# The structure of the food matrix at different length scales affects the mechanisms of digestion and the nutrient bioavailability

Didier Dupont

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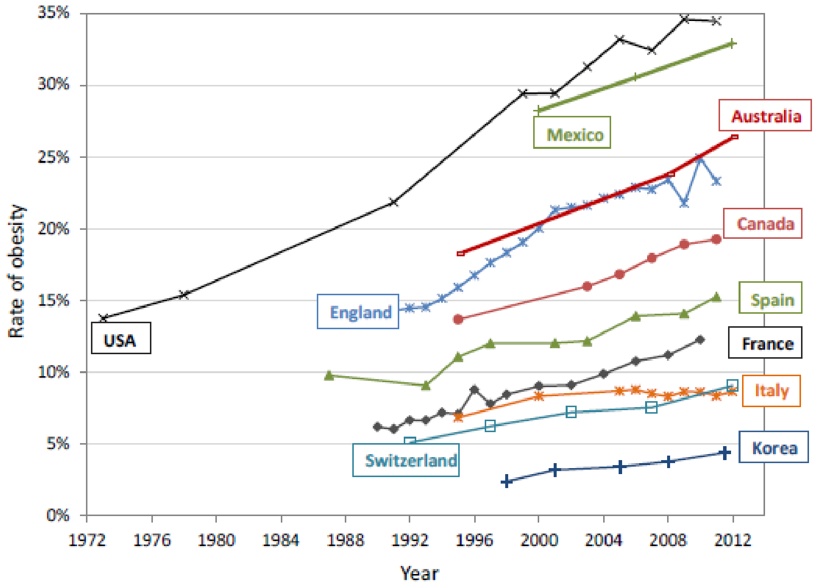
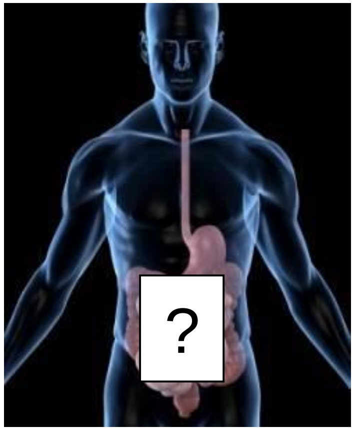
Dr Didier DUPONT, INRAE, STLO, Rennes, France

