Digestion des aliments chez l'homme: Comment la microscopie aide à comprendre l'évolution des structures dans le tube digestif

Steven Le Feunteun, Didier Dupont

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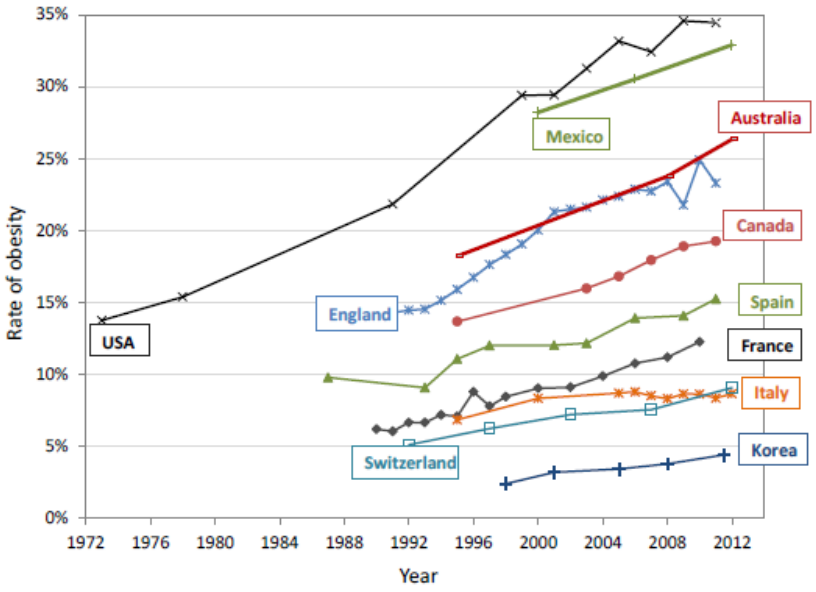
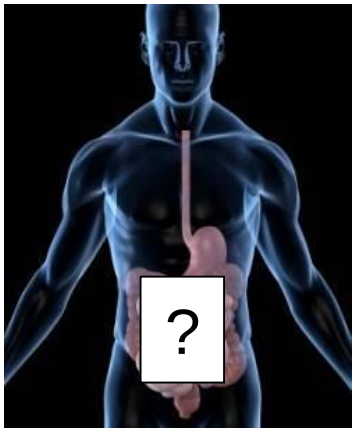
Steven LE FEUNTEUN et Didier DUPONT

INRAE – Institut Agro, STLO, Rennes, France

Food and human health: the key role of digestion



Diet-related diseases ↑
Prevent these pathologies rather than cure them



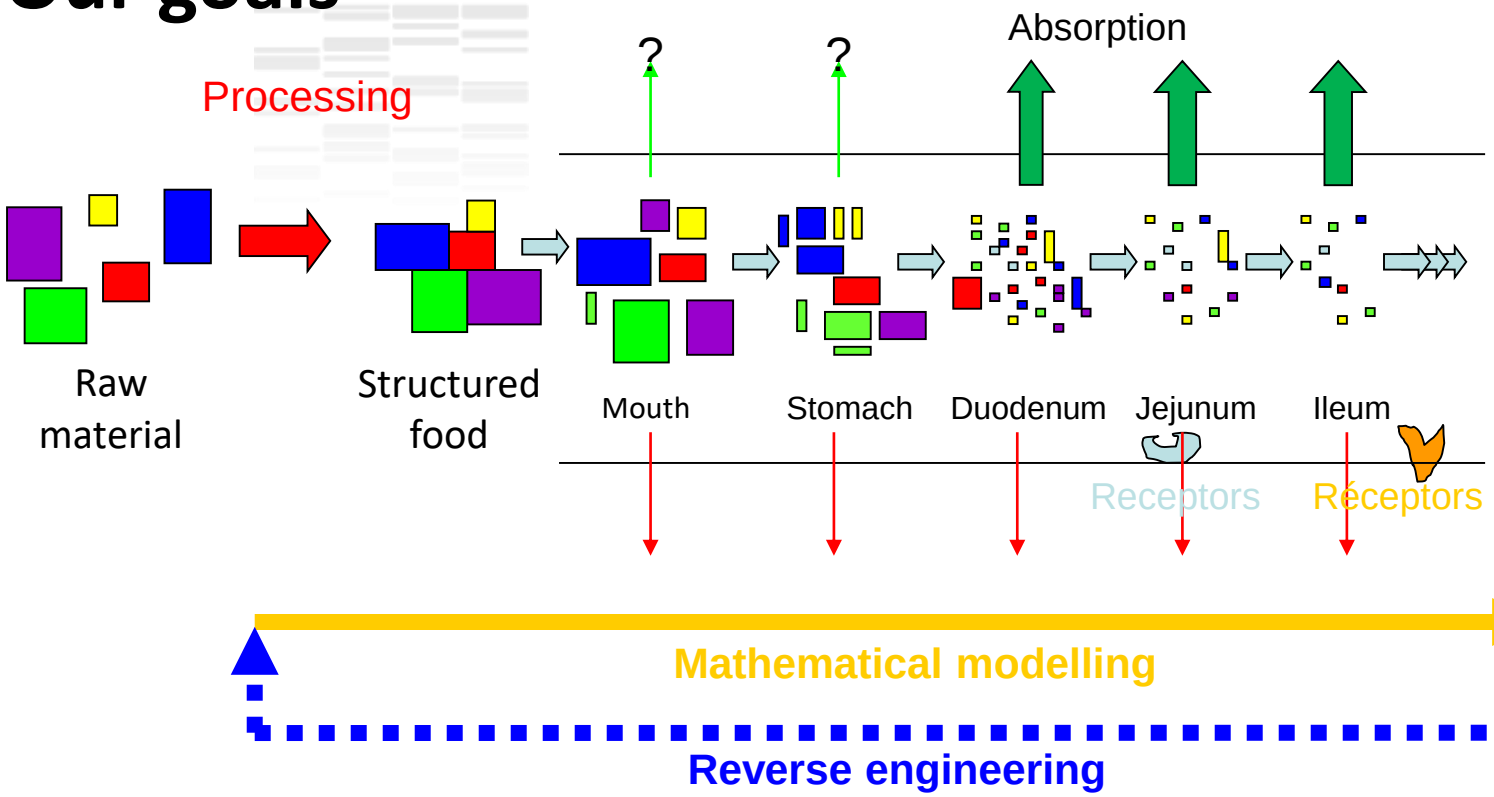
Gut = interface between food and human body
Digestion releases food components that can have a beneficial or a deleterious effect on human health

… but the mechanisms of food disintegration in the gastrointestinal tract remain unclear and the digestive process has been considered as a black box so far

By increasing our knowledge on food digestion, we will increase our knowledge on the effect of food on human health

