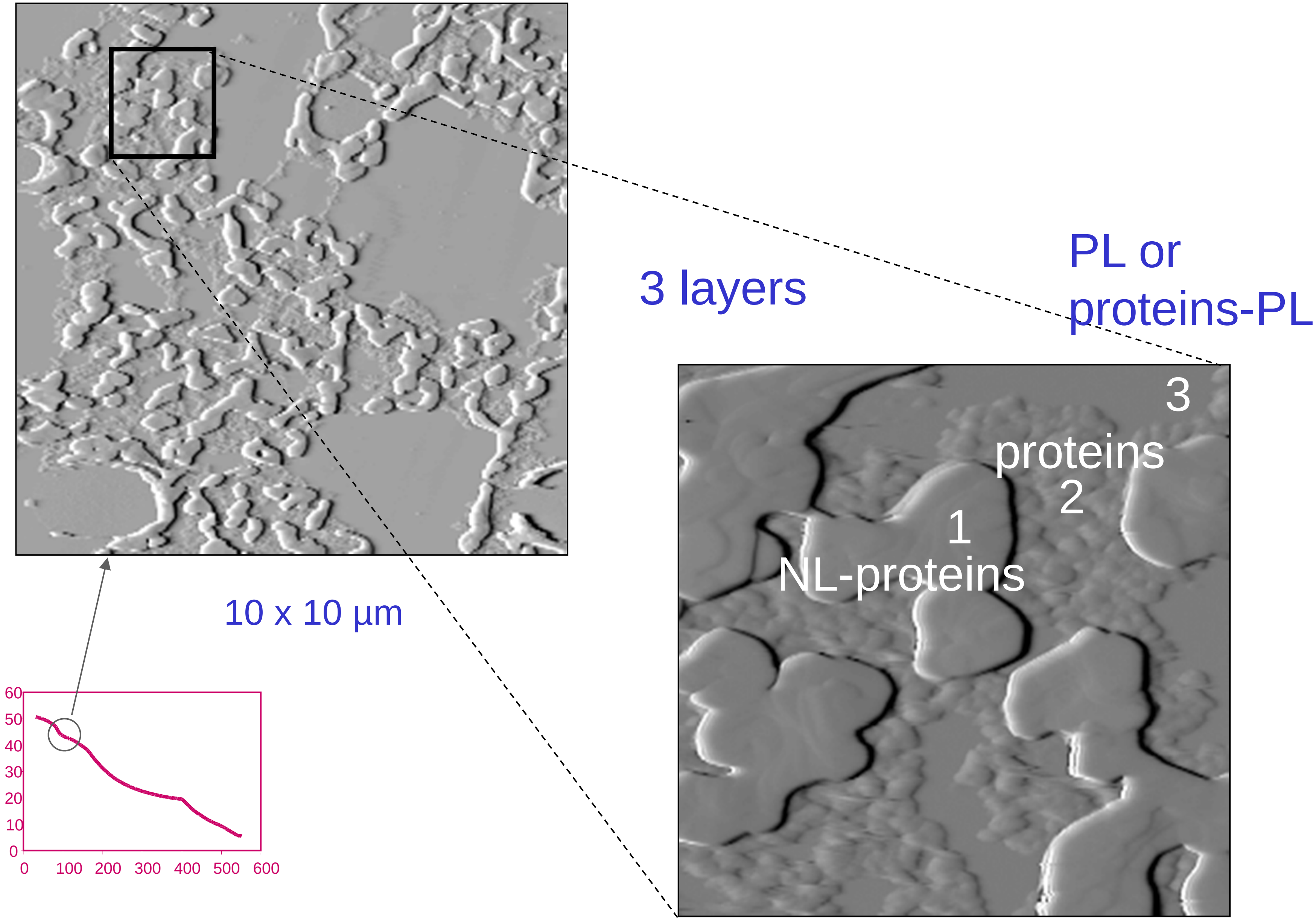




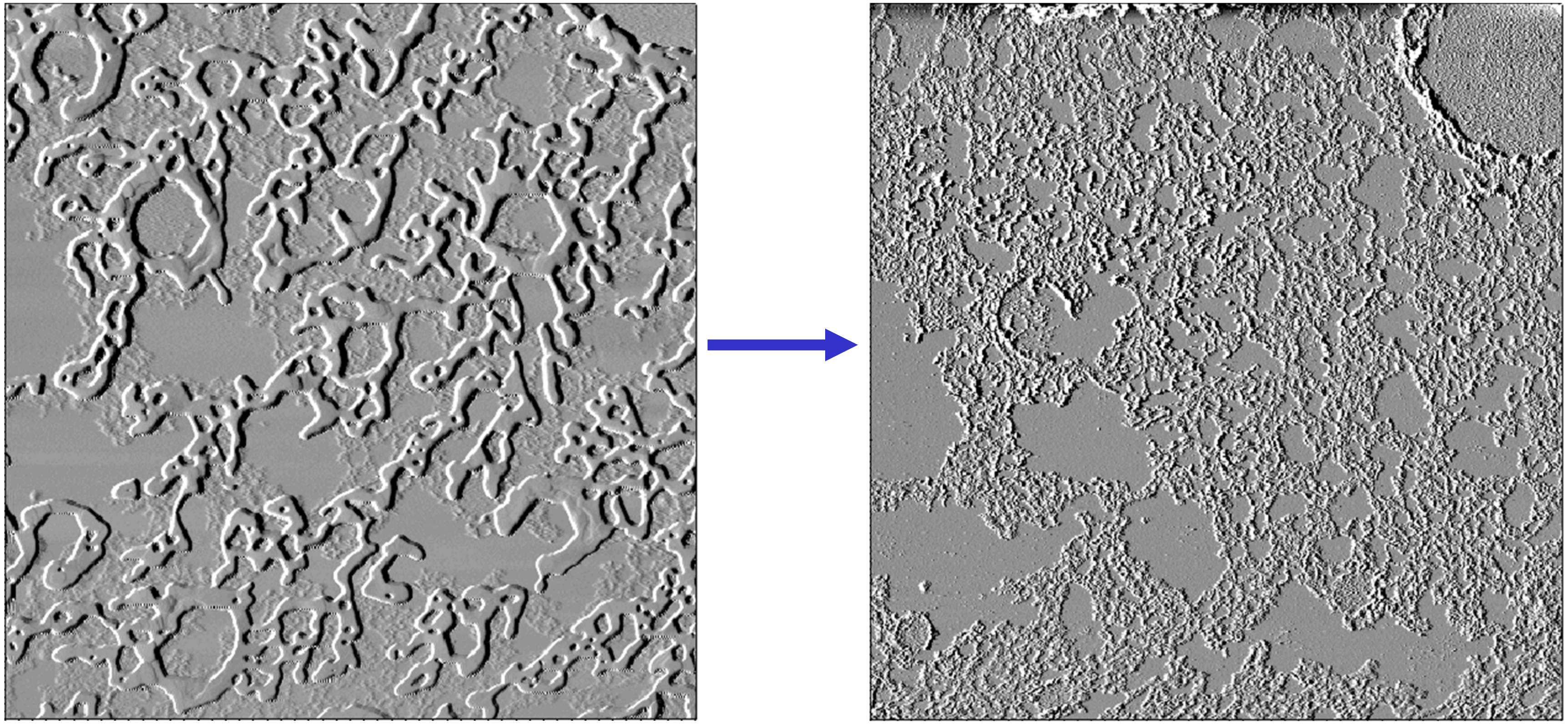


Martinet et al., 2003, Colloids and Surfaces B: Biointerfaces, 31, 185-194
Dauphas et al., 2006, J. Agric. Food Chem., 54, 3733-3737
Dauphas et al., 2007, Colloids and Surfaces B: Biointerfaces, 54, 241-248

pH 7


3 layers
PL or
proteins-PL
3
proteins
2
1
NL-proteins
10 x 10 µm
2 x 2 µm
60
50
40
30
20
10
0
0
100
200
300
400
500
600