# Food and human health: the key role of digestion




Diet-related diseases ↑

Prevent these pathologies rather than cure them



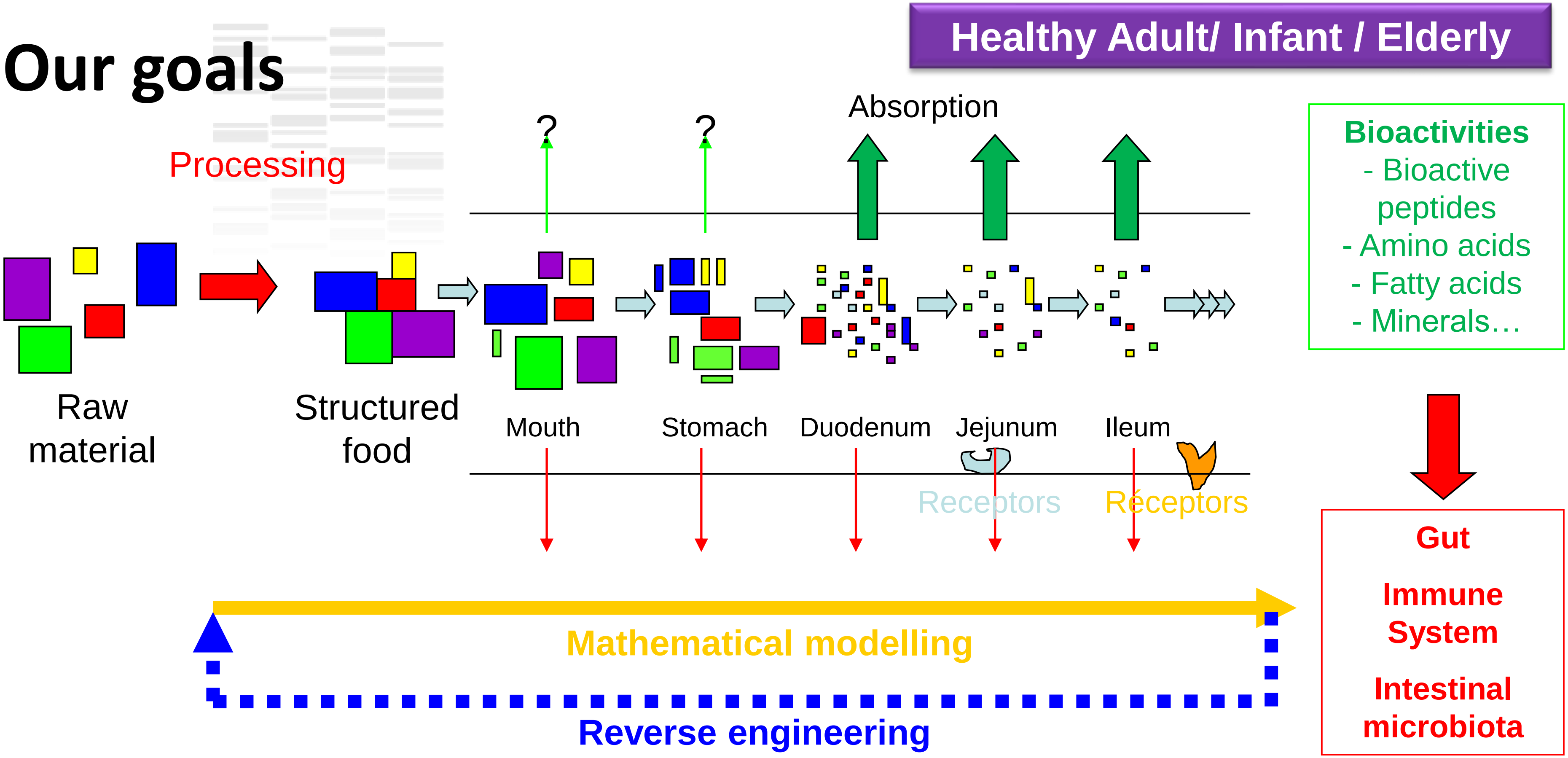

Gut = interface between food and human body

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

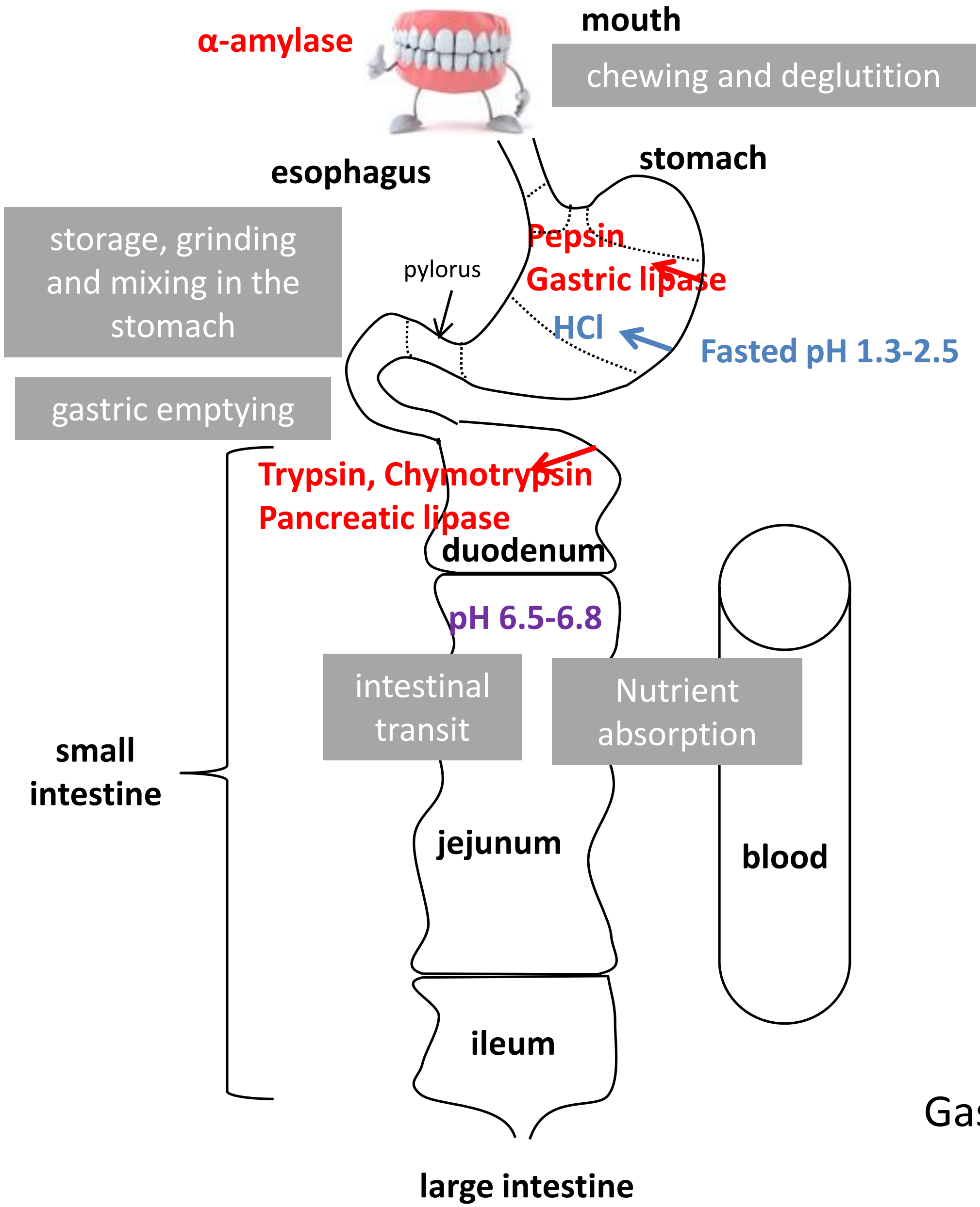


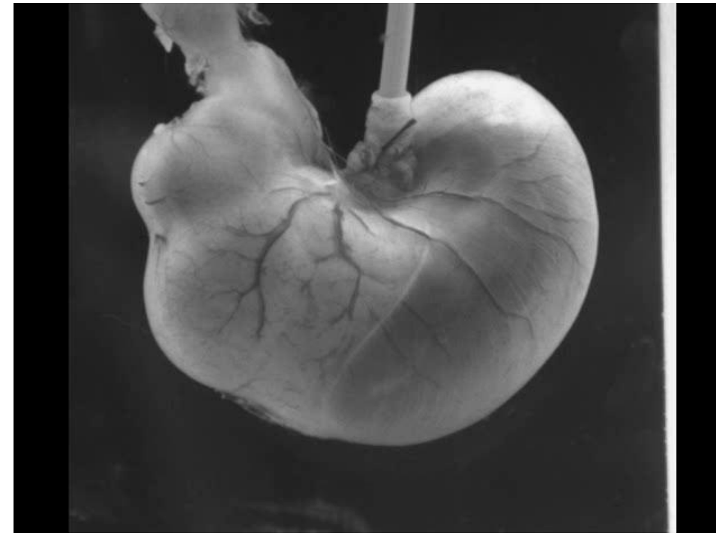

☞To understand the mechanisms of breakdown of food matrices and their constituents in the gut and identify the beneficial/deleterious food components released during digestion

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

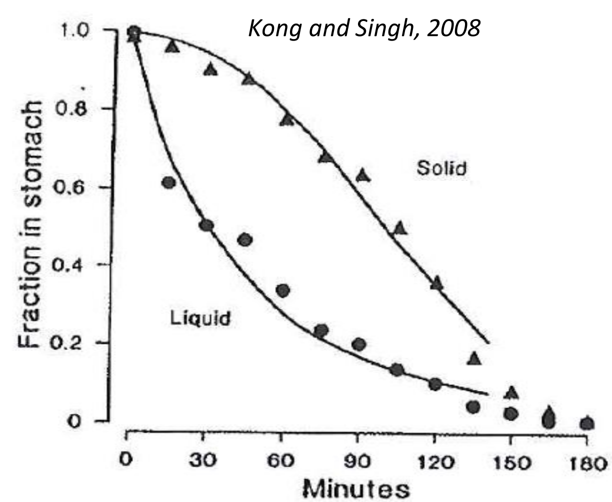
☞To model these phenomena in order to develop a reverse engineering approach

# 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

**Menard et al. 2018, 2023**
**Wang et al. 2022**


*In vitro static models (infant, adult, elderly)*

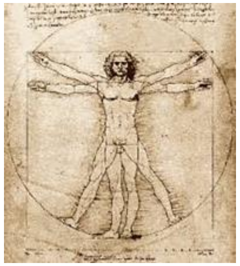
**Peng et al. 2021**
**Halabi et al. 2021**
**Giribaldi et al. 2021**
**Chauvet et al. 2023**
**Nebbia et al. 2022, 2023**