Our goals

Healthy Adult/ Infant/ Elderly



Bioactivities
- Bioactive peptides
- Amino acids
- Fatty acids
- Minerals…

Gut

Immune System

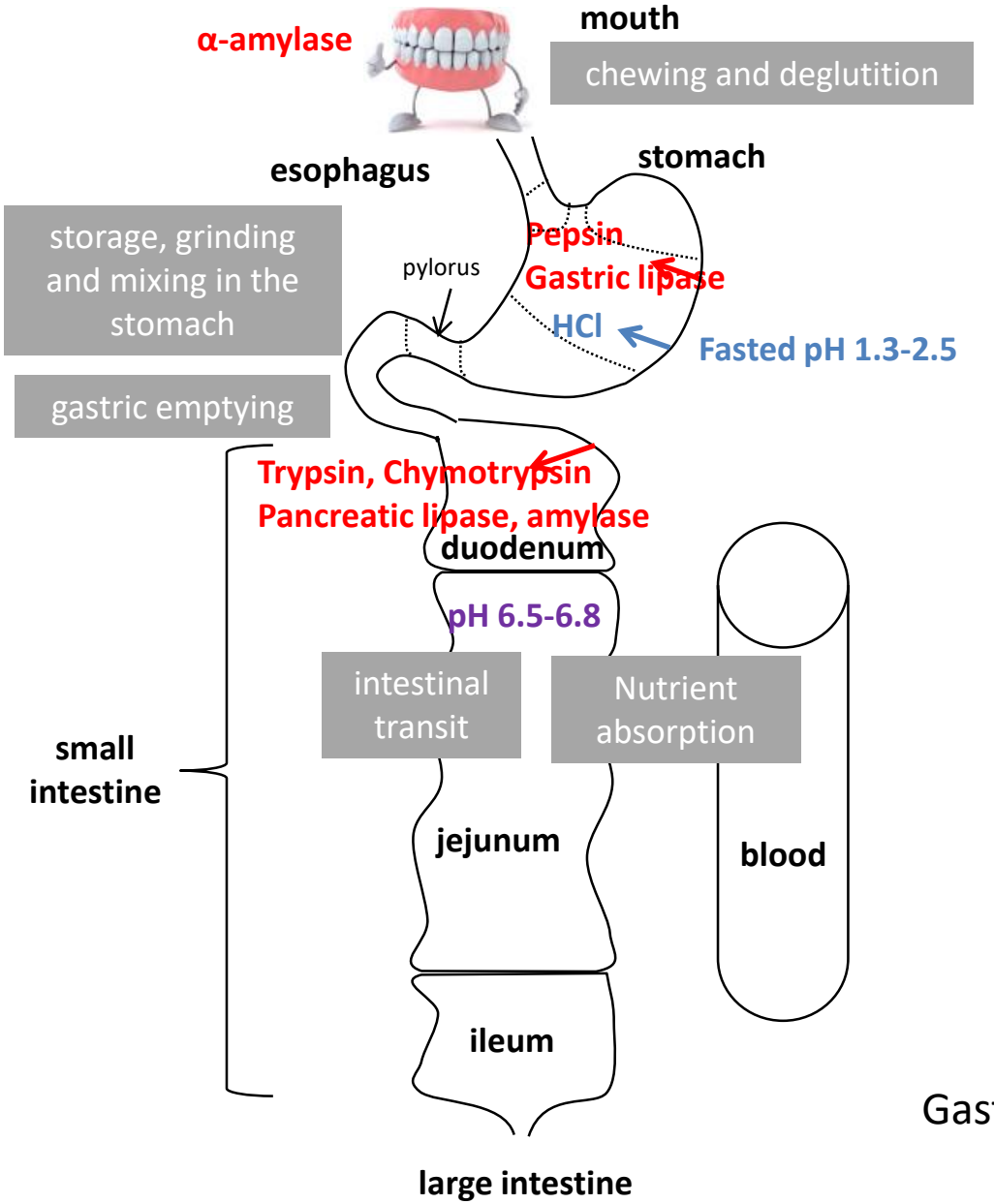
Intestinal microbiota

☞To understand the mechanisms of breakdown of food matrices and their constituents in the gut and identify the beneficial/deleterious food components released during digestion

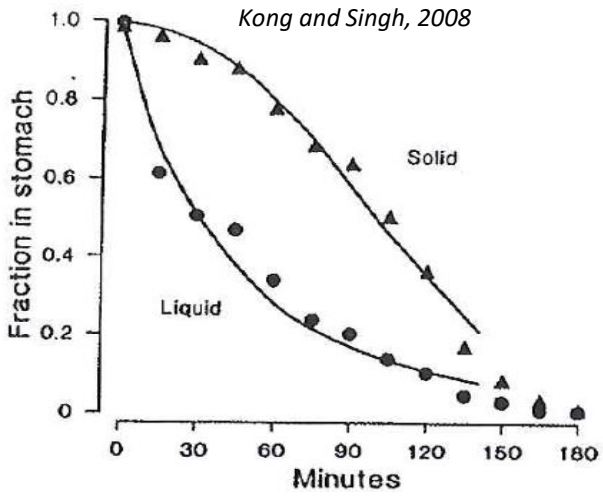
☞To determine the impact of the structure of food matrices on nutrient bioavailability

☞To model these phenomena in order to develop a reverse engineering approach

The digestive process



From Roger Lentle, Massey Univ. NZ



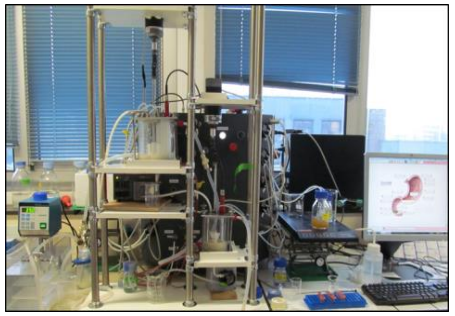
Gastric phase = a very complex but crucial step for the whole digestion process

Models available at INRAE for simulating digestion

Dupont et al. 2010ab, Mol Nutr Food Res

In vitro static models (infant, adult)

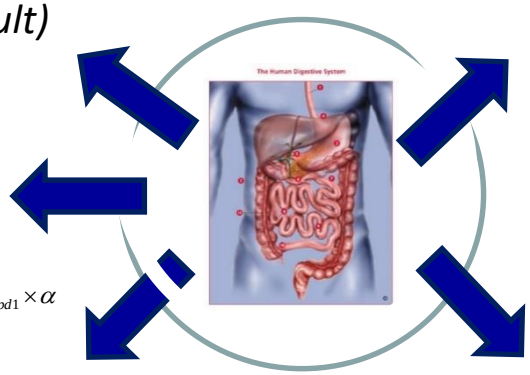
Menard et al. 2014, Food Chem
Sanchez et al. 2015 Food Res Int



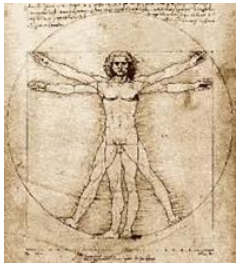
In vitro dynamic models (infant, adult, elderly)

Le Feunteun et al. 2014 Food Bioprocess Tech

In silico models



$$\Phi_{12} = k_{12whey} \times \left(V_1 - m_{caswpd1} \times \alpha\right) + k_{12aggr} \times m_{caswpd1} \times \alpha$$