Air | Butanol

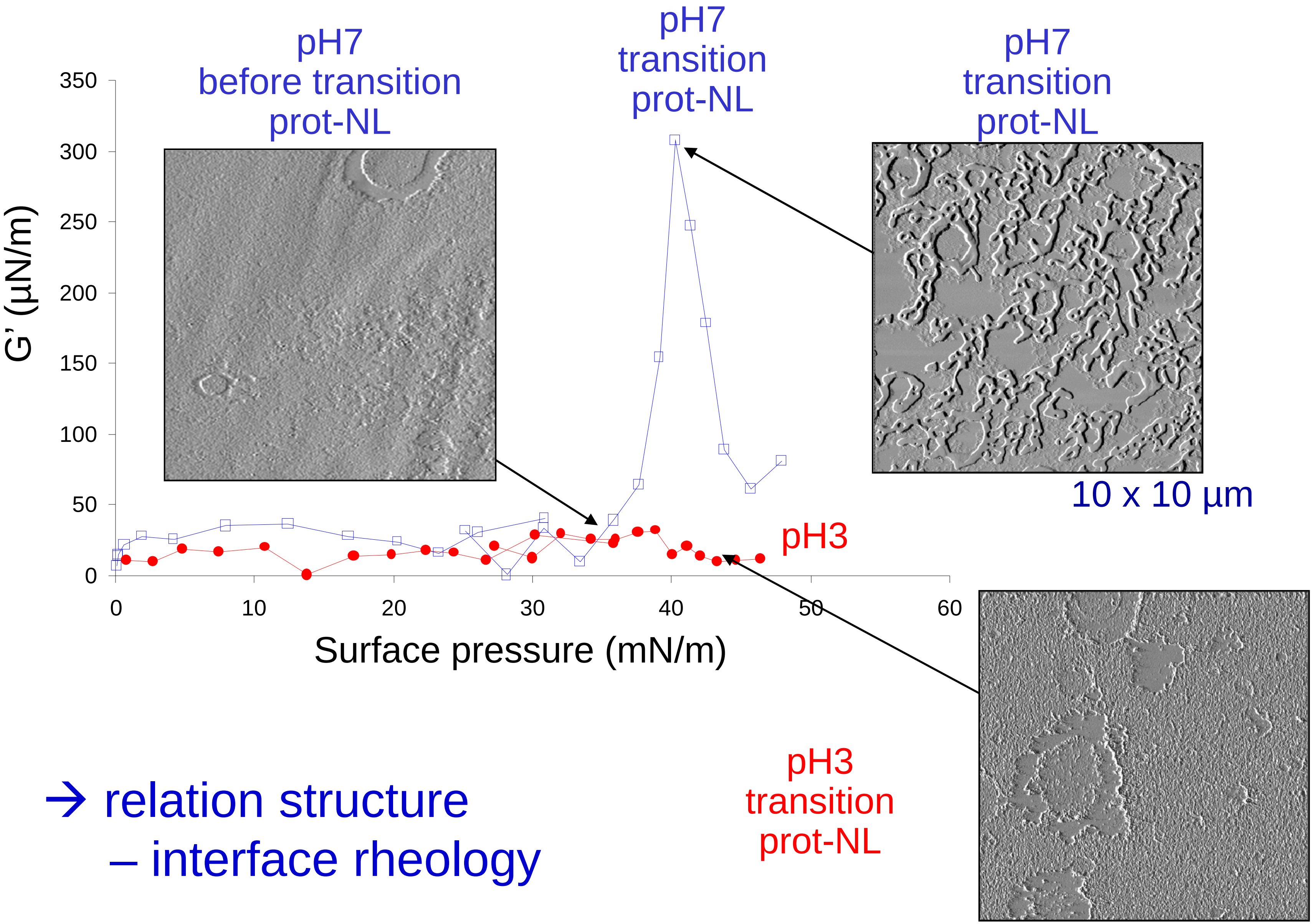


10 x 10 µm | 10 x 10 µm

➔ blocks: presence of lipids

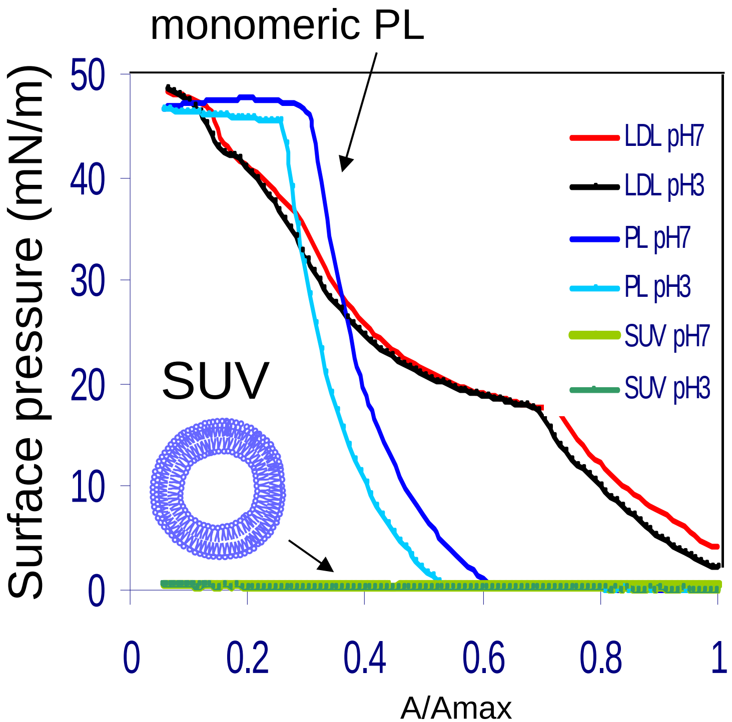
➔ rough: proteins

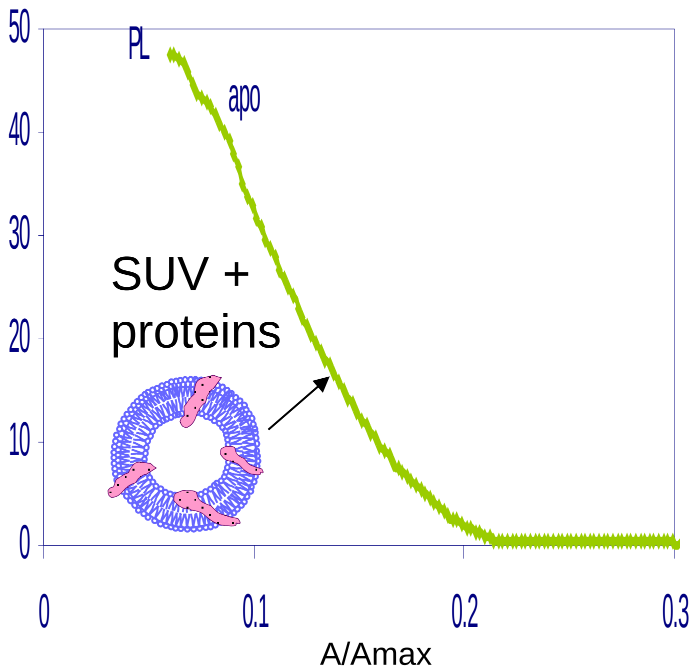
Shear rheology



→ relation structure
– interface rheology

Biomimetic study



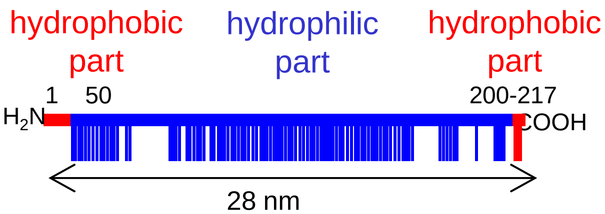


- ❑ monomeric PL give the same transition than that observed with LDL
- ❑ PL organized in SUV do not spread at the interface

- ❑ the biomimetic model (with inserted proteins) spread very rapidly

❑ proteins serve as an anchorage point before denaturation and then LDL spreading at the interface

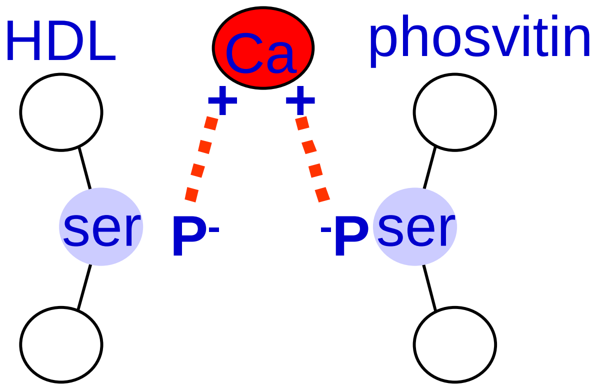
Phosvitin characteristics



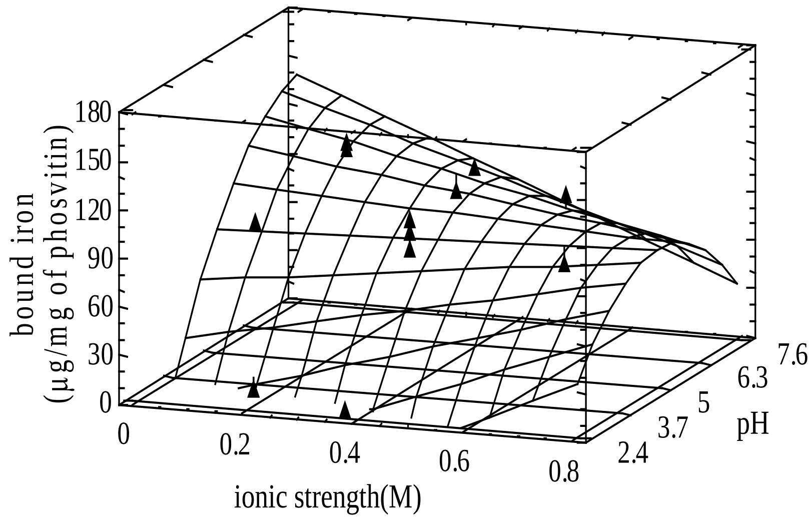
50% phosphorylated serines
8% hydrophobic a.a at the two extremities

Highly charged tribloc model (-220 mv)

Granular structure

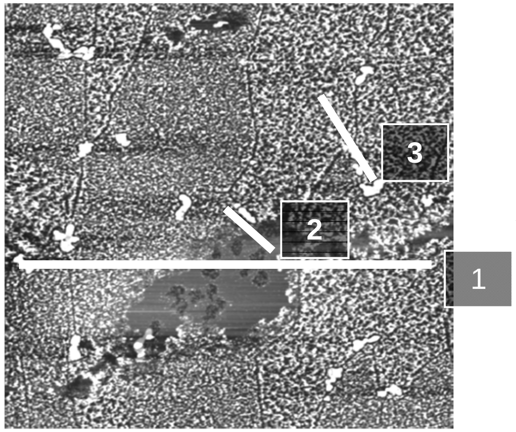


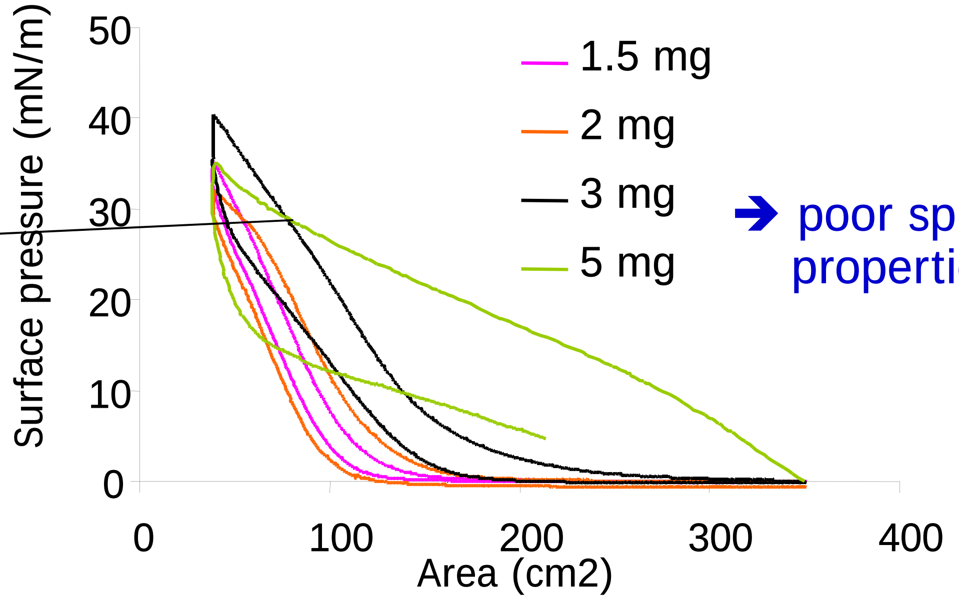
Metal chelation



Castellani et al., 2004, Food Chem., 85, 569–577

Phosvitin at an interface

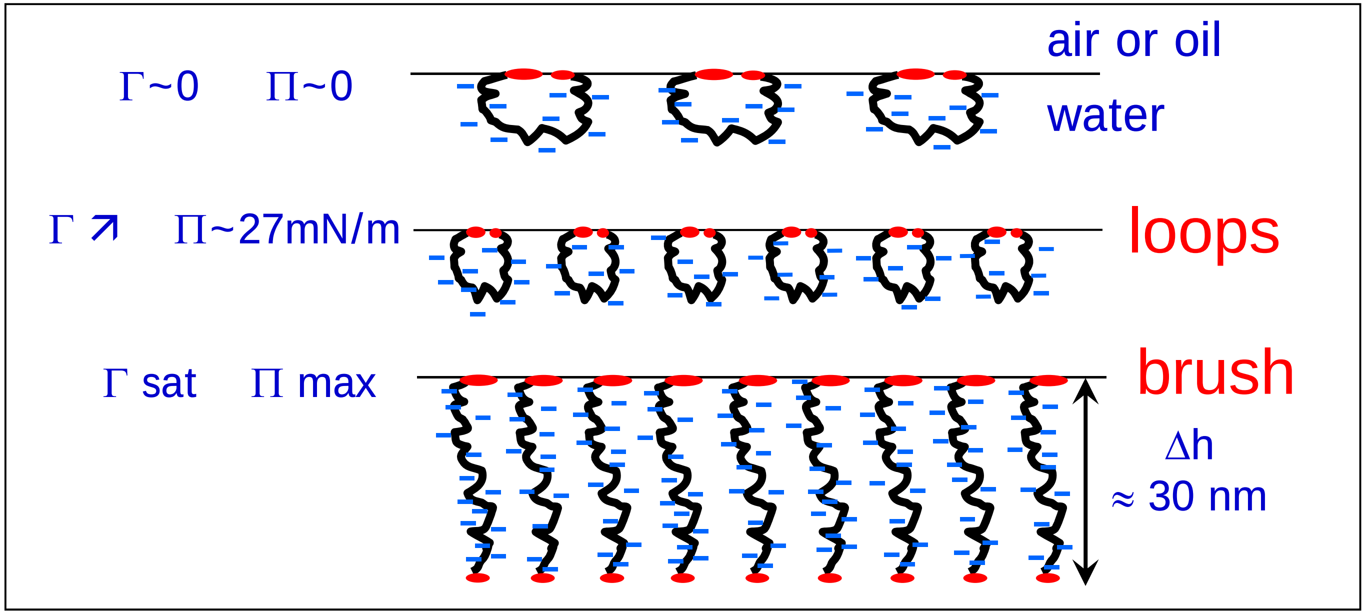




➔ poor spreading properties

Δh = 25-30 nm at Π ~ 27 mN/m

Δh = 12-14 nm at Π ~ 15 mN/m



Belhomme et al., 2007, Food Hydrocolloids, 21, 896–905

Belhomme et al. 2008, Colloids and Surfaces B: Biointerfaces, 63, 12–20

Highlights

- relevance of supramolecular organisation LDL through interactions between amphiphilic apoproteins and phospholipids