*In vitro dynamic models (infant, adult, elderly)*

**Le Feunteun et al. 2014, 2020**

*In silico models*

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



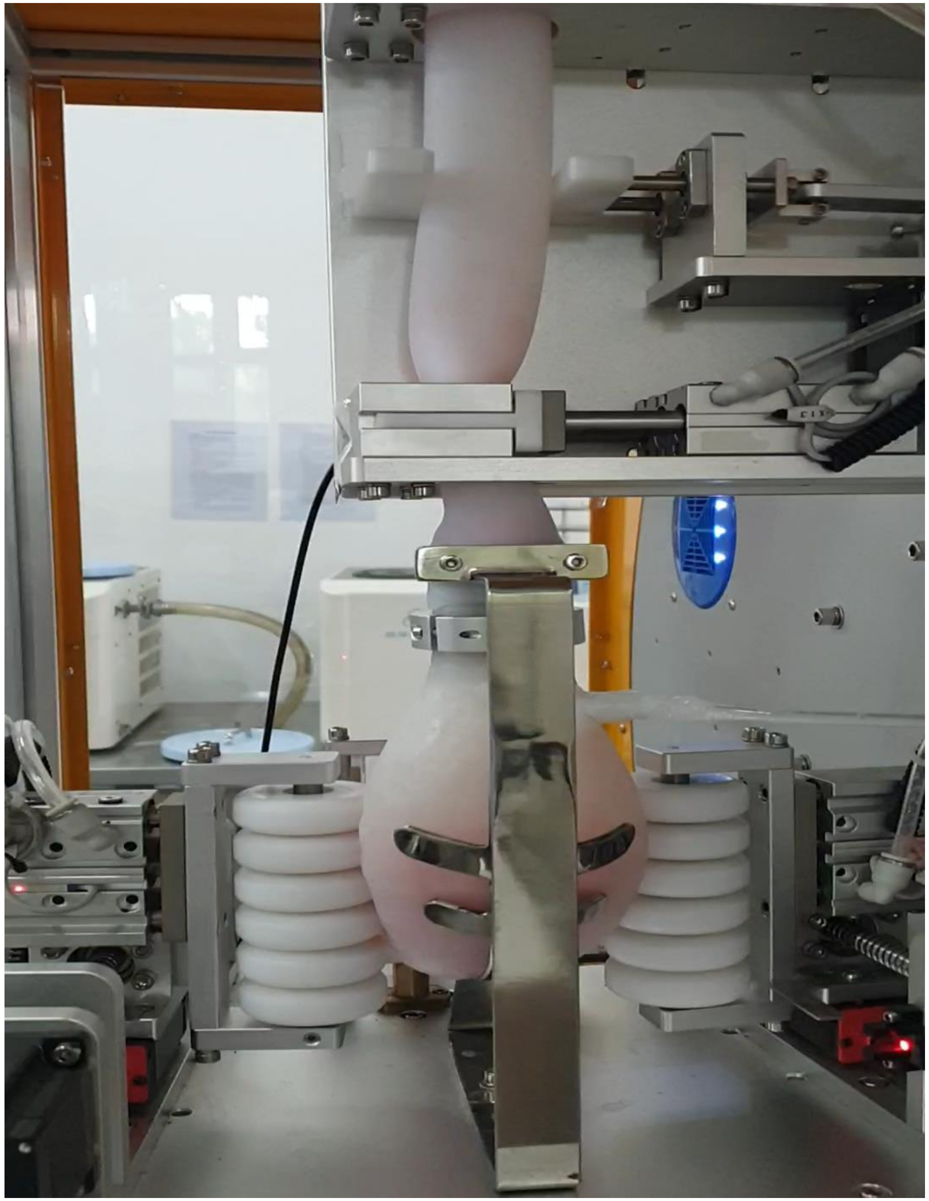
*Human models*

**De Oliveira et al. 2016**
**De Oliveira et al. 2017**
**Buffière et al. 2020**
**Boulier et al. 2023**

*Animal models*

**Lemaire et al. 2021**
**Nau et al. 2022**
**Jimenez-Barrios et al. 2023**
**Charton et al. 2022, 2023**

# NERDT™ : the NEar Real Digestive Tract



**STOMACH**

Xiao Dong Pro-Health
Smart Digestion
Suzhou University

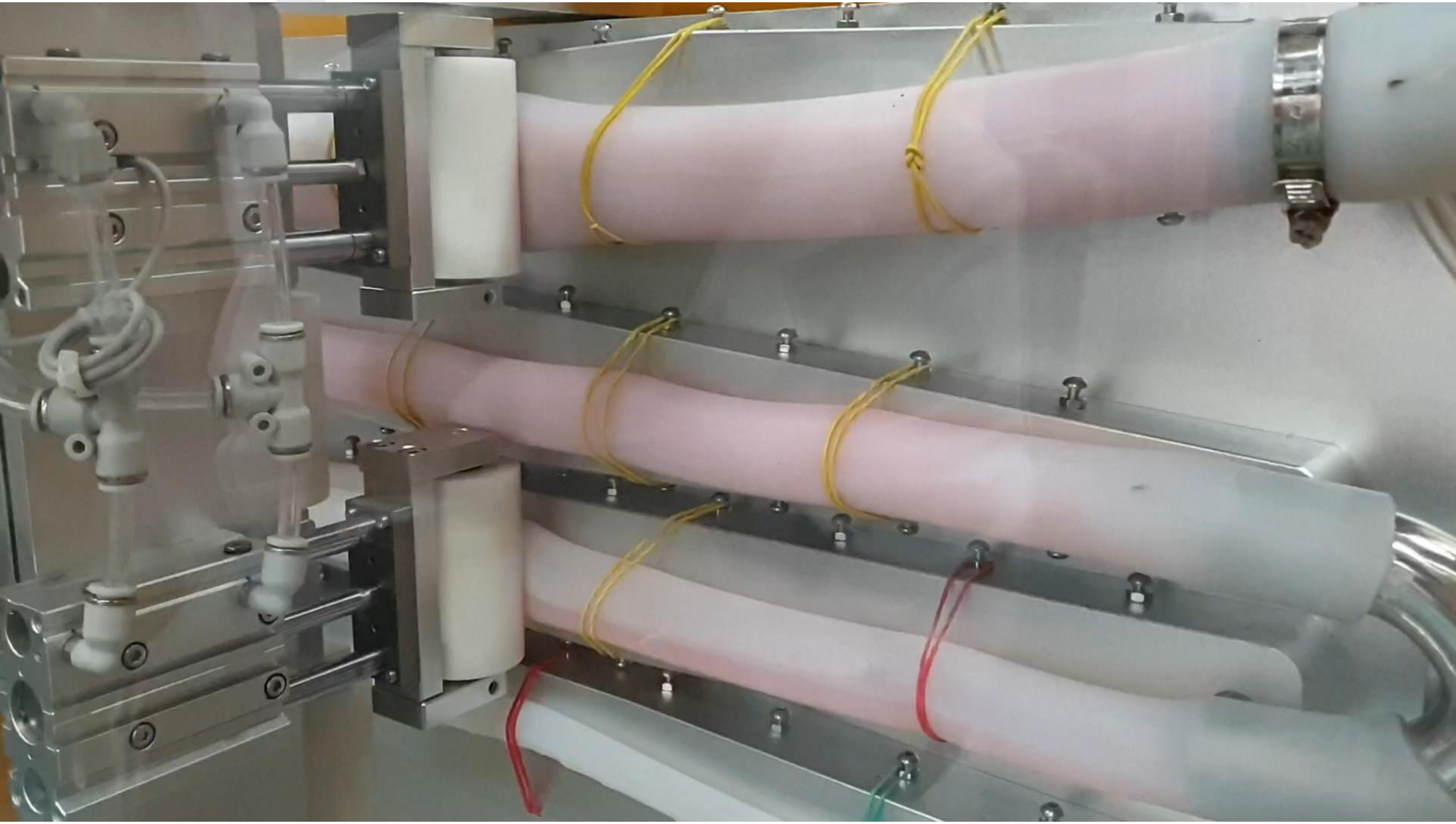
SOOCHOW UNIVERSITY
UNTO A FULL GROWN MAN

INRAE

L'INSTITUT agro Rennes Angers

INSTITUT CARNOT QUALIMENT

# Simulating the small intestine

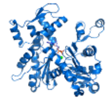


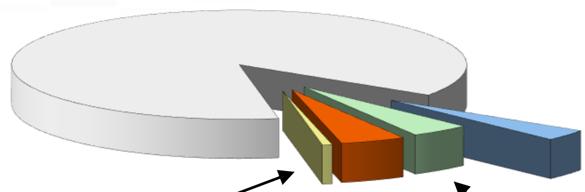
# The molecular structure of food protein affects the kinetics of digestion