Human models

Animal models

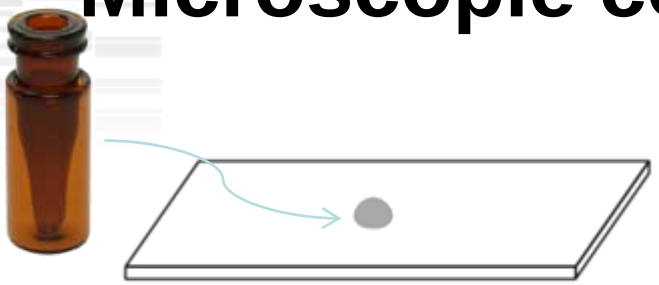
De Oliveira et al. 2016 Am J Clin Nutr
De Oliveira et al. 2017 Clin Nutr

STLO

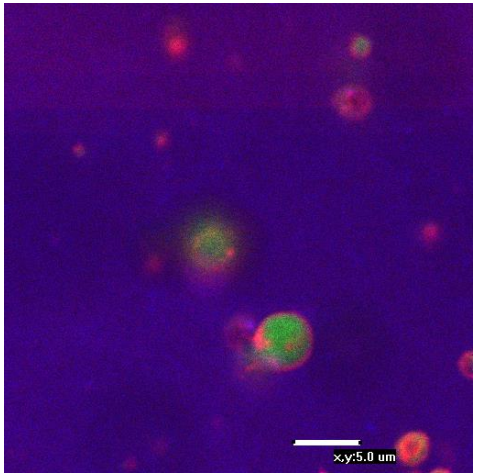
Barbé et al. 2013, 2014 Food Chem
Le Huerou-Luron et al. 2016 Eur J Nutr

Microscopie confocale

Digestas
+ 3 sondes
fluorescentes

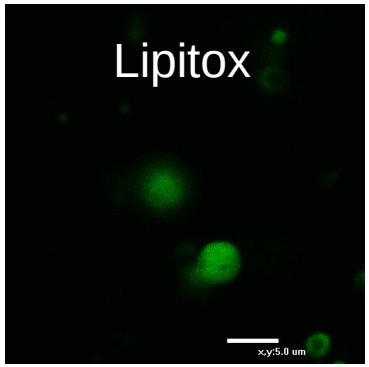


OBS X60

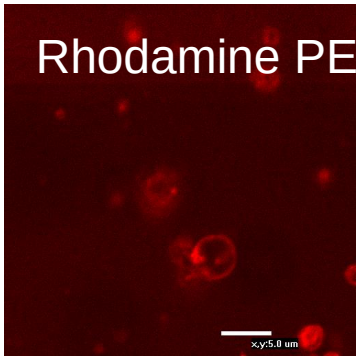


3 sondes

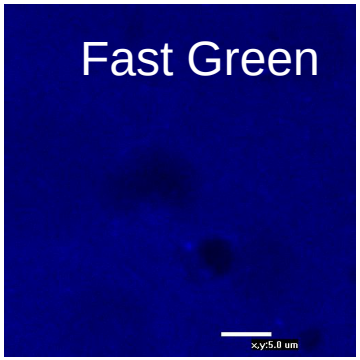
Lipides Apolaires



Amphiphiles



Protéines

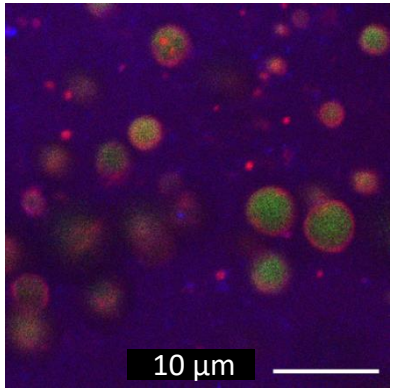


Pasteurization affected the initial structure and the emulsion disintegration of HM

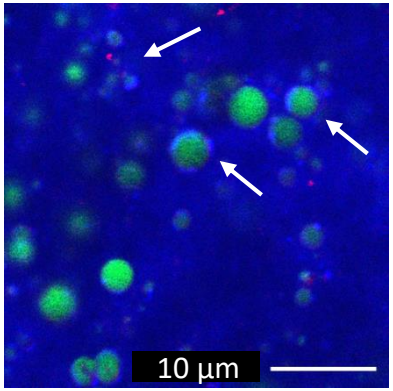
(n = 6 infants)