  → this structure allows the transport through the aqueous phase until the interface of these non soluble amphiphilic species where they spread

  → proteins are essential for the initial adsorption and disruption of LDL at the interface, allowing the adsorption of proteins and phospholipids in different mixed layers

- surface active soluble granules are in reality constituted by micelle-like aggregates of 100-200 nm

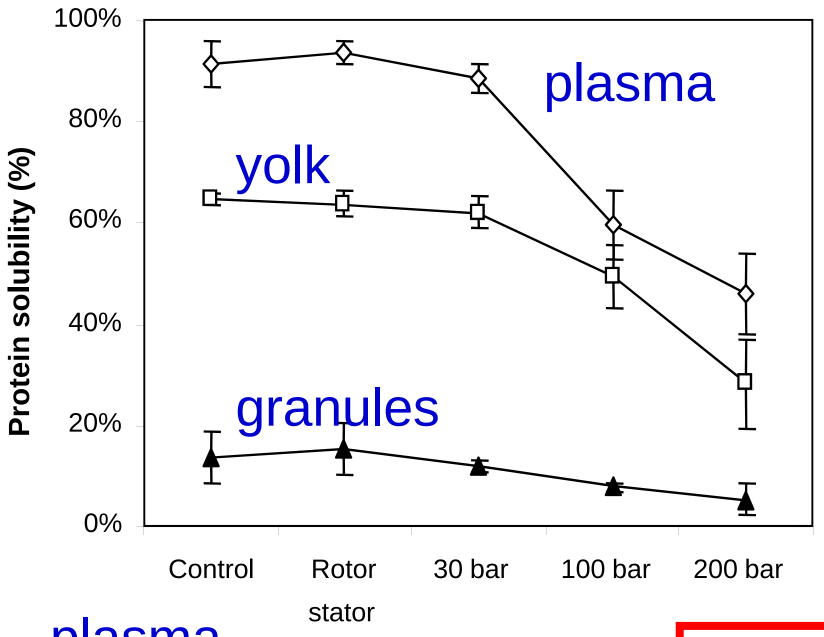
  → in purified form phosvitin constitutes loops or brushes depending on environmental conditions

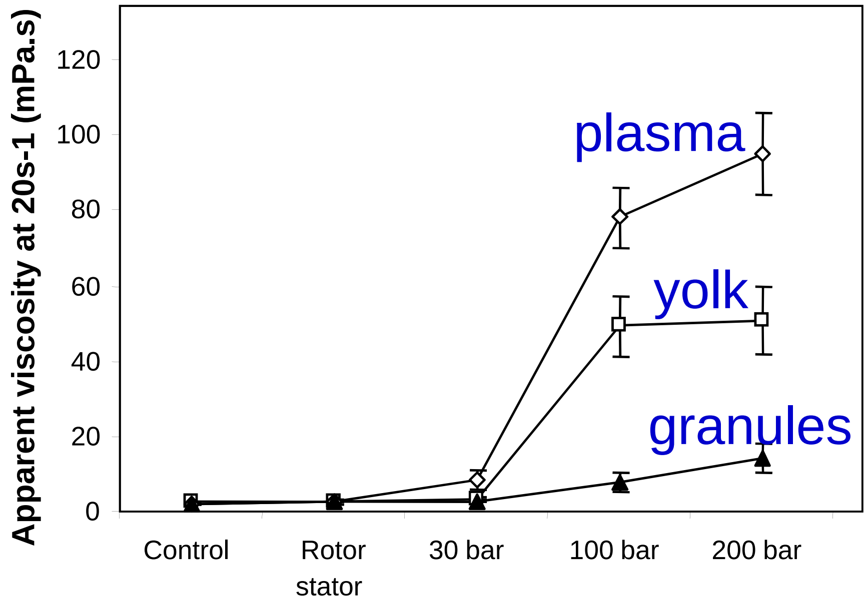
Impact of various processes on strctures and functionalities

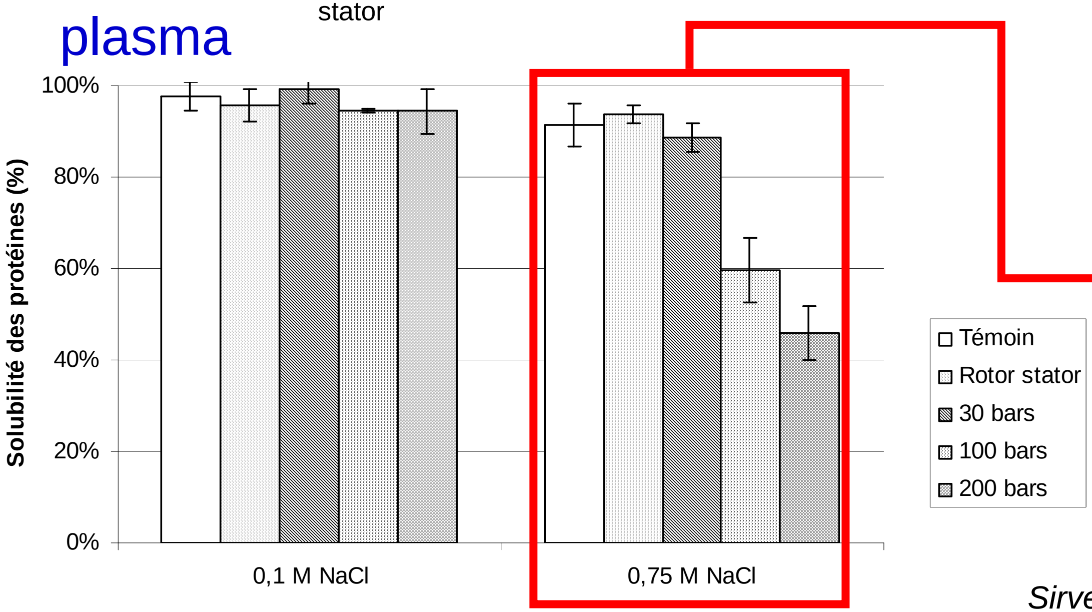
1. dynamic high-pressure
2. static high-pressure
3. heat treatments
4. mechanical treatments
5. gastro-intestinal tract

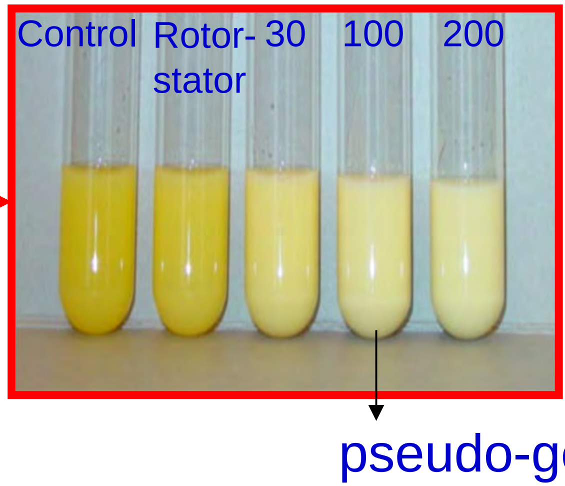
❶ Dynamic high-pressure treatments

pH 4 and 0,75 M NaCl







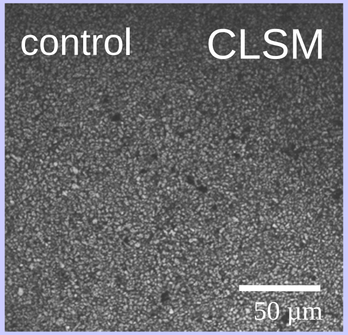


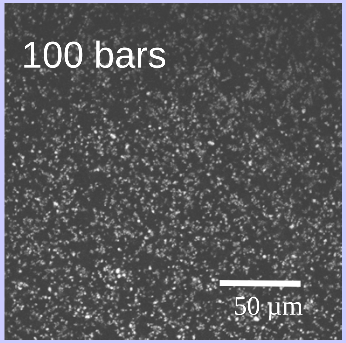
Sirvente et al., 2007, J. Agric. Food Chem., 55, 9537–9544