Boudry G,, Henry G & Dupont D.
INRAE, Rennes, France

# Milk

## Molecular scale

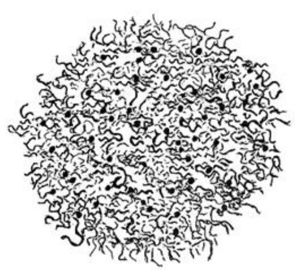




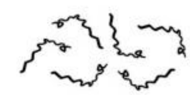

Caseins (80%)
$\alpha s_1$, $\alpha s_2$, β, κ

Whey Proteins (20%)
β-lg, α-la

ø~200 nm
(Holt, 1994)



Casein organized into a supramolecular structure: the **casein micelle (CM)**

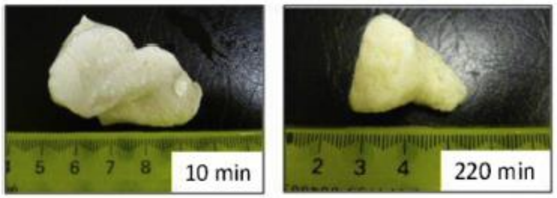


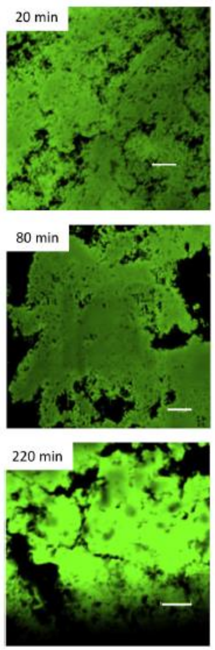
ø~11 nm
~15 casein molecules;
(Thomar *et al*. 2013)

Casein can also be extracted after acidification followed by neutralization: the **caseinate (CS)**

# Milk coagulates in the stomach

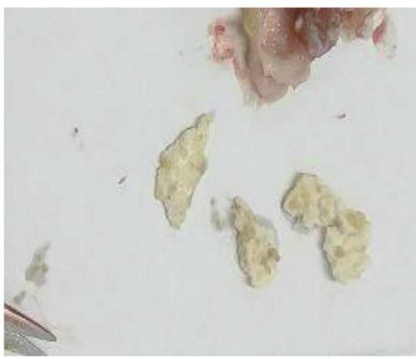




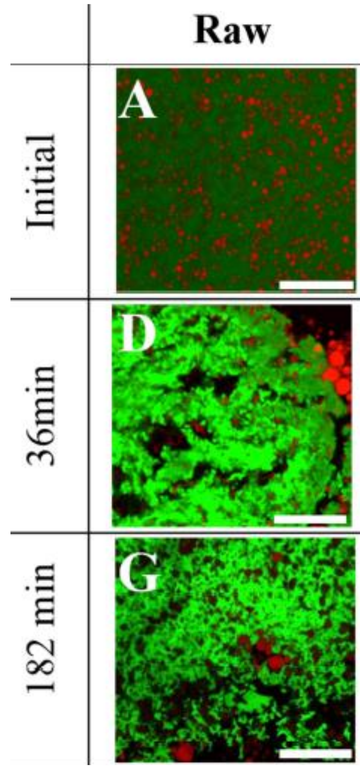



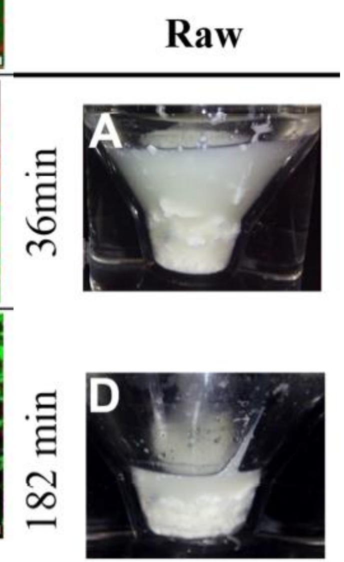

Unheated milk

*In vitro* demonstration using the HGS
Ye *et al*. 2016



Ye *et al*. 2019
*In vivo* evidence using a rat model




Mulet-Cabero *et al*. 2019
*In vitro* semi-dynamic model

Skim Milk Powder

Sodium Caseinate

Casein micelles and sodium caseinate form different coagulums
Wang *et al*. 2018

# Objective



The objectives of the study were to:

1 Determine whether gastric emptying of an isoproteic solution of CM and CS are different or not (exp. 1)

2 Characterize the structure of the resulting chyme and determine if CM and CS are differently metabolized (exp. 2)

**Experiment 1 – Determination of Gastric Emptying**

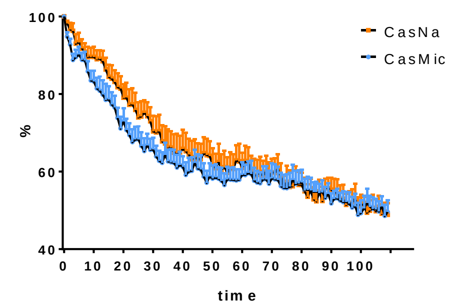
$\gamma$-scintigraphy over 120 min

96 g of CM or CS rehydrated in 800 ml of water

+12 g of glucose

+ $^{99m}$Tc-colloidal (25Mbq)

9 pigs (20-25 kg)

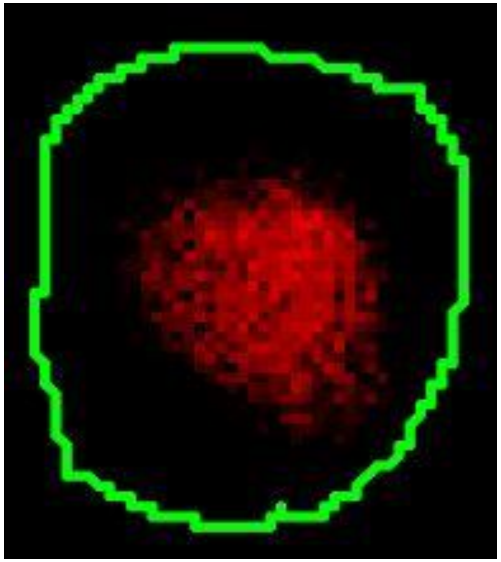



Gastric emptying half-time ($T_{1/2}$) and shape of the curve ($\beta$)

# But a differential behaviour of CS and CM in the stomach

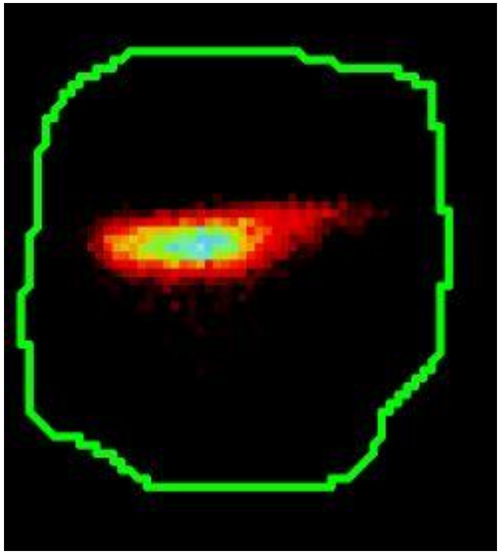
Exemple scintigraphic images at the beginning of gastric emptying (5-10 min after ingestion)