Initial structure

Raw HM



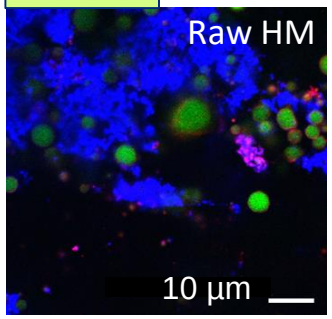
Past HM

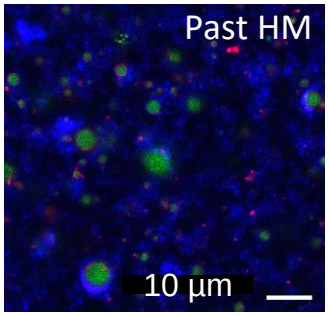


→ Protein heat-induced aggregation

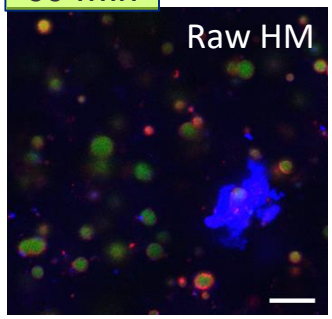
Gastric disintegration

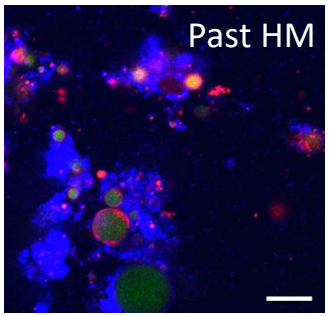
35 min



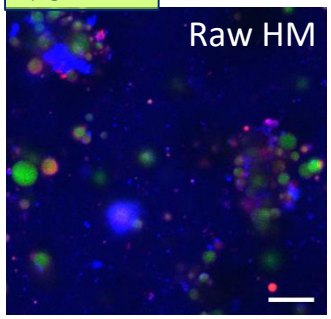


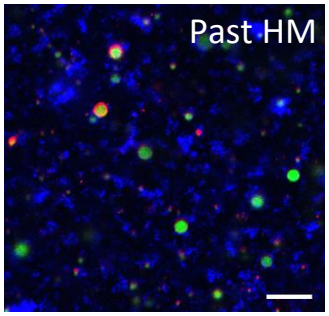
60 min

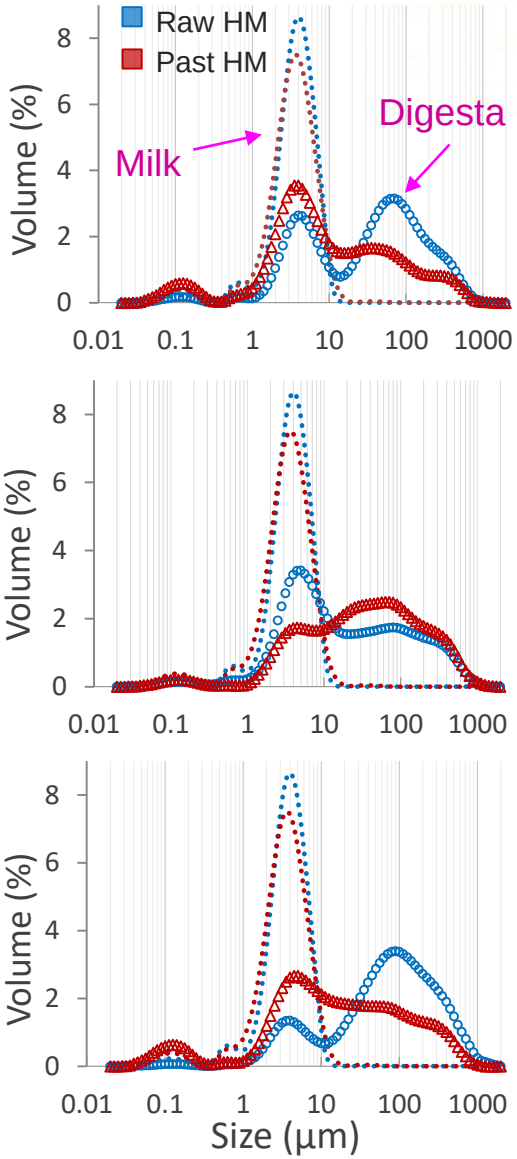




90 min

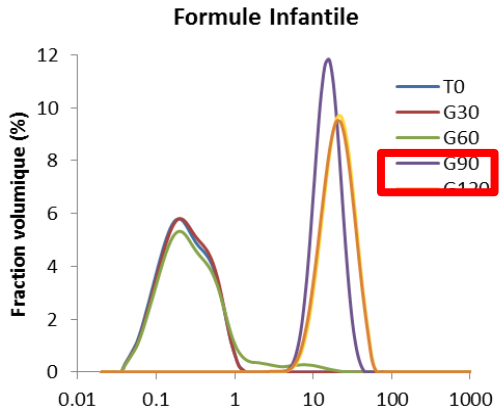


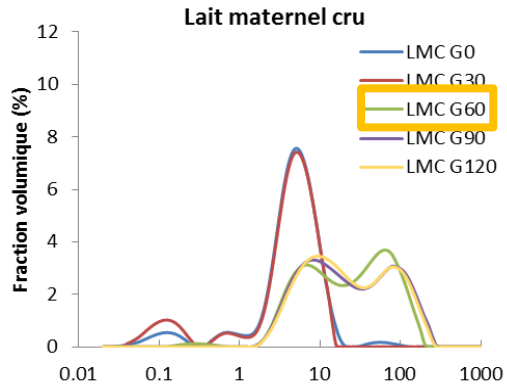


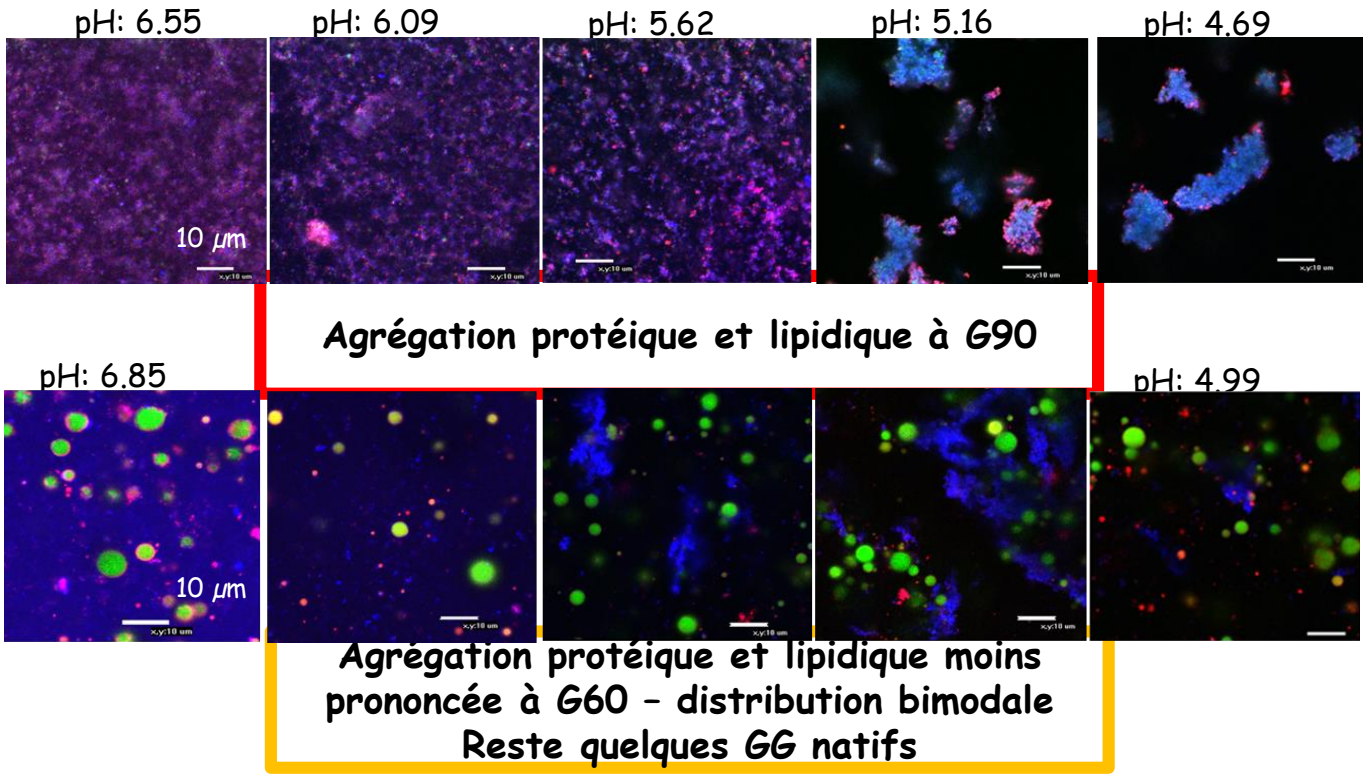


Apolar lipids | Amphiphiles | Proteins

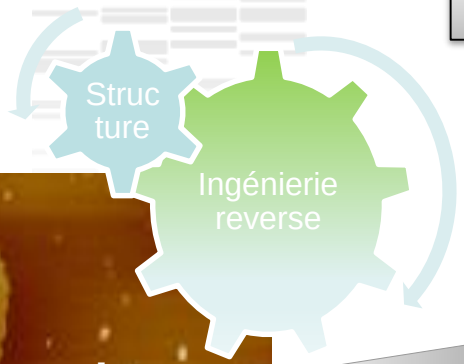
STRUCTURE - PHASE GASTRIQUE