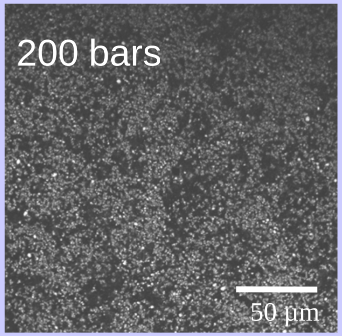
Dynamic high-pressure treatments

Granules

pH 4 and 0,75 M NaCl





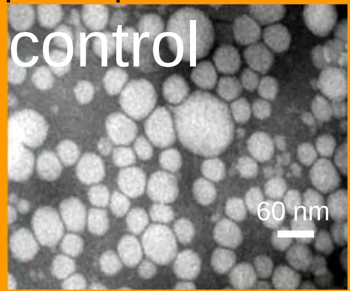


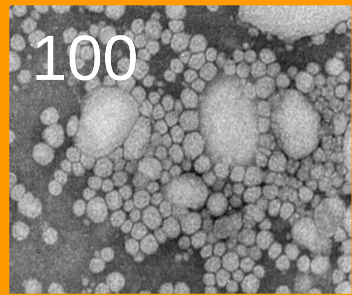
→ structuration of granules under HP

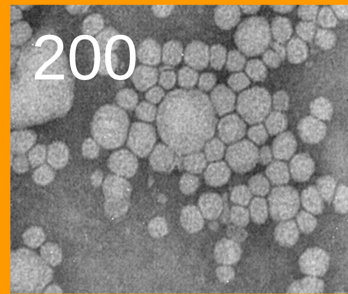
Plasma → LDL

TEM

pH 7 / pH 4 and 0,1 M NaCl

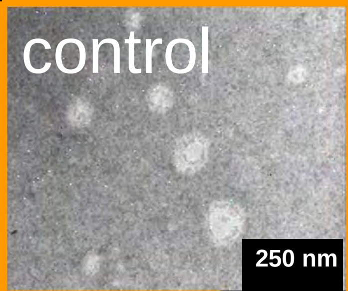


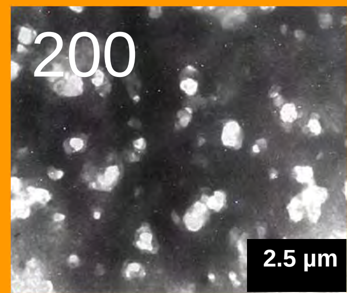




→ intact structures

pH 4 and 0,75 M NaCl



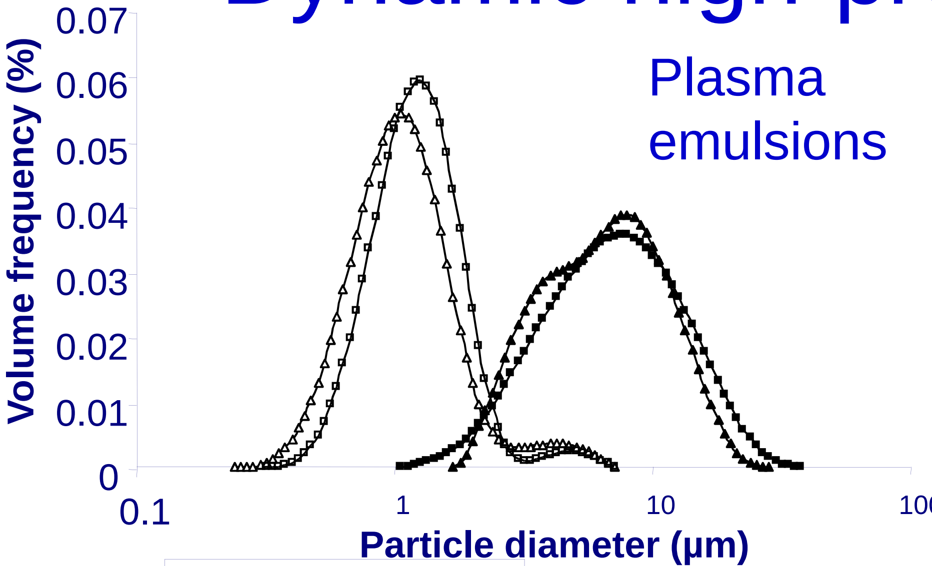


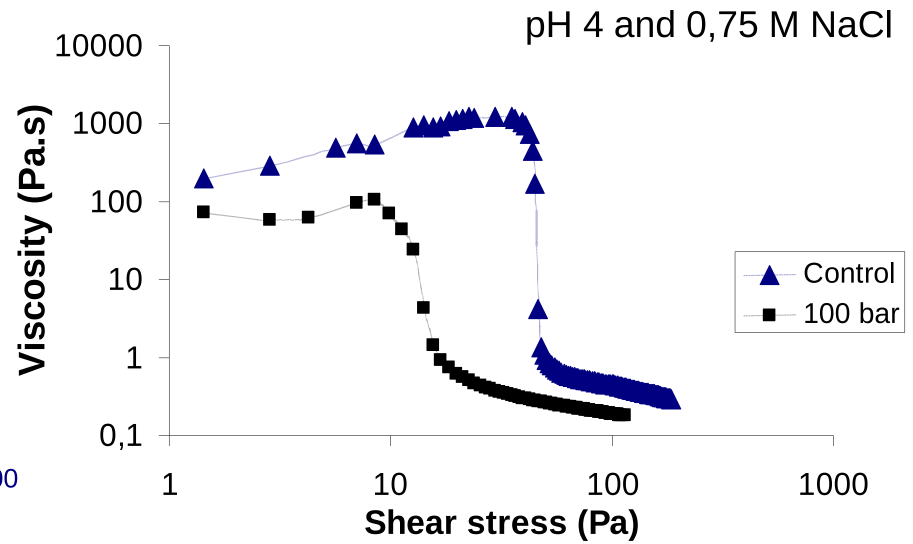
→ disruption, re-organisation, gelation

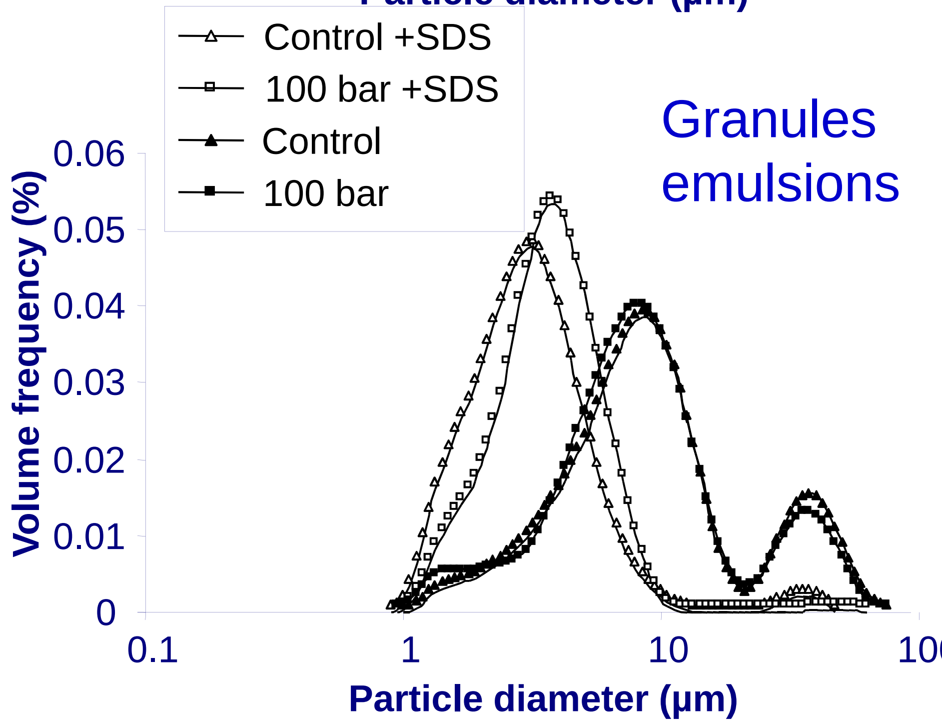
→ environment dependent

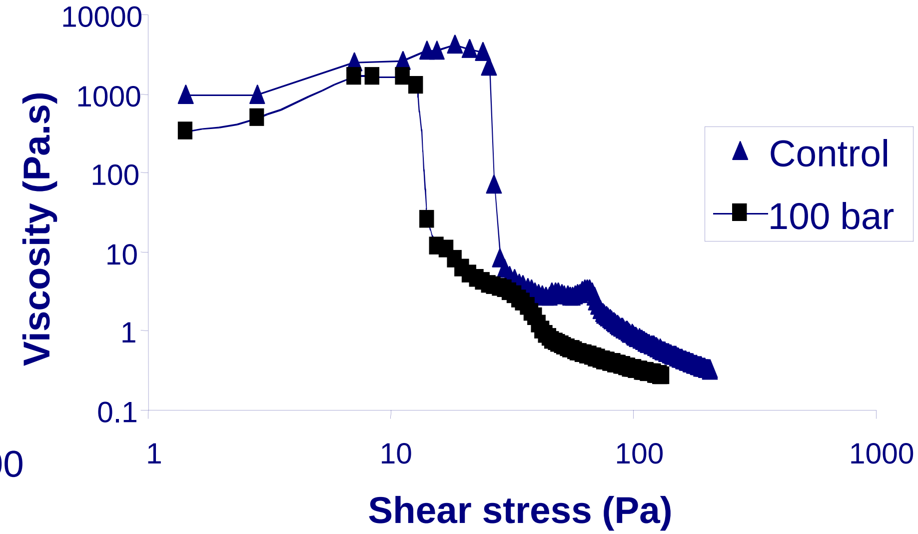
Sirvente et al., 2007, J. Agric. Food Chem., 55, 9537–9544