**CM**



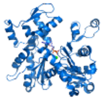
Radioactivity fully fills the stomach

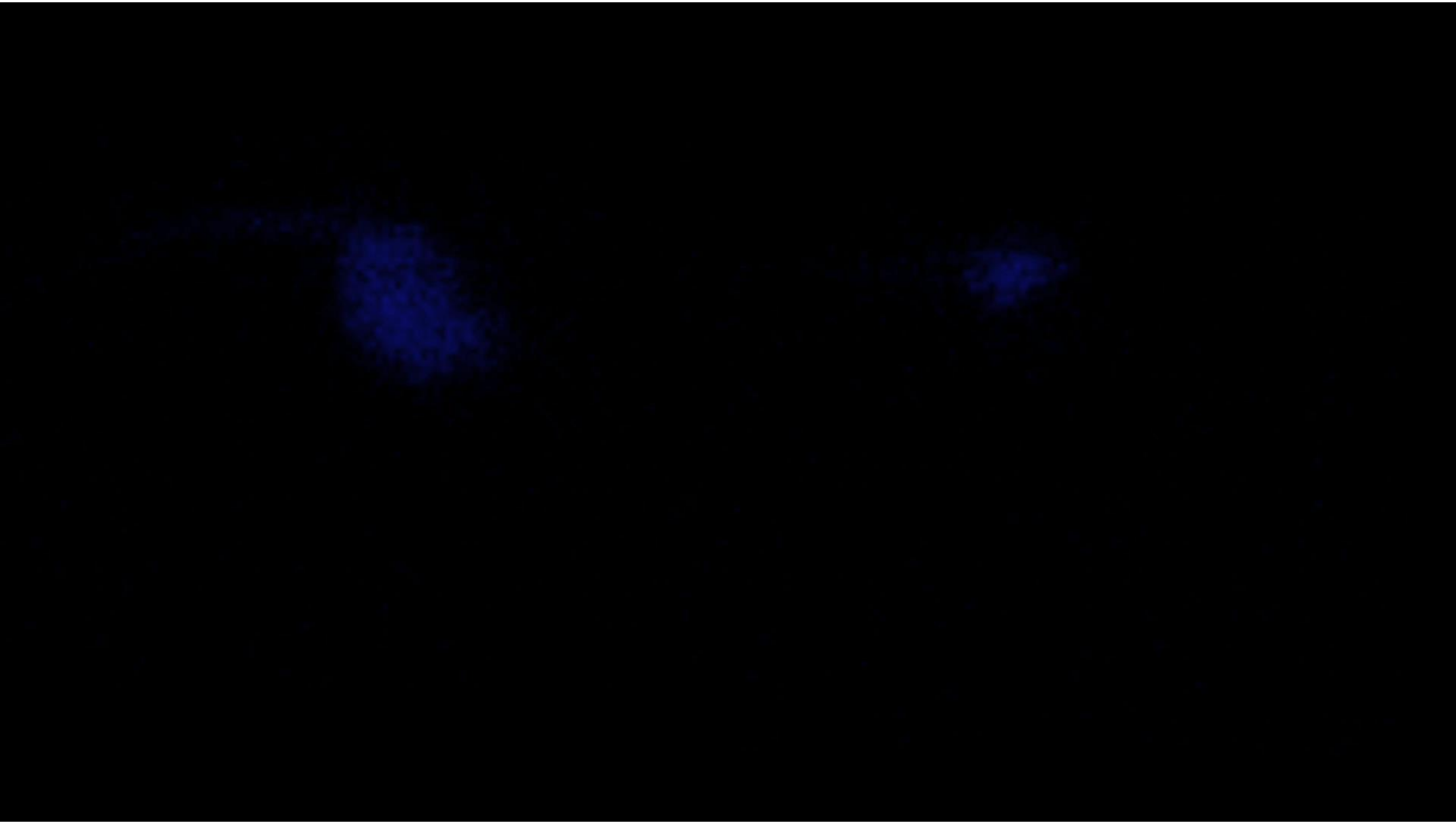
**CS**



Radioactivity is highly concentrated in the proximal part of the stomach

# Gastric emptying

**Molecular scale** 



# Objective



The objectives of the study were to:

1 Determine whether gastric emptying of an isoproteic solution of CM and CS are different or not (exp. 1)

2 Characterize the structure of the resulting chyme and determine if CM and CS are differently metabolized (exp. 2)

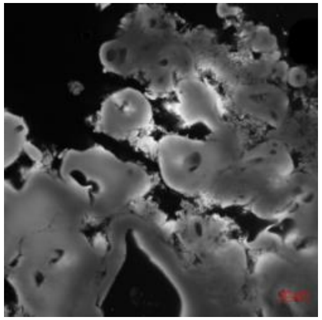
**Experiment 2 – Chyme structure and protein metabolism**

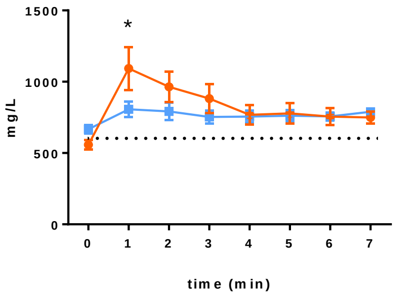
96 g of CM or CS rehydrated in 800 ml of water

+12 g of glucose

10 catheterized pigs (20-25 kg)

Characterization of the chyme structure (slaughtering after 10 min, n=4)





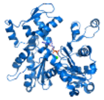

Free plasma amino acids over 7h n=6

# Collection of the stomach contents

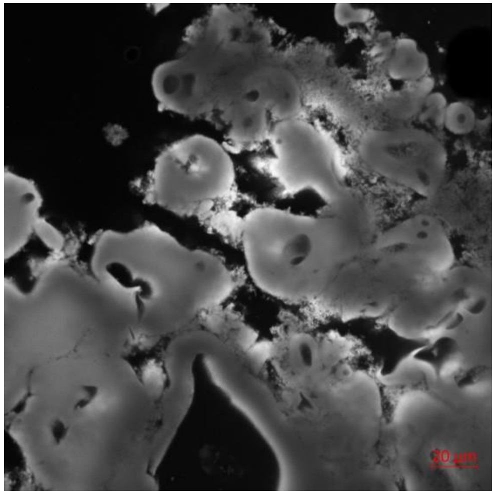
**Molecular scale**

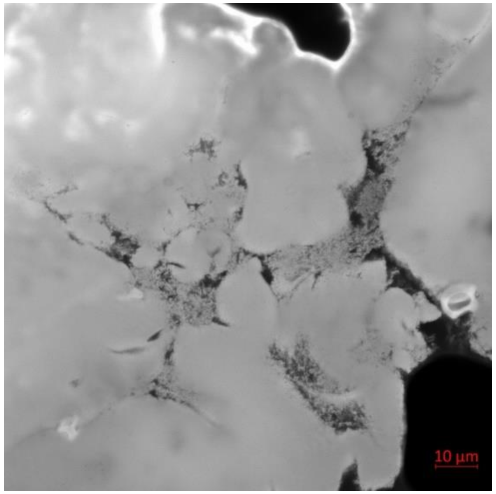

CM forms a large coagulum in the stomach whereas CS mainly remains in the liquid form