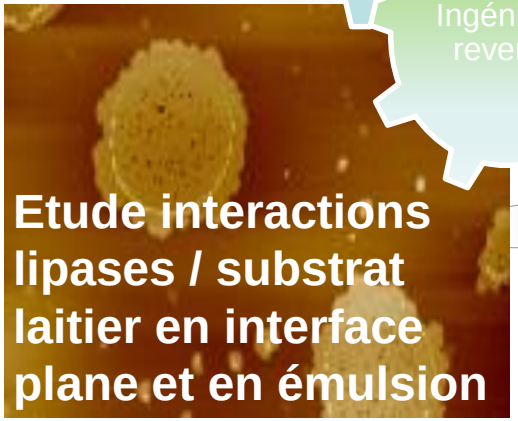






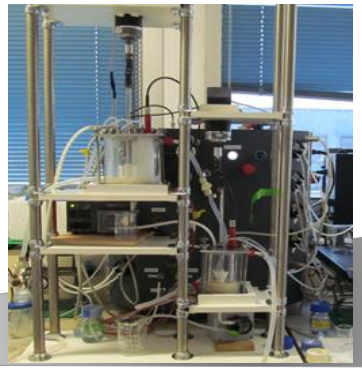
PROJET LIPA





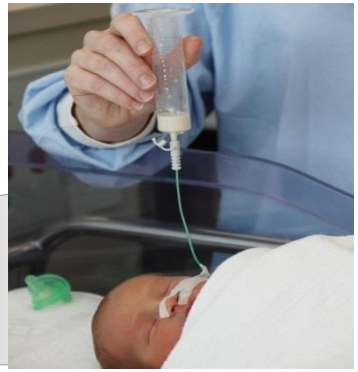
Etude interactions lipases / substrat laitier en interface plane et en émulsion

in vitro digestion



Samira de Oliveira (FRI)

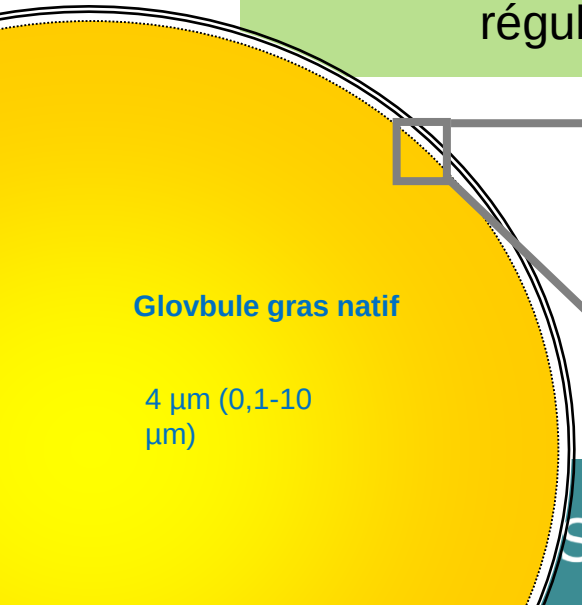
in vivo digestion



ARCHILACT clinical trial (2014-2015)

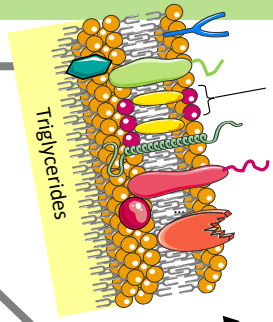
Systèmes de complexité croissante

En quoi la composition et l'organisation latérale de la membrane de globule gras de lait (bovin ou humain) régulent l'activité des lipases digestives ?

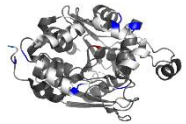


Glovbule gras natif

4 µm (0,1-10 µm)