Dynamic high-pressure treatments



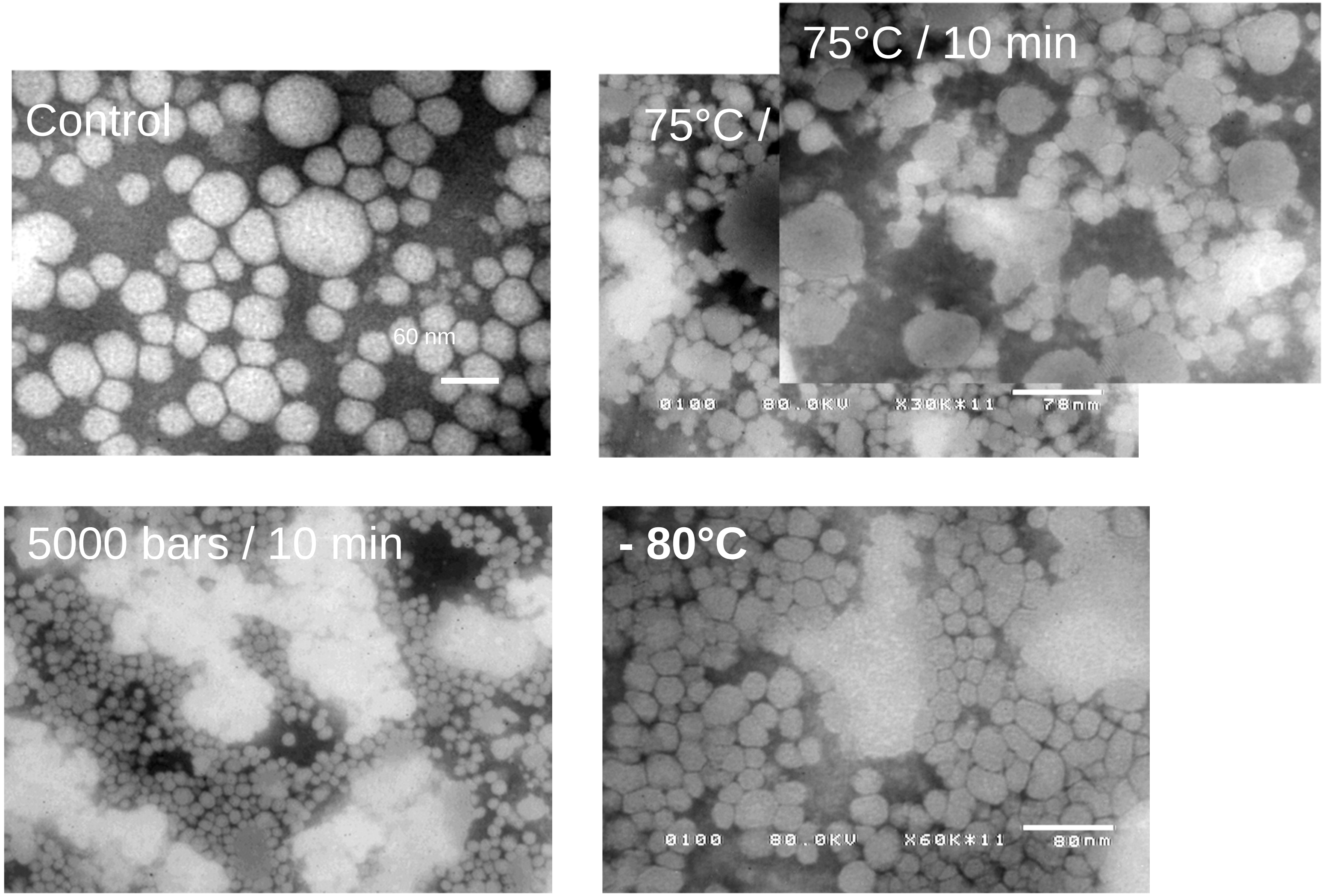






Sirvente et al., 2007, J. Agric. Food Chem., 55, 9537–9544

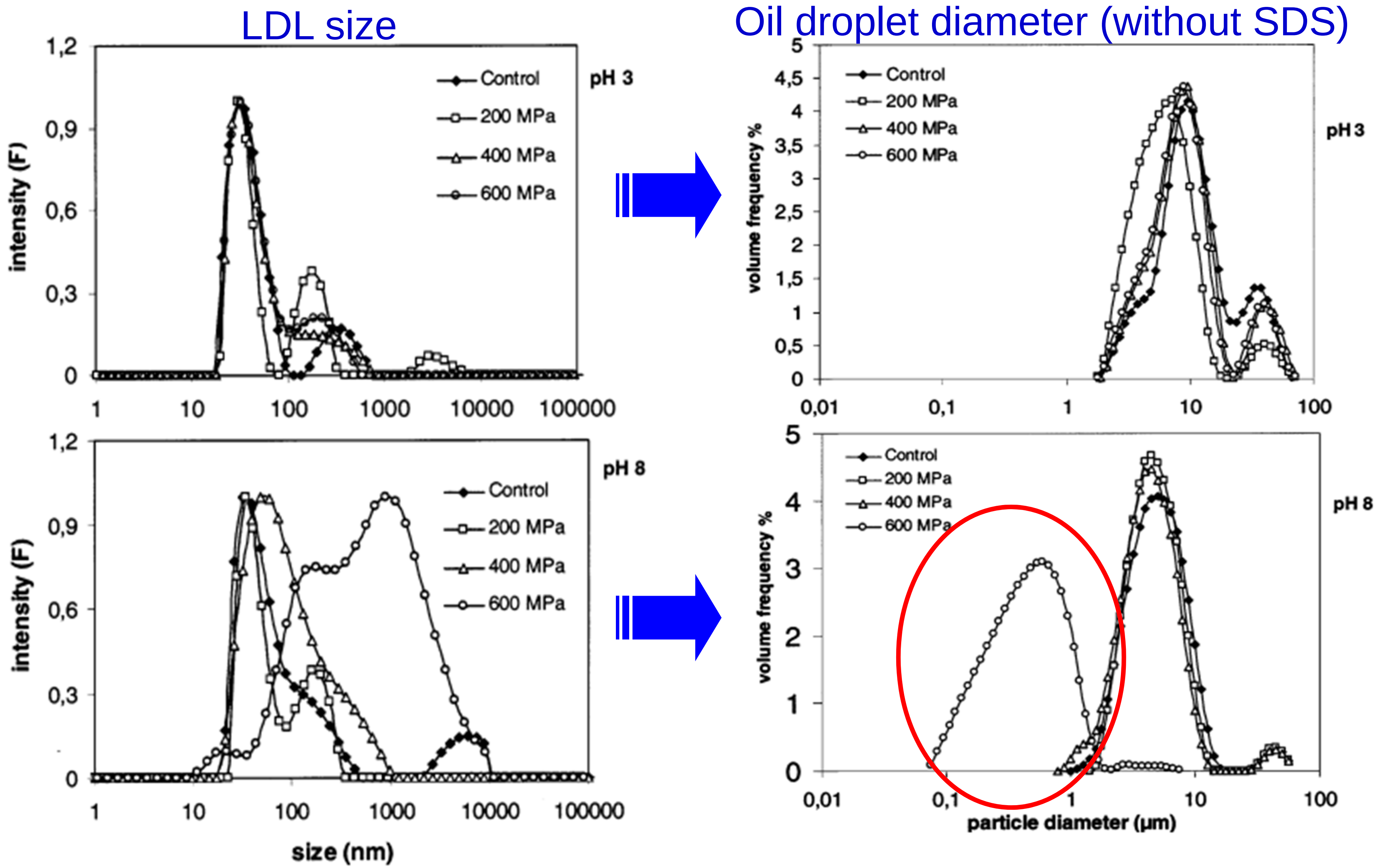
Different treatments on LDL



→ disruption and re-arrangements under these different treatments

Anton et al., 2003, Food Chemistry, 83, 175–183

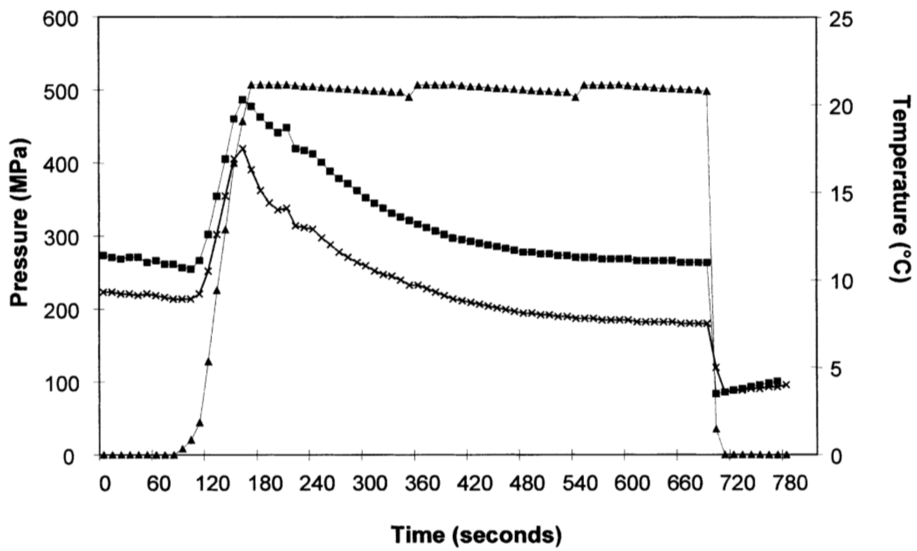
❷ Static high-pressure on LDL

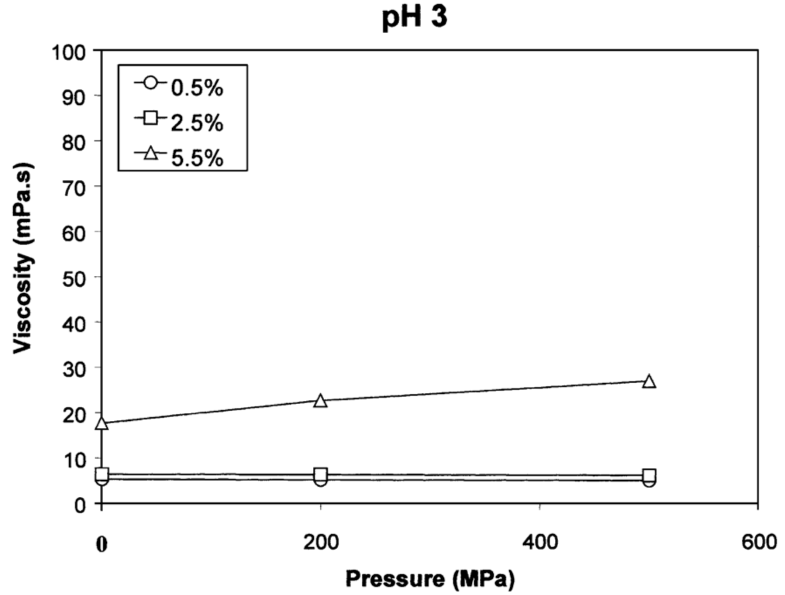


→ modifications of LDL increase functionality from 600 MPa

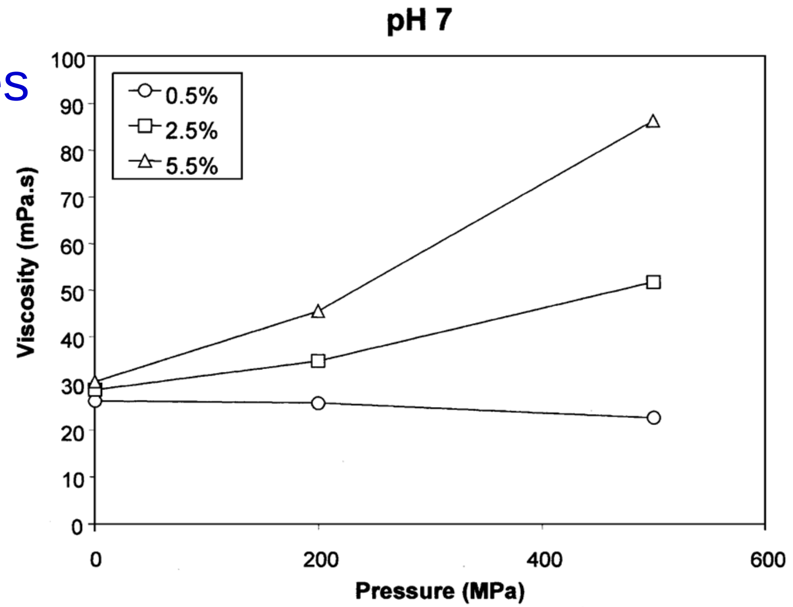
Speroni et al., 2005, J. Agric. Food Chem., 53, 5719−5725

Static high-pressure on LDL emulsions





- ❑ HP treatment of yolk emulsions provides suitable elimination of total microbial flora
- ❑ no change of physicochemical properties at pH 3
- ❑ increase of viscosity at pH 7 → droplet flocculation



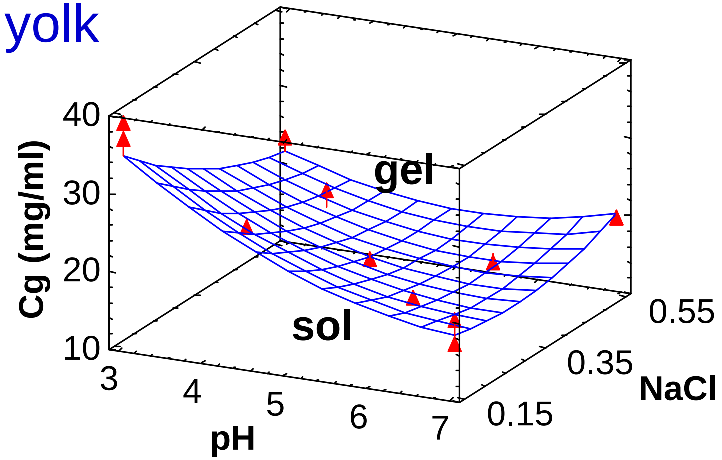
Anton et al., 2001, Innovative Food Sci. Emerg. Tech., 2, 9−21

❸ Thermal treatment

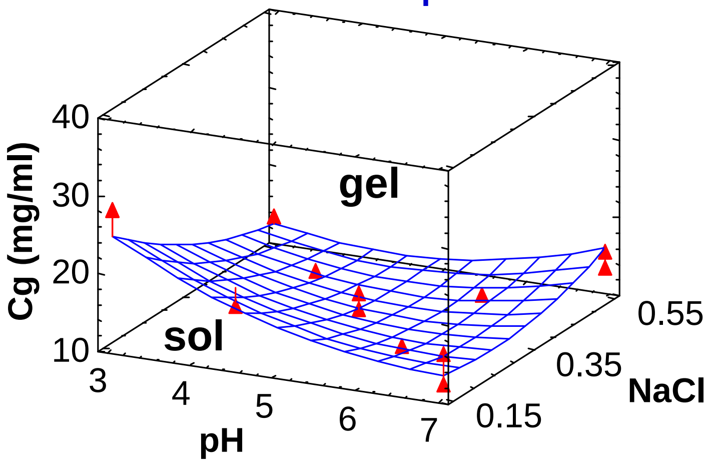
Heating solutions of yolk,
plasma and granules at 80°C