# Microstructure of gastric chymes

**Molecular scale** 

**CM**





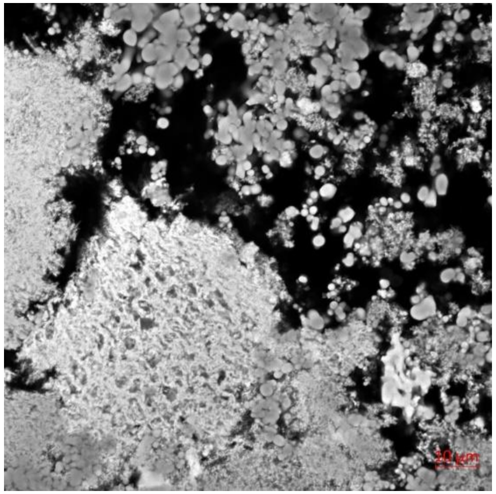

CM Gels (left) are compact and dense =

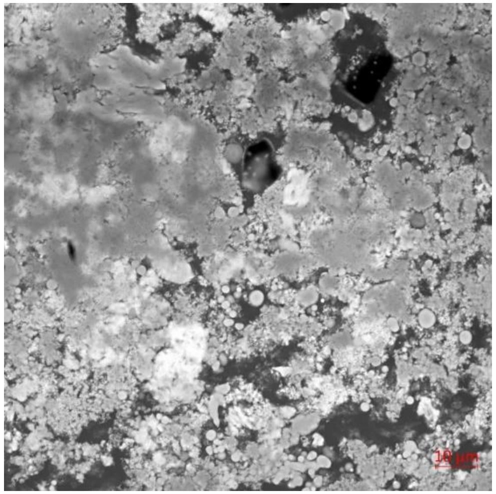
**Strong coagulum**

CS Gels (right) are an agglomerate of spherical particles that can easily dissociate. The gel have a very « loose » structure =

**Protein precipitate**

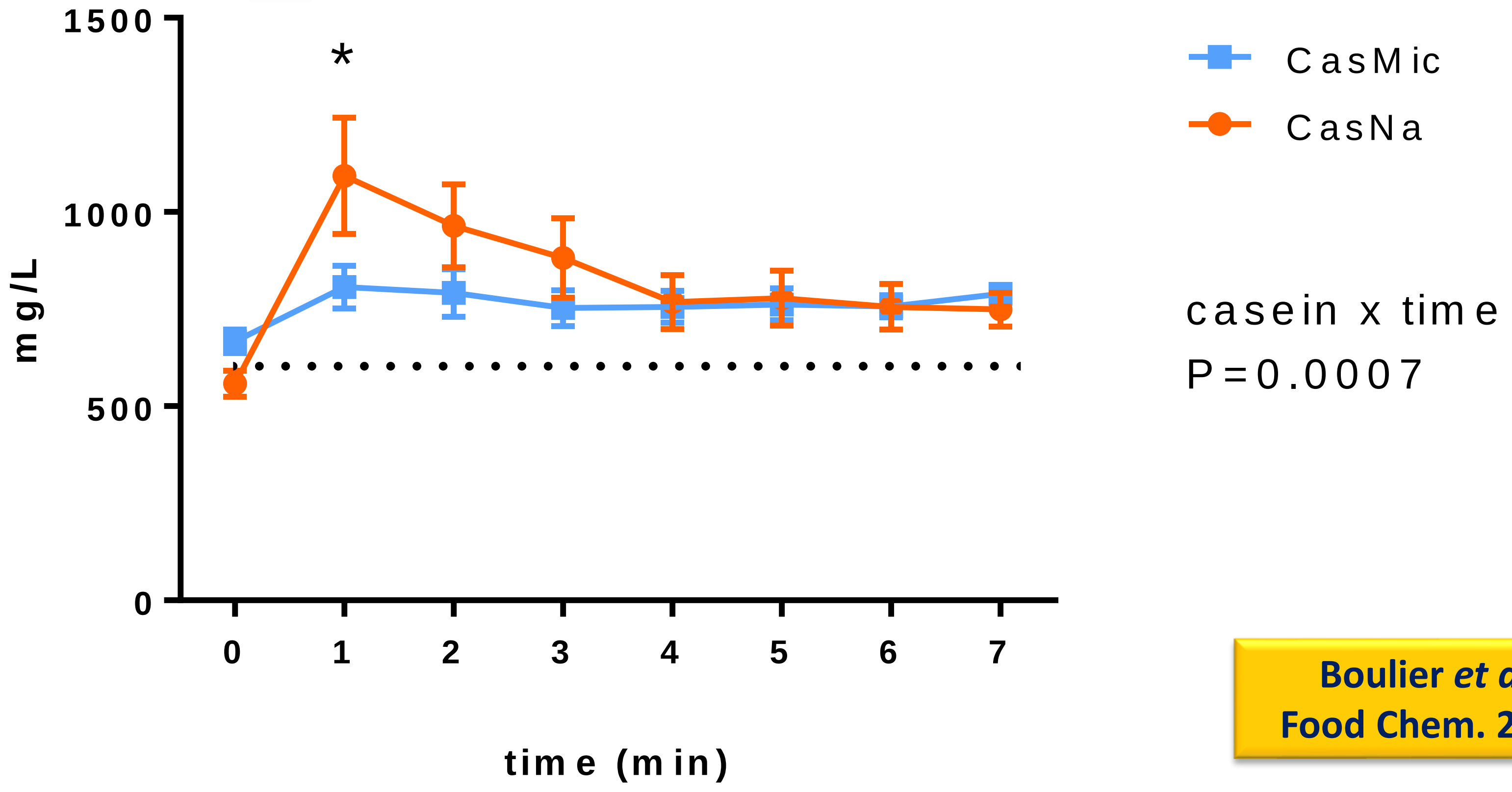
**CS**





# Plasma amino acids

Molecular scale




**Boulier *et al.***
**Food Chem. 2023**

**AA peak after 1h for CM whereas the concentration remains stable for CS**

# Conclusion

* CM form a strong coagulum in the stomach leading to a slow and constant release of plasma amino acids up to 7 h

* CS form a loose precipitate in the proximal part of the stomach but most of the caseins remain solubilized in the liquid fraction

* CS are rapidly metabolized in the small intestine leading to the appearance of a peak of plasma amino acids one hour after protein ingestion

**CM = slow caseins, CS = fast caseins**

# Perspectives

Do some *in vivo* kinetics experiments
Use $^{15}N$ labelled-caseins to differentiate endo/exogenous proteins