~ 15 nm

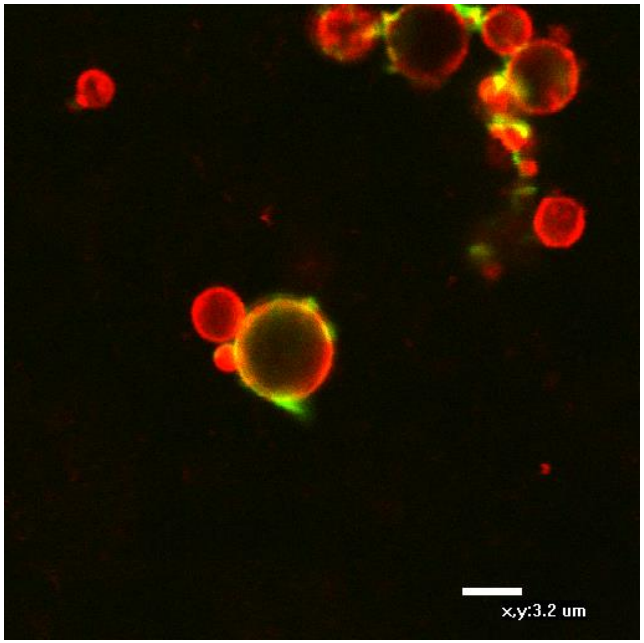


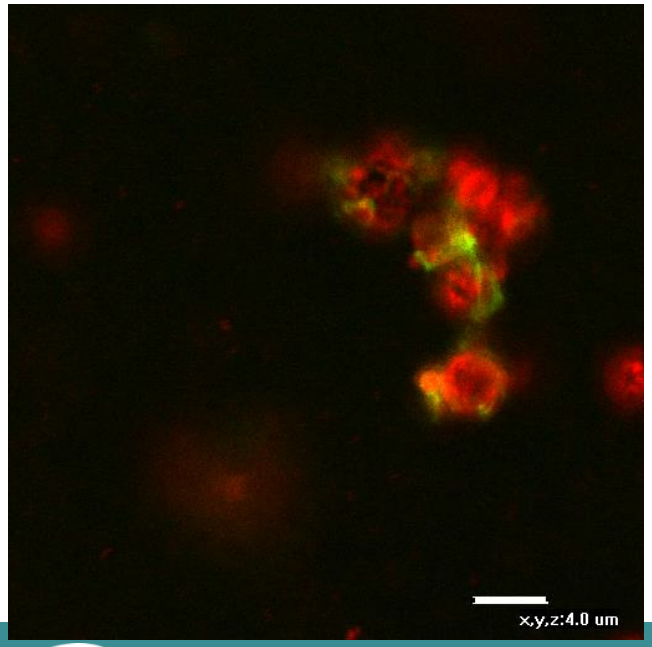
Lipase gastrique humaine

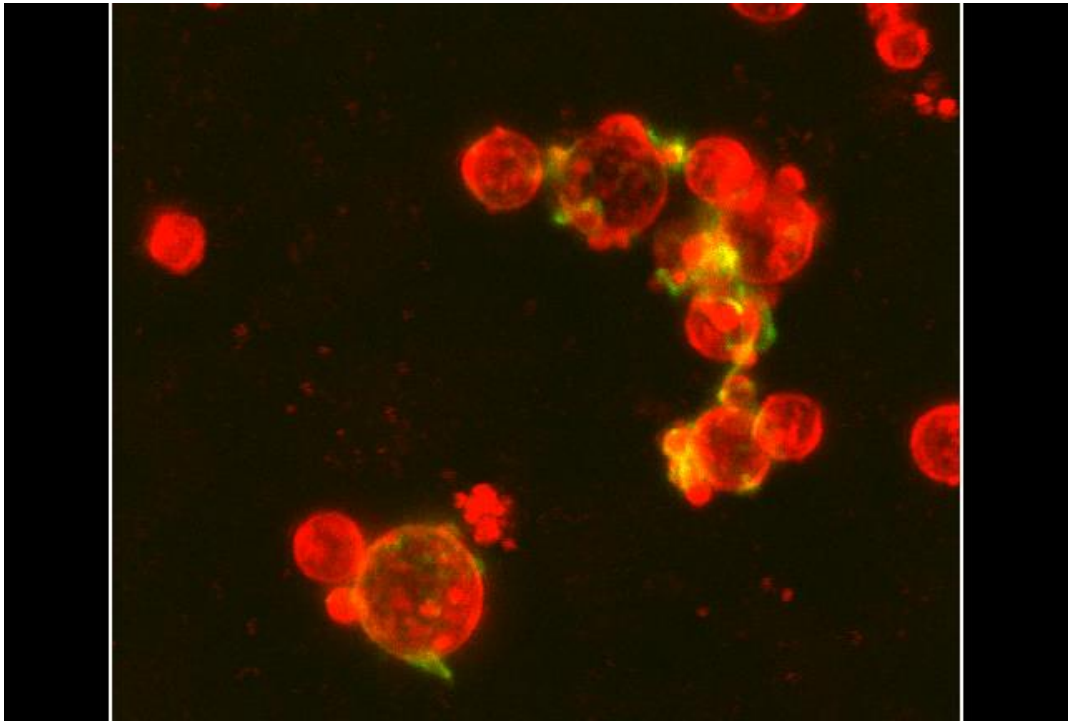
S=19.6 nm^2
ø=5 nm

STLO

Immunolocalization lipase gastrique(pH 6)



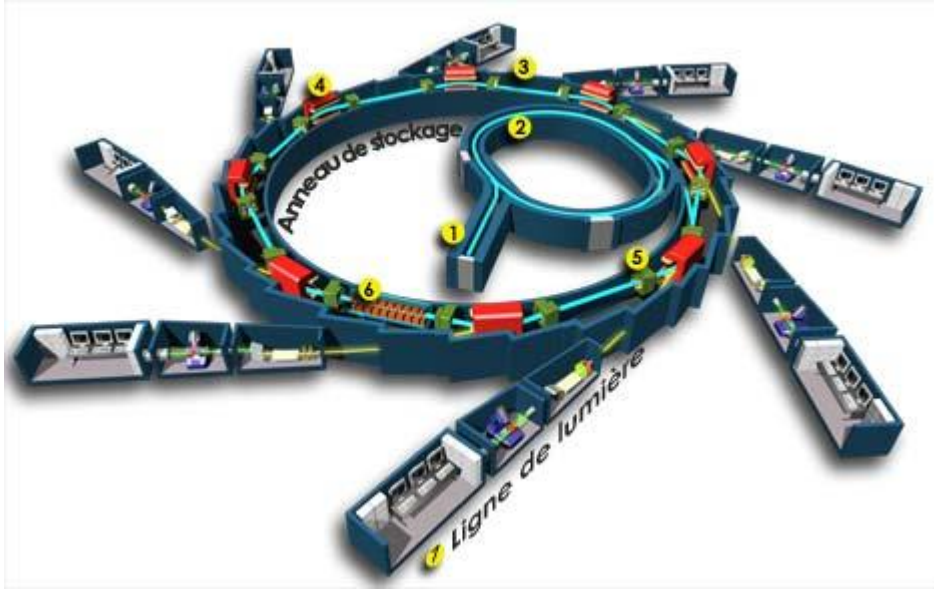




Observation des micro-domaines **membranaires**
Lipase adsorbée à l'interface (colocalisation zones rouge et verte) – mais limite de résolution en microscopie confocale

→ COMPLEMENT synchrotron SOLEIL – ligne UV

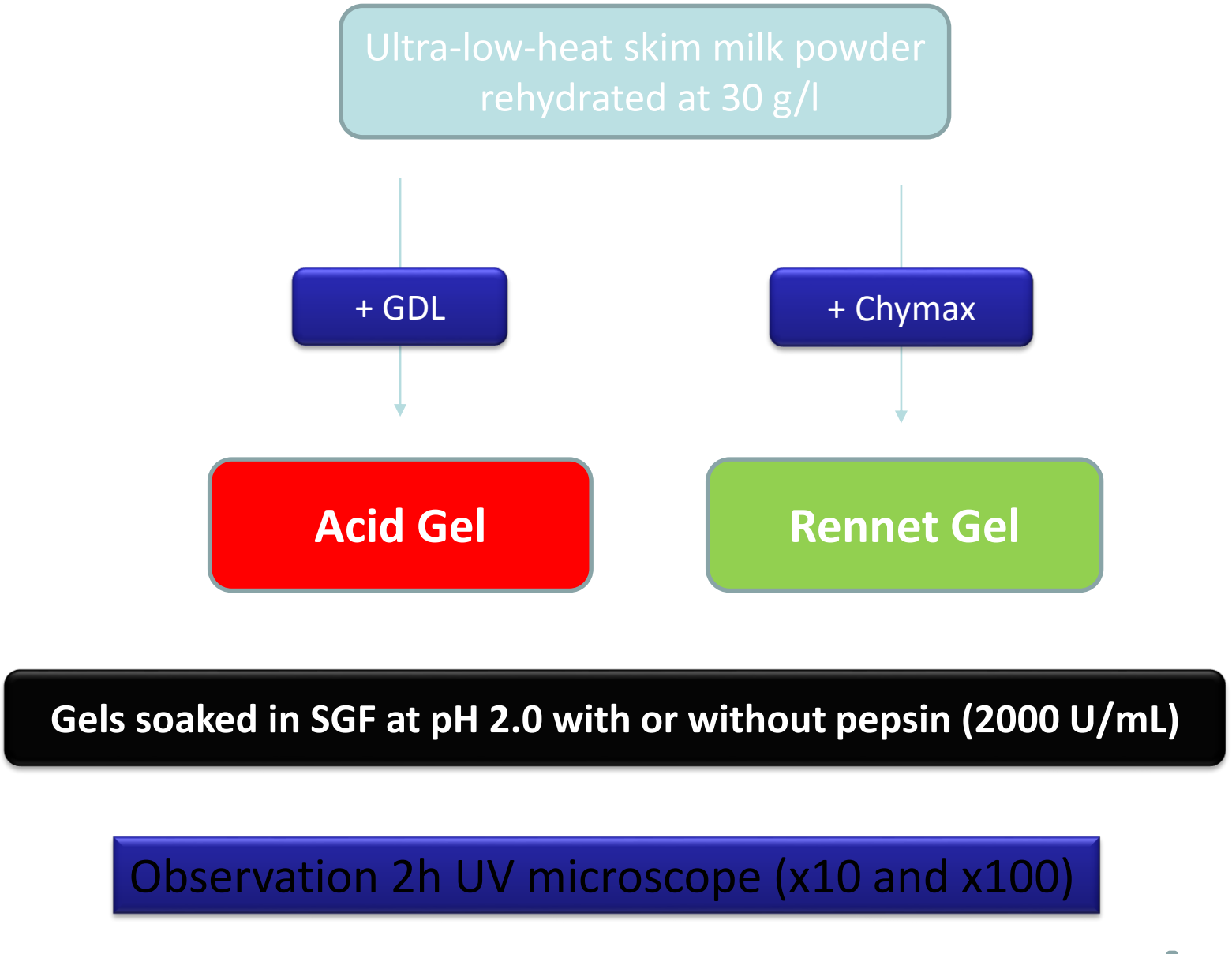
Soleil is a particle (electron) accelerator that produces the synchrotron radiation, an extremely powerful source of light that permits exploration of inert or living matter