→ phase diagrams

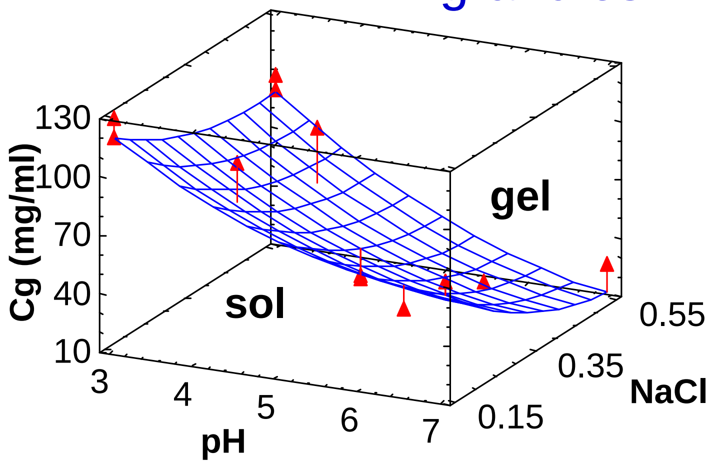
yolk



plasma



granules



- ❑ plasma much more sensitive
- ❑ depends on conditions for granules

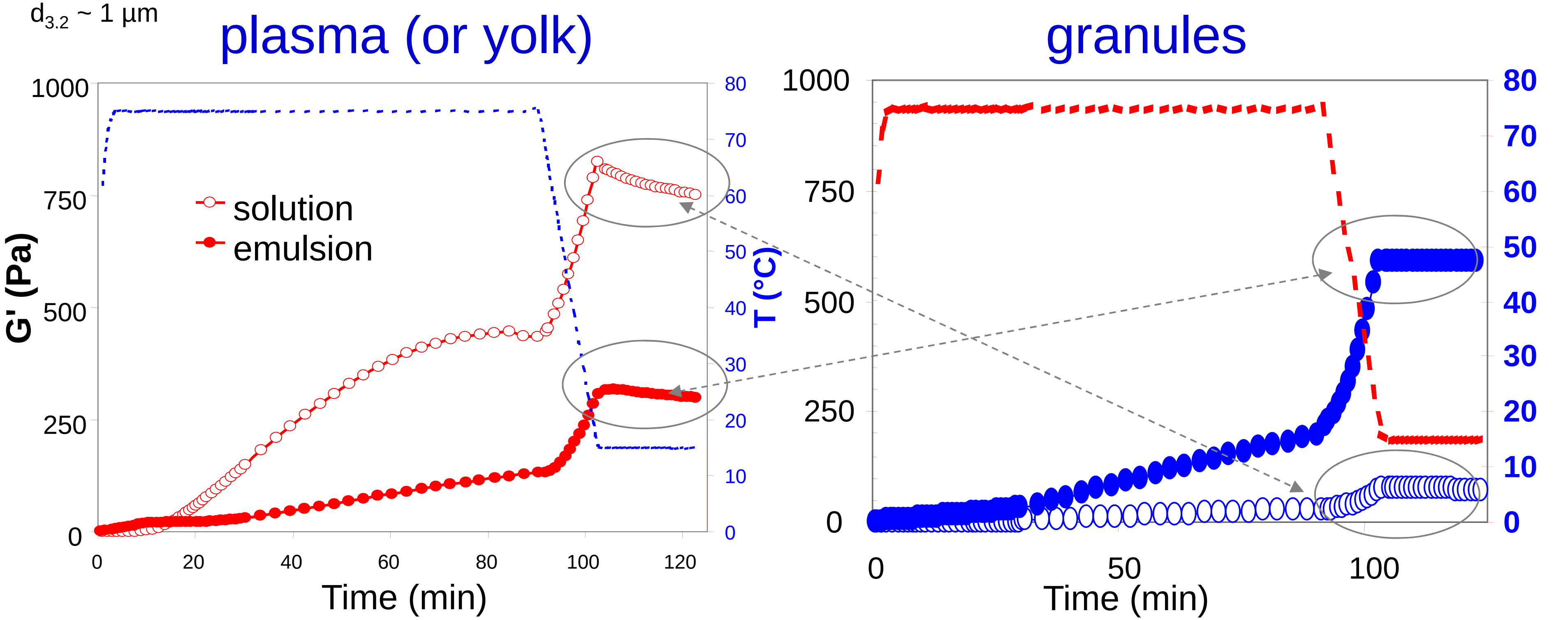
Ledenmat et al., 1999, J. Food Sci., 64, 194-197

Ledenmat et al., 2000, J. Food Sci., 65, 581-584

pH 7,0
NaCl 0,55 M
protéines 55 mg/ml

In solution or in emulsion ?

emulsions H/E 30:70
$d_{3.2}$ ~ 1 µm



inactive fillers

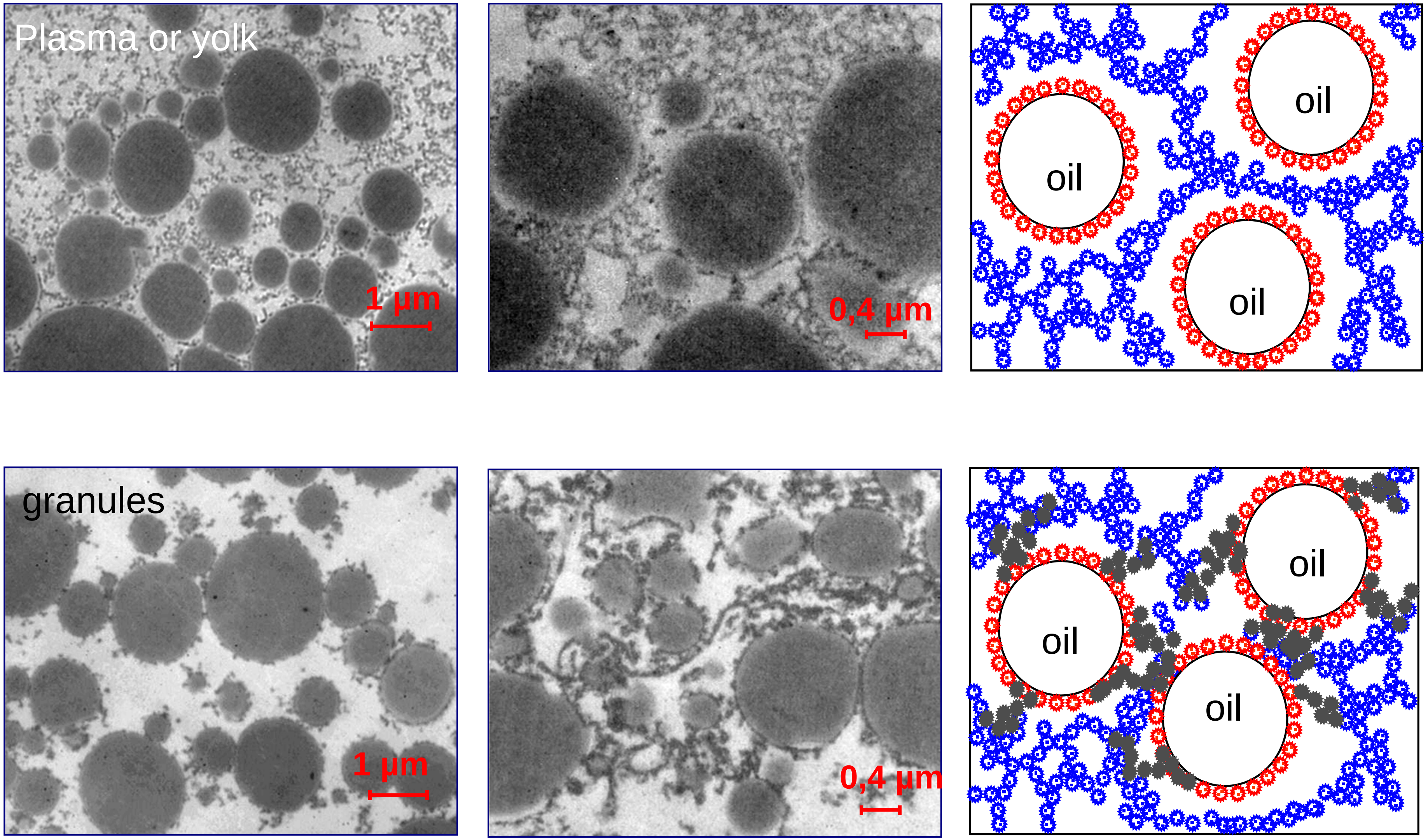
active fillers

- ❑ weakening of gel due to ↘ prot. conc. and lack of droplet-droplet interactions with plasma constituents

- ❑ re-inforcement of gels due to droplet-droplet interactions through granules proteins

Anton et al., 2001, Colloids and Surfaces B: Biointerfaces, 21, 137–147

Inactive fillers

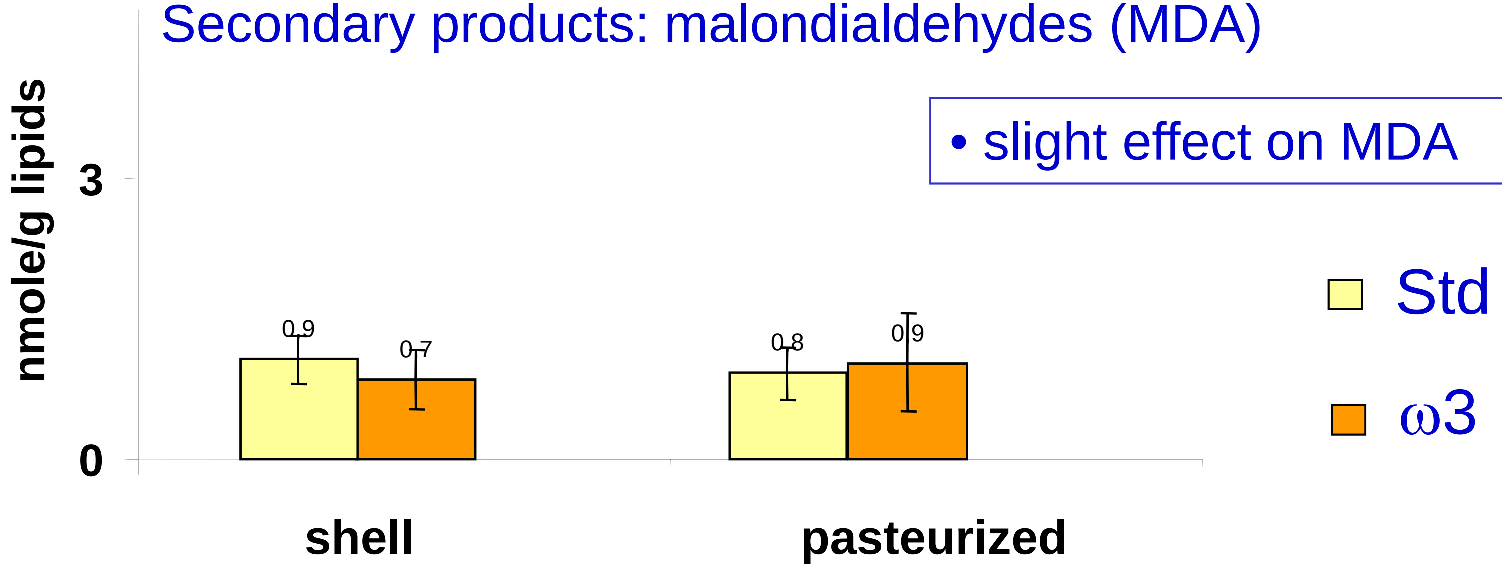


Active fillers

Anton et al., 2001, Colloids and Surfaces B: Biointerfaces, 21, 137–147

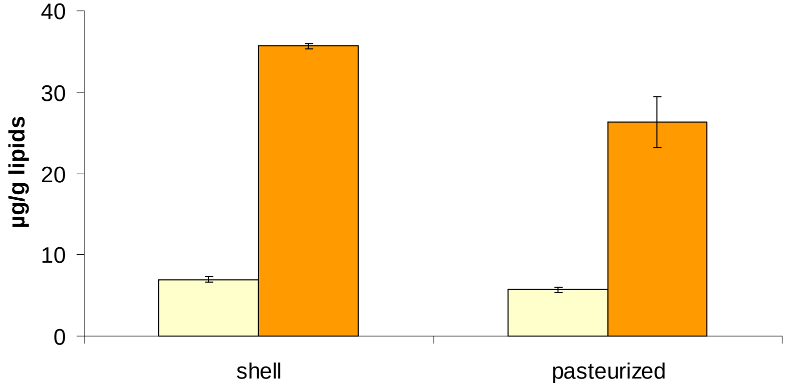
Pasteurisation and lipid oxidation

Secondary products: malondialdehydes (MDA)