# From the protein molecular structure to the the food microstructure: The case of egg white gels

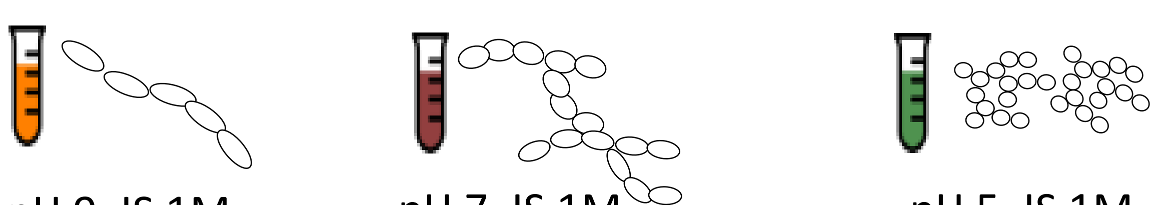
INRA
SCIENCE & IMPACT

Nau F, & Dupont D.
INRAE, Rennes, France

# The microstructure of egg-white gels made from different types of aggregates affects the kinetics of proteolysis

**Microscopic scale**

80°C/6h

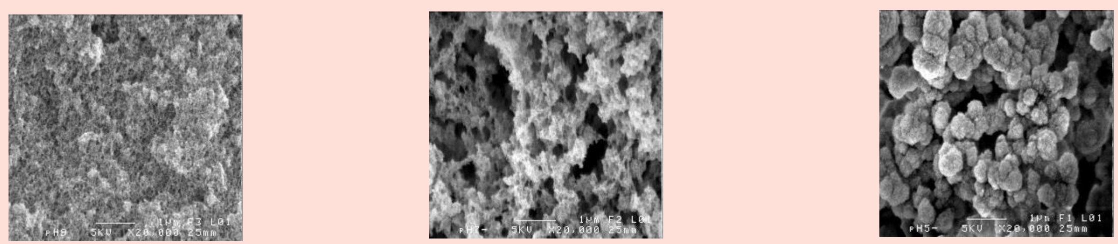


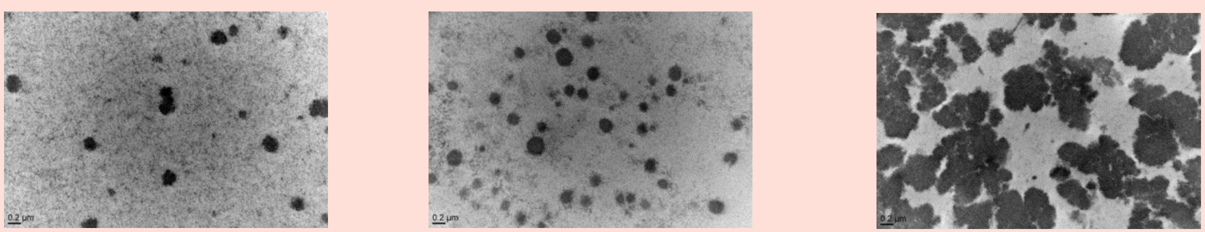
pH 9, IS 1M | pH 7, IS 1M | pH 5, IS 1M

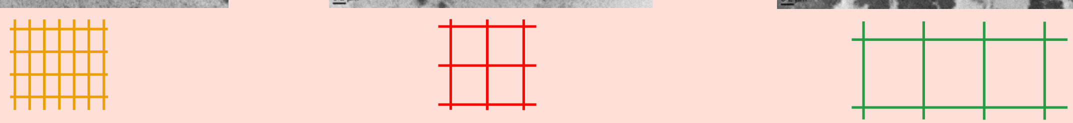
| | | | |
|---|---|---|---|
| **Aggregates** | **linear** | **branched** | **spherical** |
| **Rate of *in vitro* digestion** | +++ | ++ | + |

**Gels** 90°C/2.5 h

**Nyemb *et al*.**
**Food Hydro. 2016**
**Nyemb *et al*.**
**Food Res Int 2016**



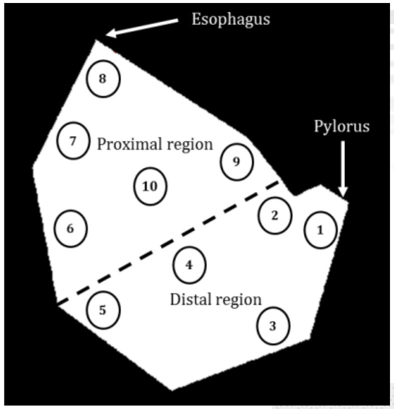



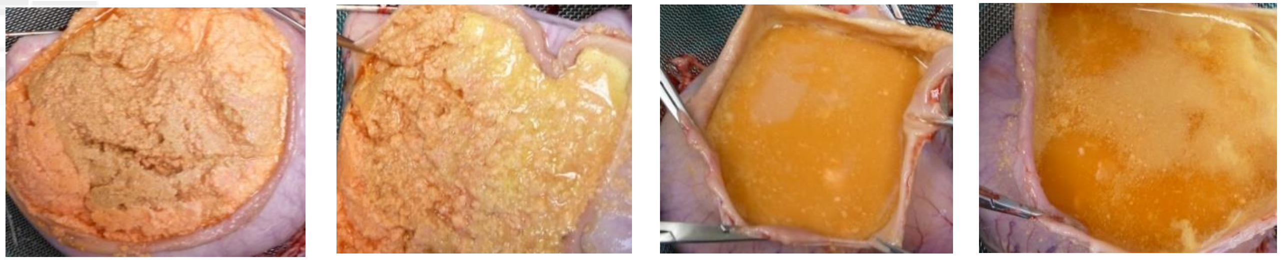



| | | | |
|---|---|---|---|
| **Rate of *in vitro* digestion** | + | ++ | +++ |

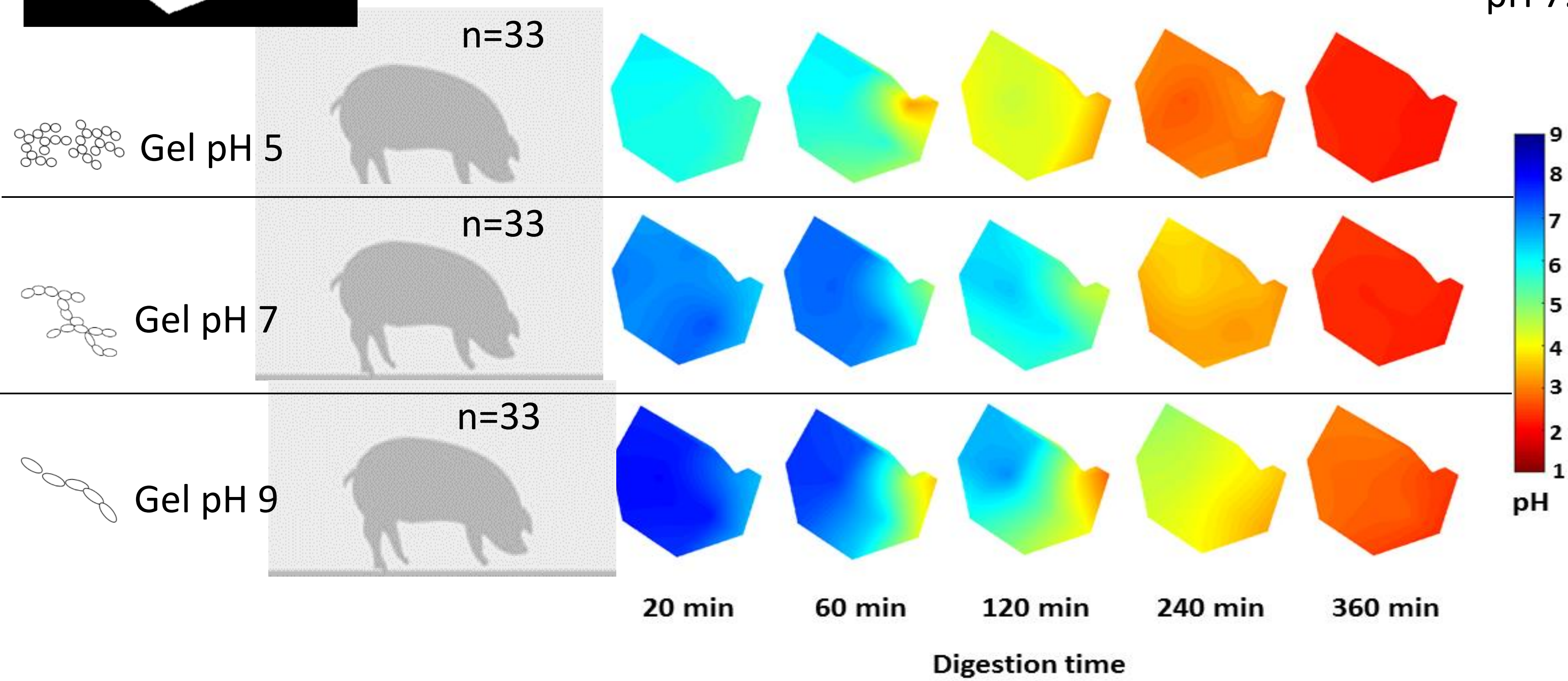
# Spatial-temporal evolution of pH during an *in vivo* digestion