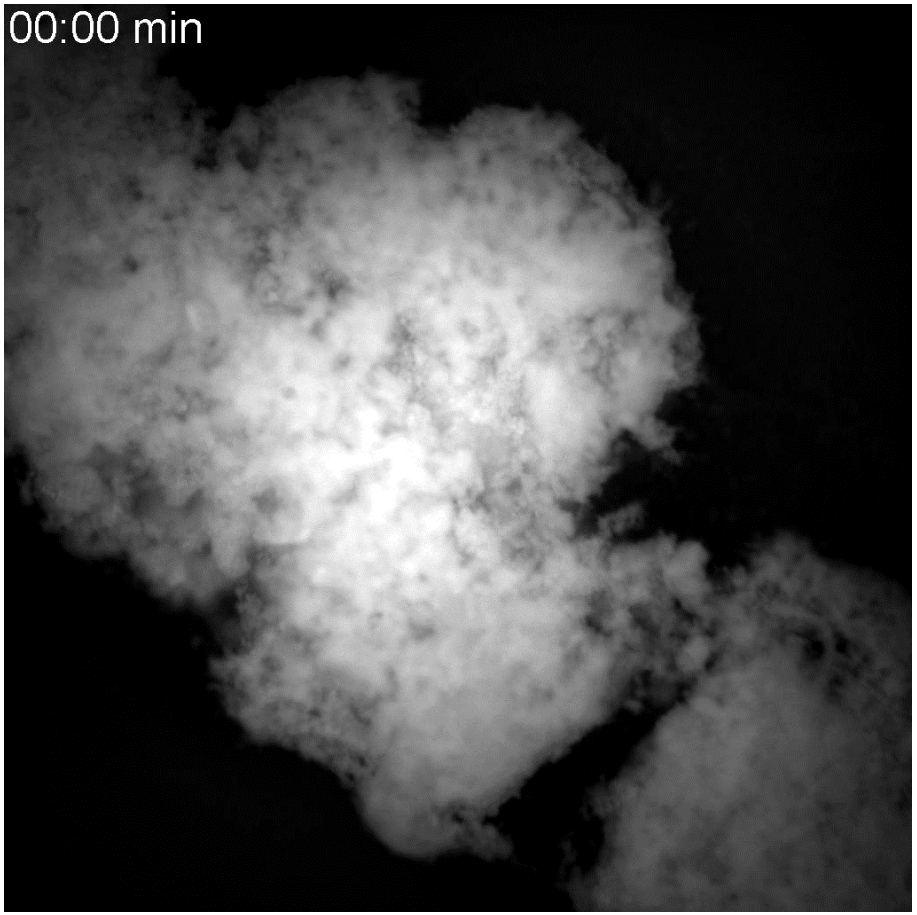
DISCO is a VUV to visible beamline dedicated to biochemistry, chemistry and cell biology. The spectral region is optimized between 60 and 700 nm with conservation of the natural polarization of the light

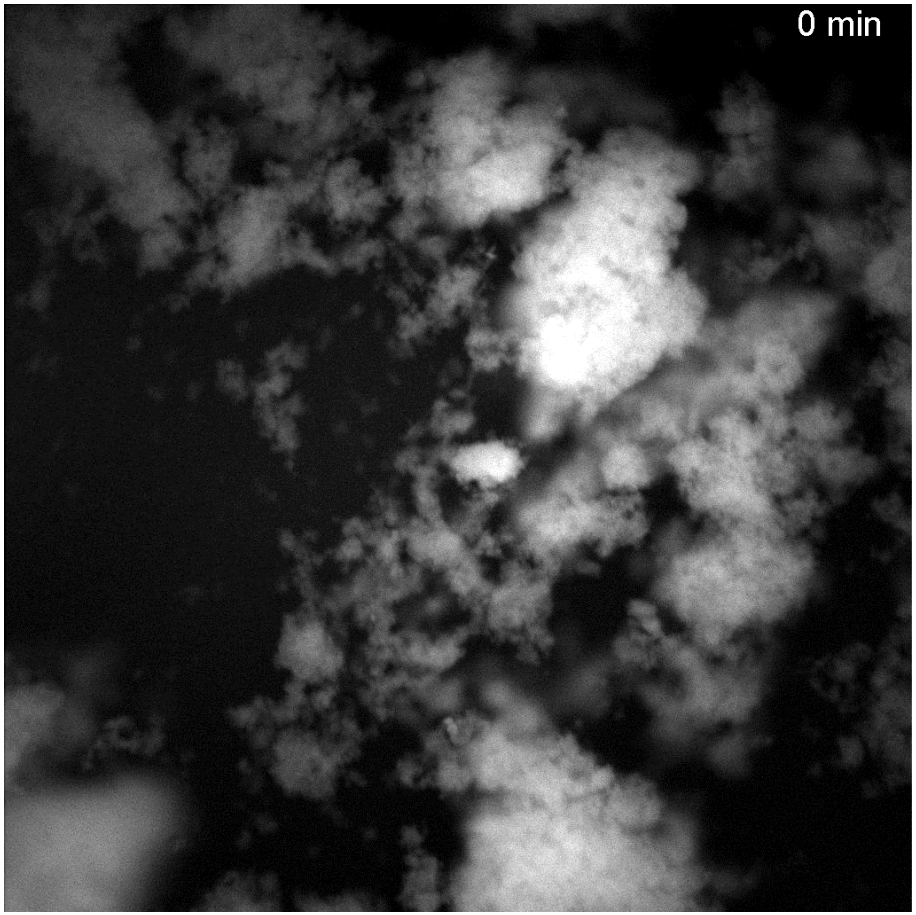
☞ Allow the imaging of protein intrinsic fluorescence with a UV microscope

Protocol


Ultra-low-heat skim milk powder rehydrated at 30 g/l
+ GDL
+ Chymax
Acid Gel
Rennet Gel
Gels soaked in SGF at pH 2.0 with or without pepsin (2000 U/mL)
Observation 2h UV microscope (x10 and x100)