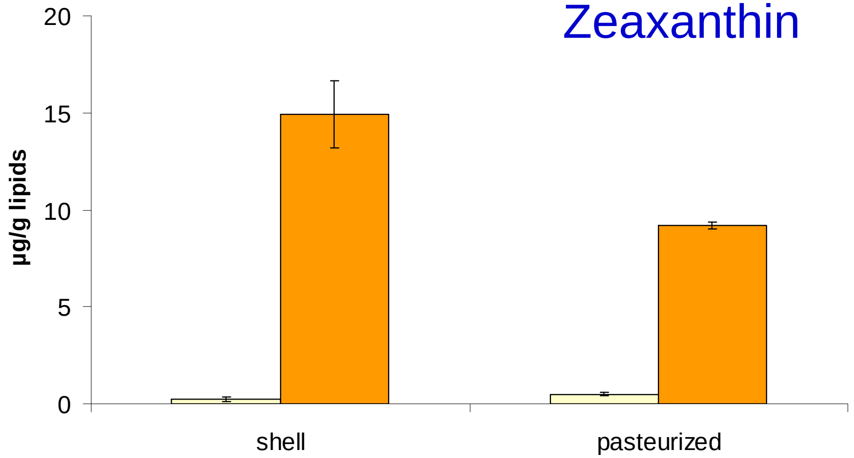


• slight effect on MDA

Lutein



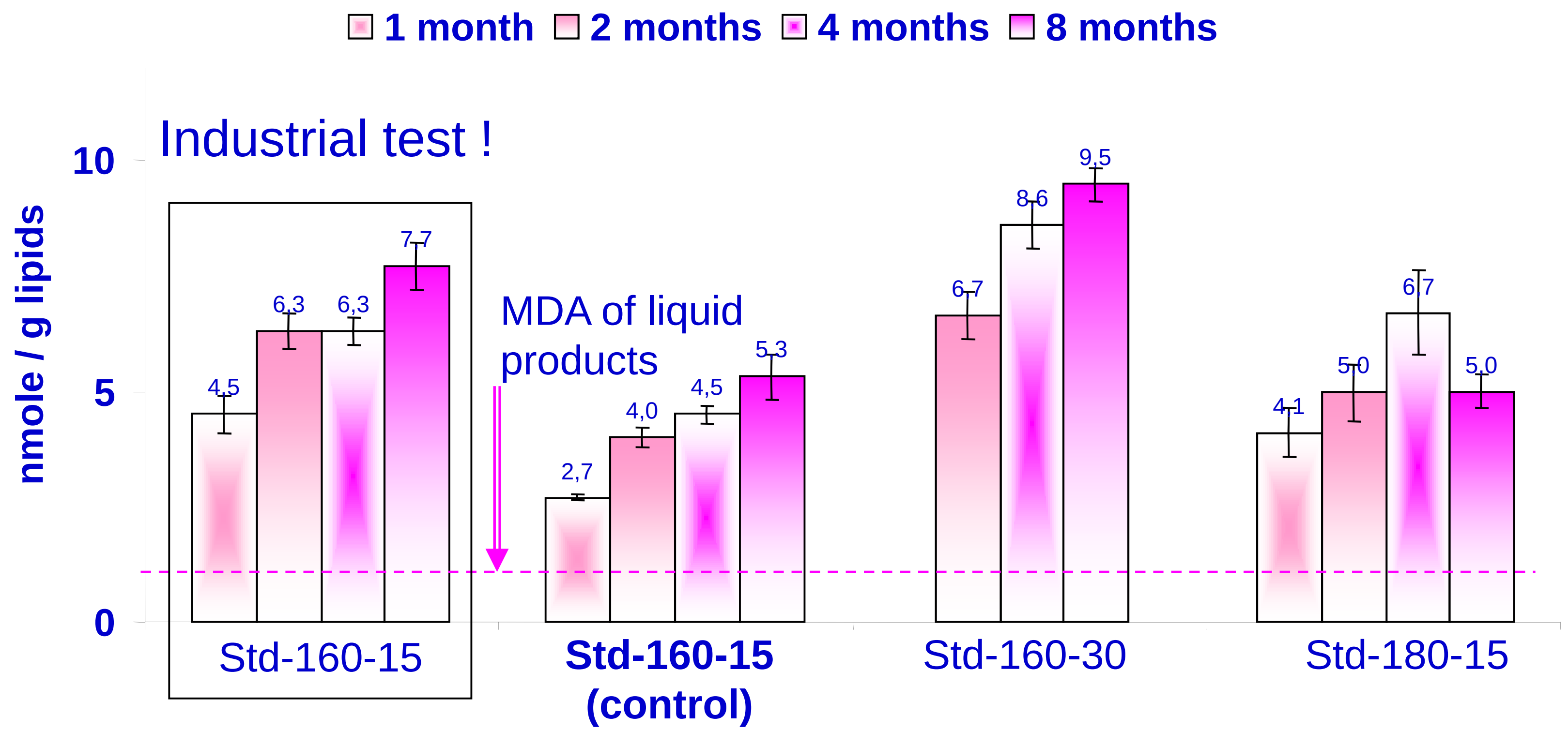
Zeaxanthin



• pasteurization: ↘ carotenoids → protective effect

Spray-drying and lipid oxidation

Secondary products (MDA)



- ↗ MDA / liquid → ↗ of oxidation due to spray-drying
- ↗ MDA with T° spray-drying
- important ↗ MDA with storage T° and storage time
- differences between pilot and industrial processes
- levels “reasonable” ! → no sensorial degradation

❹ Mechanical treatment: foaming

Sunflower oil

Yolk solution

Silverson → 7.000 rpm, 5 min

HPH → 200 bar

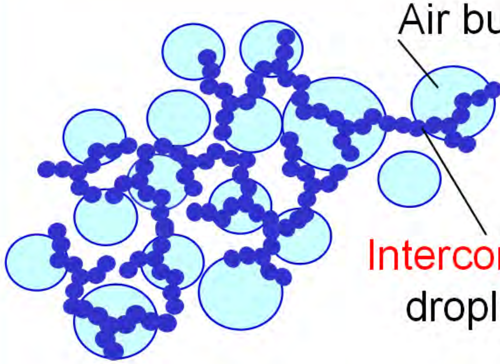
→

Y

G

P

Day0 Day3 Day6 Day21



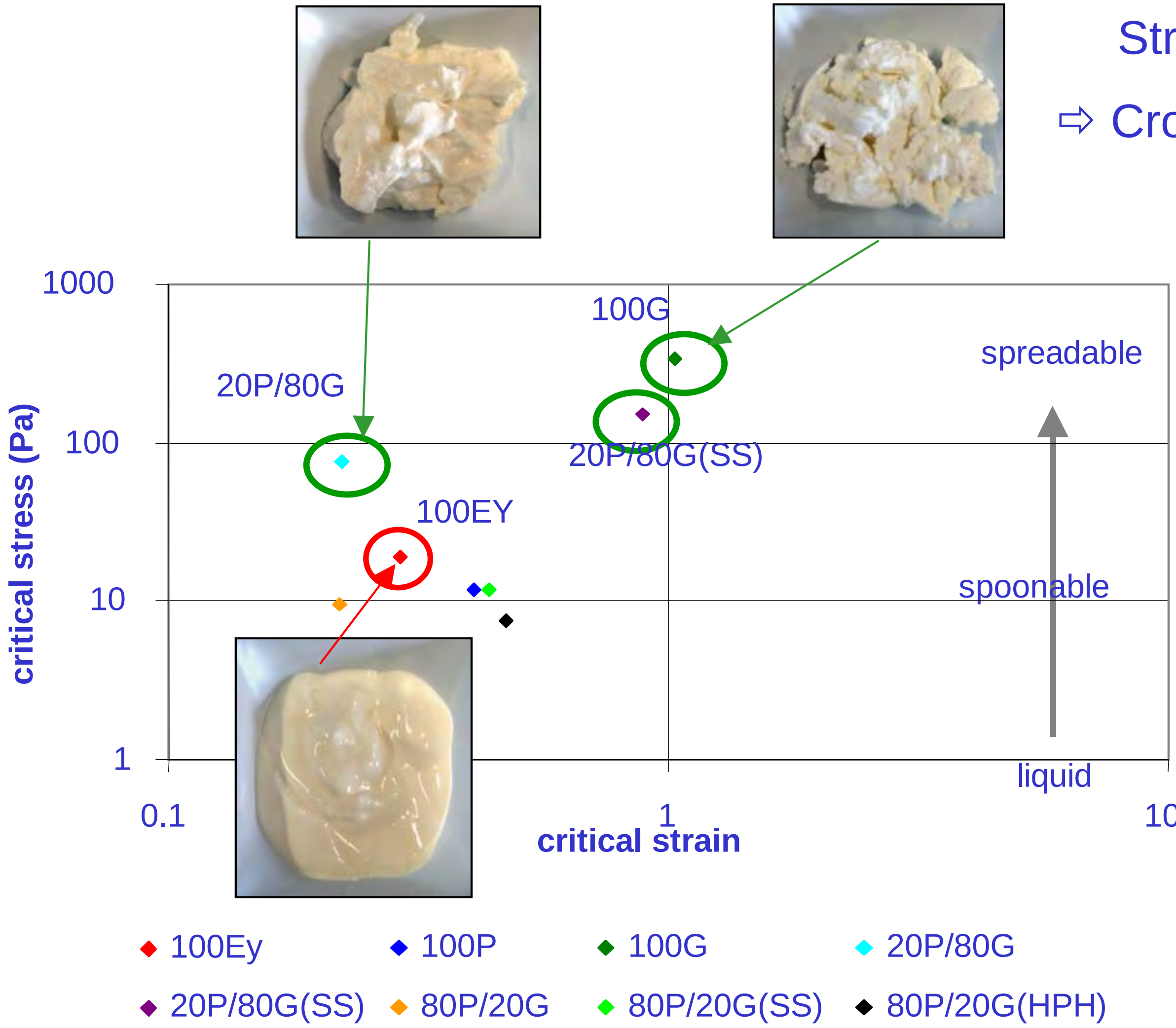
Aerated granules emulsion

- ❑ foams made with granules emulsions are the most promising (texture and stability)
- ❑ no coalescence observed after foaming

- ❑ oil volume fraction obtained : 30-40% for mayonnaise-like texture → low-fat mayonnaise
- ❑ foam stability favored by high elastic modulus and high critical stress of emulsions

Anton et al., 2007, PCT/EP2007063280

Sequential re-incorporation of treated granules and plasma

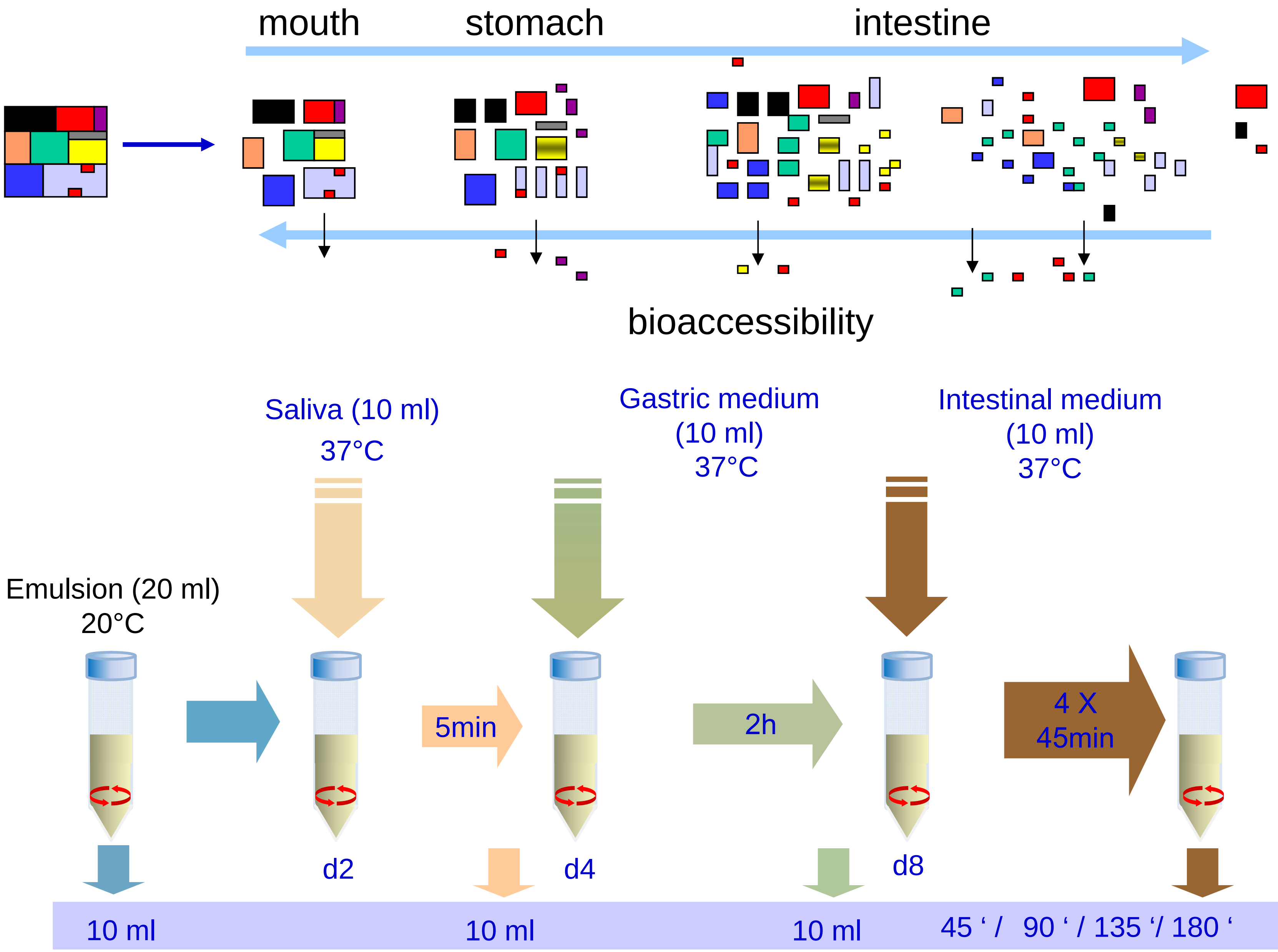


Stress sweep in oscillatory flow

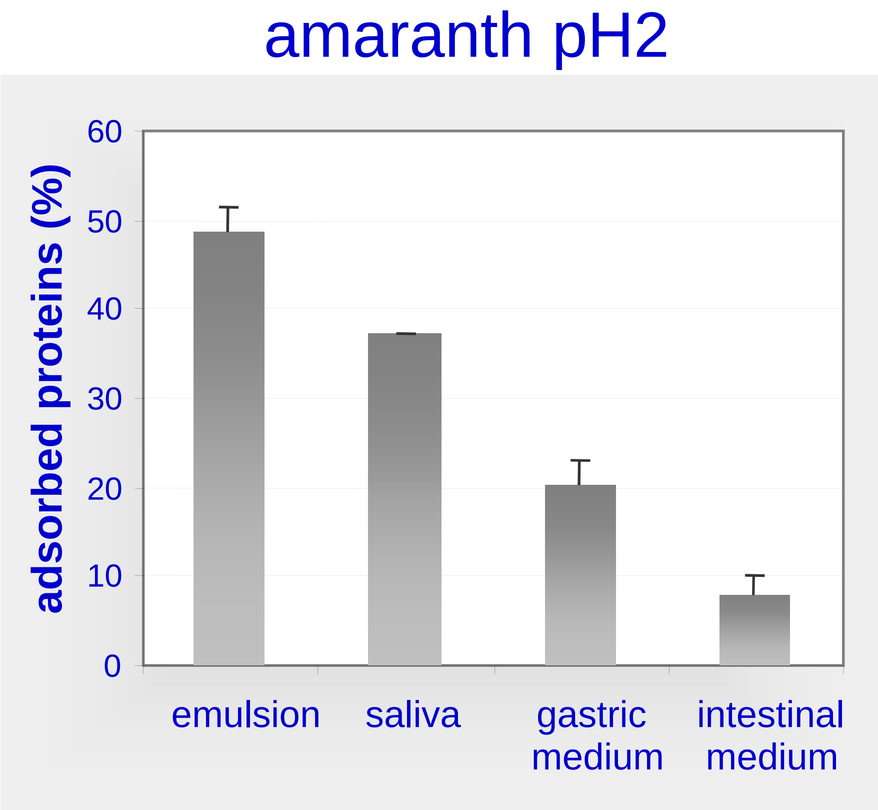
⇨ Cross over point G” = G’ (tan δ = 1)

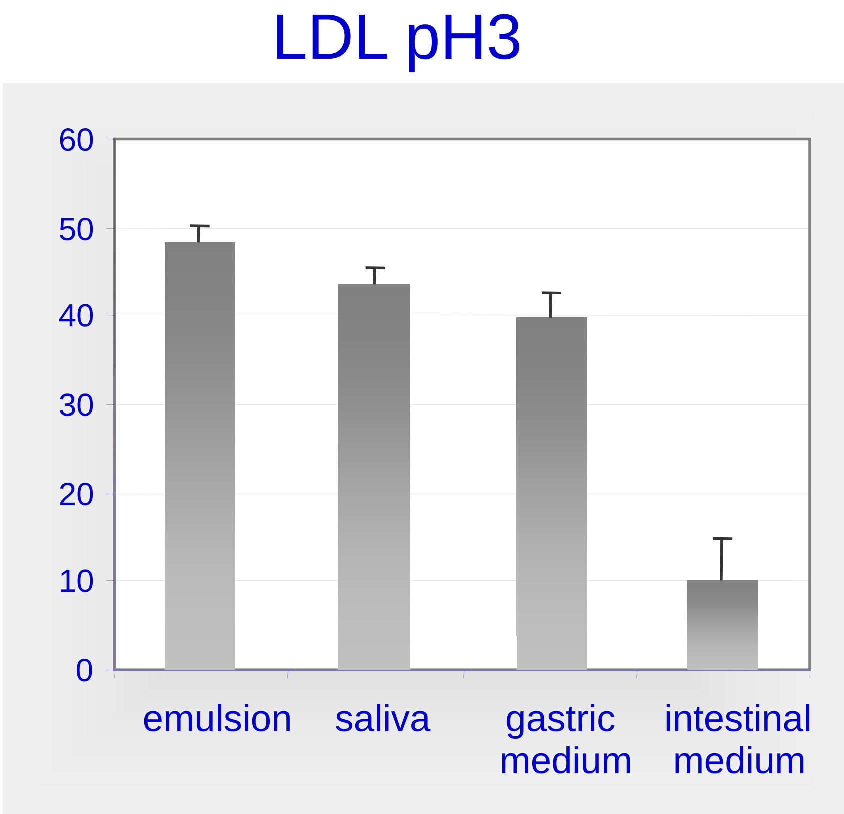
- ⇨ oil fraction: 60 %
- ⇨ granules are forming a remarkable strong network (firmness 275g vs 120g for yolk)
- ⇨ the higher the level of granules, the more spreadable is the emulsion system

❺ GIT: Food deconstruction



Adsorbed proteins on the interface along the GIT

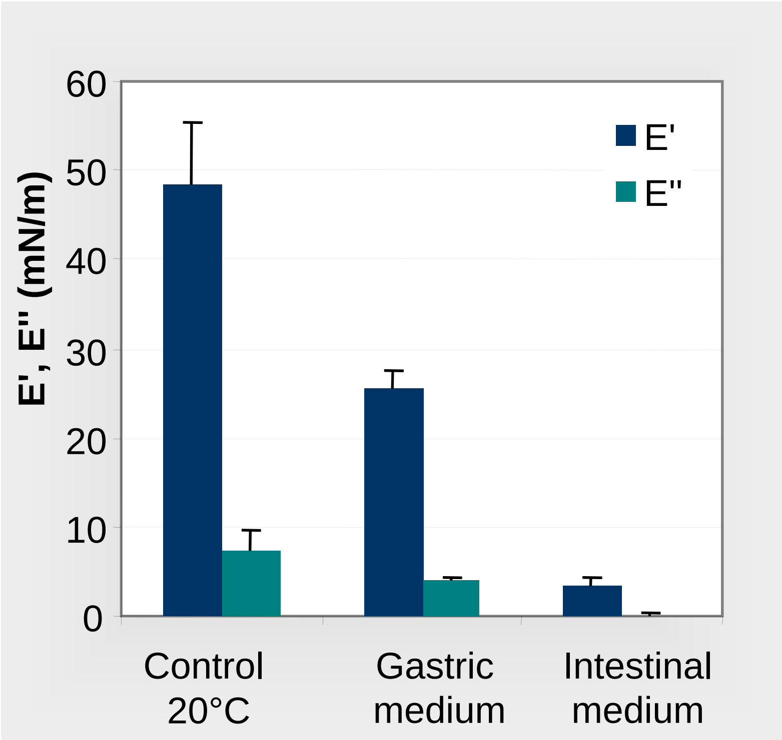




- ❑ amaranth pH2: a regular decrease of adsorbed proteins
- ❑ LDL pH3: a delay until intestinal phase

Dilatational rheology of interface

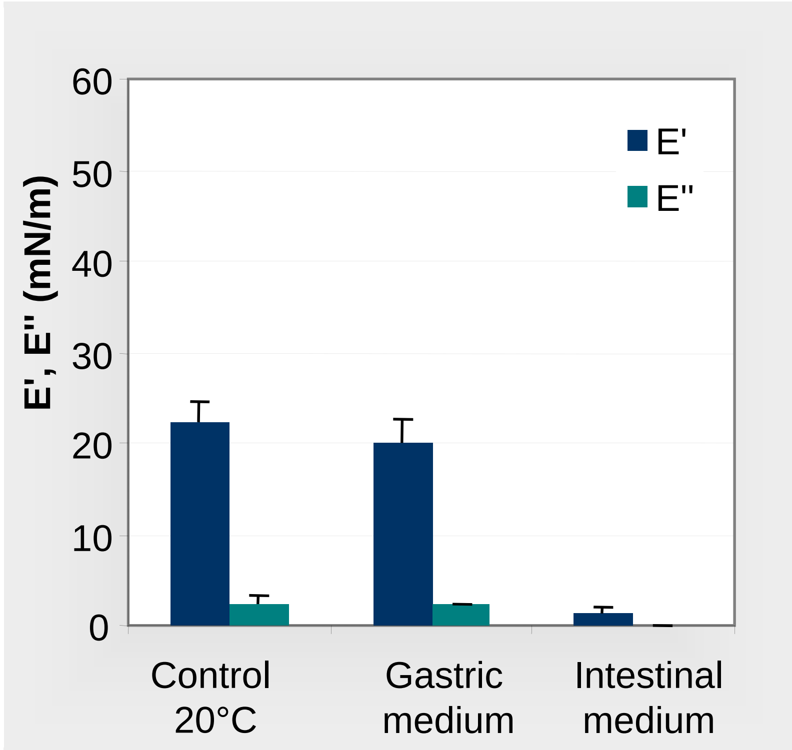
amaranth proteins pH2



❑ higher E’ for control amaranth interface

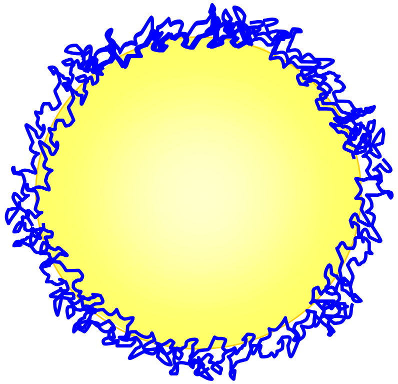
❑ regular decrease of E’ for amaranth interface

LDL pH3



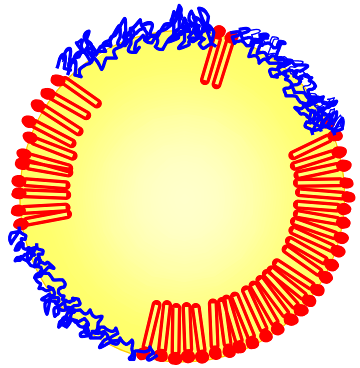
❑ maintain of E’ after gastric medium for LDL interface

❑ total change of rheology in intestinal medium film with pure proteins



- highly elastic film rapidly desorbed/digested and destructured (coalescence from gastric phase)
- no competition with biliary salts
- high structuration is not the unique response

proteins and lipids from yolk LDL



- low viscoelasticity but high resistance to coalescence and delay in film desorption and destructuration (at pH3)
- combination of charged and mixed film (proteins and surfactants: lecithins)
- possible competition with biliary salts

Conclusions

- importance of natural micro- and nano- structures of egg yolk constituents

- clear (and varied) impacts of processes on physical and chemical properties
  → influence on functionalities

- understanding of combination structures X medium X treatments is essential

- processes as **tools** to design new properties for food and non food applications
  - protective structures
  - targeted delivery
  - smart interfaces
  - …