Kinetics of gel particles disintegration

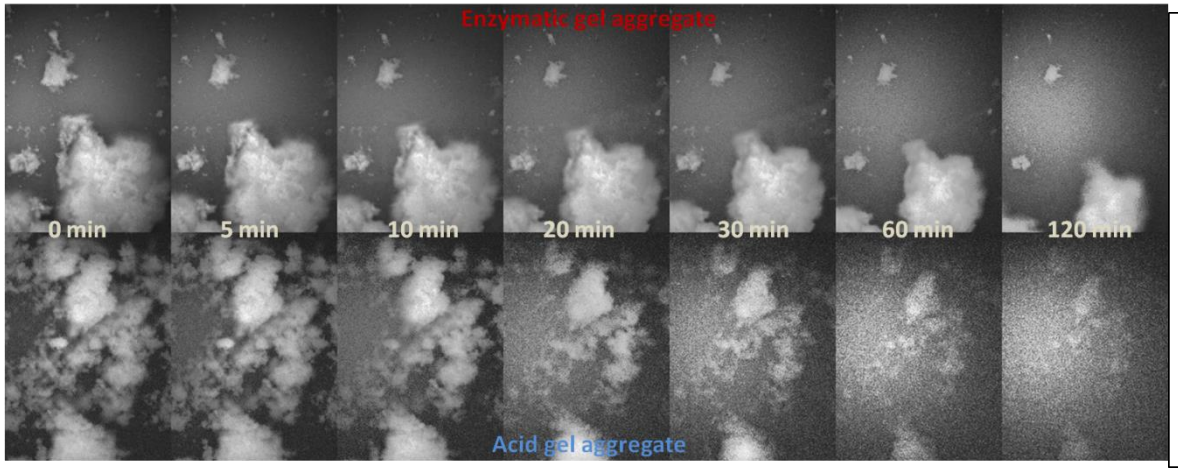




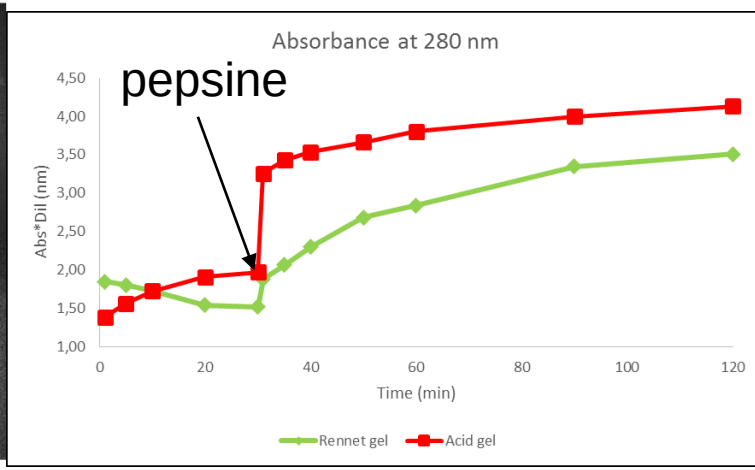
Rennet Gel

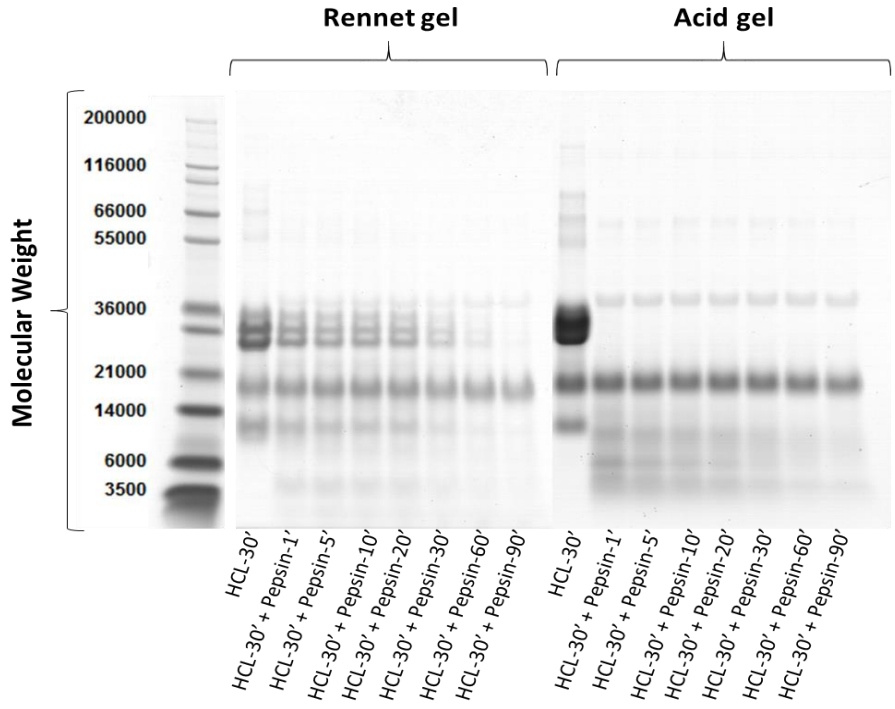
Acid Gel

Disintegration of an acid gel particle is faster than that of a ren

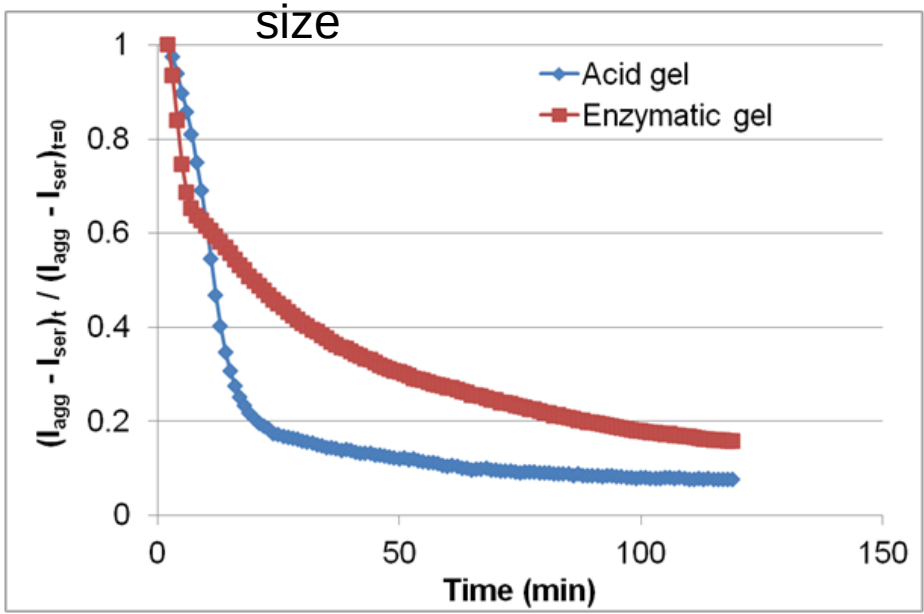


Evolution of soluble proteins





Evolution of particle size



The Bioactivity & Nutrition Team

20-25 people, 15 permanent staff

9 INRAE

6 L'INSTITUT agro Rennes Angers

2015-2021 : 12 PhD, 7 post-docs, 5 international visiting scientists

Head

Didier DUPONT – *DR*

Scientists

Françoise NAU – *PR*
Amélie DEGLAIRE – *MC*
Juliane FLOURY – *MC*
Catherine GUERIN – *MC*
Frédérique PEDRONO – *MC*
Steven LE FEUNTEUN – *CR*
Martine MORZEL – *CR*

PhDs

Elise CHARTON *(2019-2022)*
Lucile CHAUVET *(2020-2023)*
Ousmane SUWAREH *(2019-2022)*
Jiajun FENG *(2020-2023)*
Rozenn LE FOLL *(2020-2023)*

Post-docs

Ines GRECO *(2021-2023)*
Stefano NEBBIA *(2020-2022)*
Imen JEBALIA *(2021-2023)*

Engineers & Technicians

Yann LE GOUAR – *TR*
Gwénaële HENRY – *AI*
Julien JARDIN – *IE*
Olivia MENARD – *IE*
Jordane OSSEMOND – *IE*
Marie-Françoise COCHET – *IE*

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International Conference
Porto, Portugal
2024

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8th International Conference on Food Digestion

in Porto, Portugal, April 2024