**Microscopic scale**



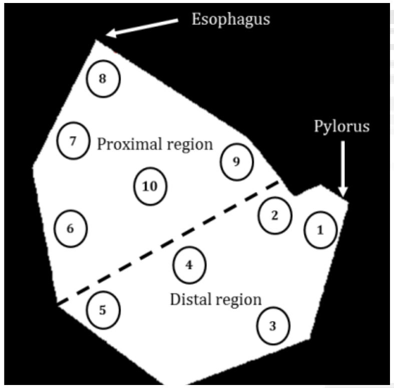
20 min | 60 min | 120 min | 240 min




**Nau *et al.***
**Food Chem. 2019**

AGRO CAMPUS OUEST | INRA SCIENCE & IMPACT | STLO | INSTITUT CARNOT QUALIMENT

# Spatial-temporal evolution of pH during an *in vivo* digestion



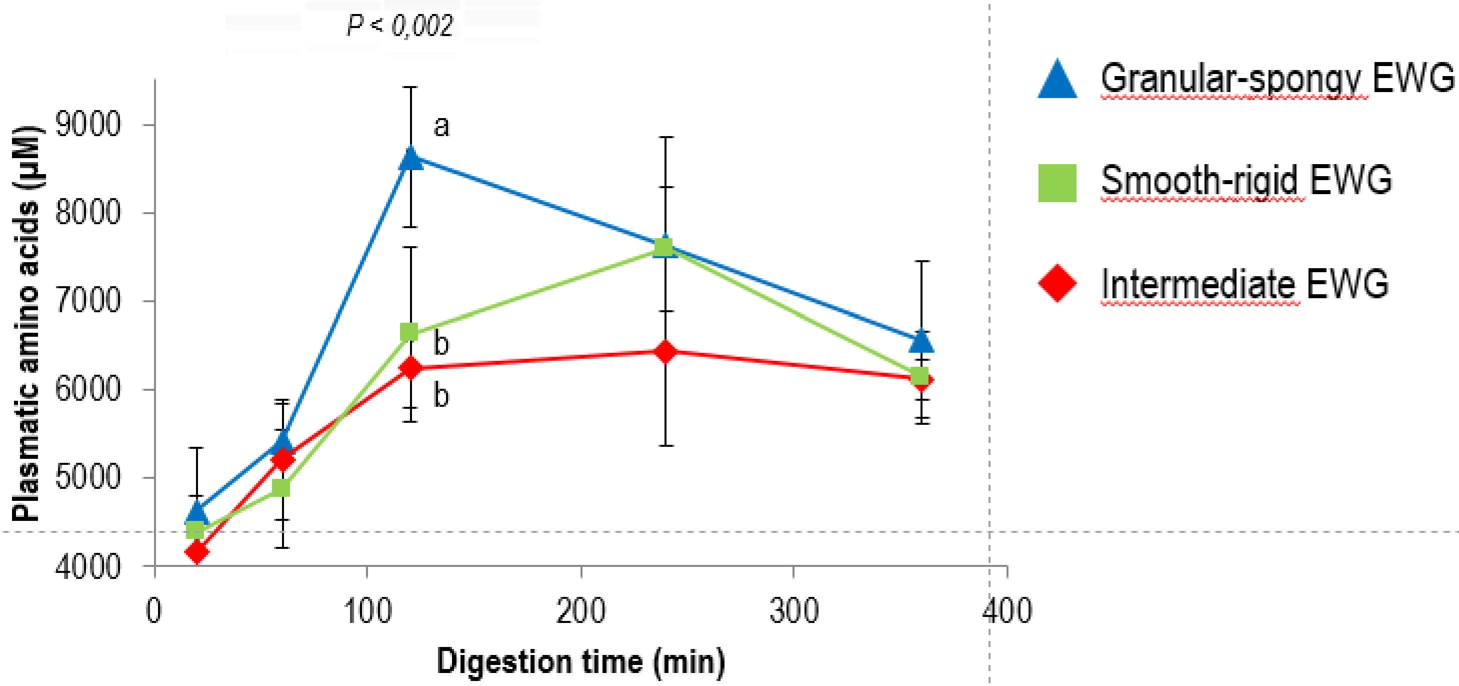

20 min

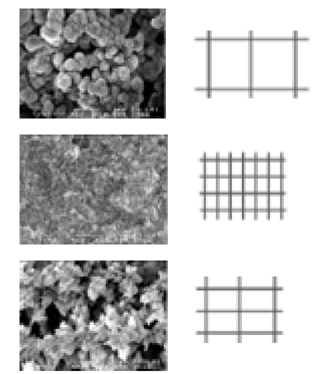
60 min

120 min

240 min

pH 7.0



**Microscopic scale**

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**Nau *et al.***
**Food Chem. 2019**

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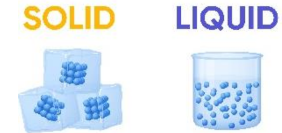
# Food structure as modified by processing affects the kinetics of food digestion

Le Feunteun S, Menard O, Dupont D.
INRAE, Rennes, France

# Comparison of 6 dairy products of identical composition but different structure




**Macroscopic scale**

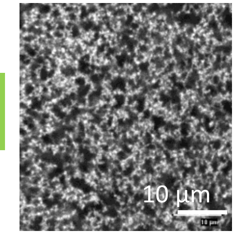
Ultra Low Heat powder

rehydration in water 14.5%

unheated milk ("raw" milk)

macrostructure

24h-20°C, rennet 0.003 % v/w → rennet gel



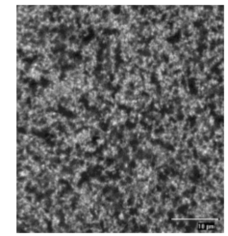

pH 6.6

heat treatment 90°C-10 min

microstructure

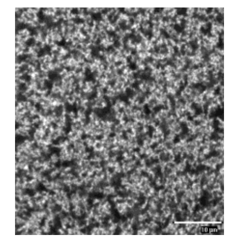
heated milk

24h-20°C, rennet 0.3 % v/w → rennet gel



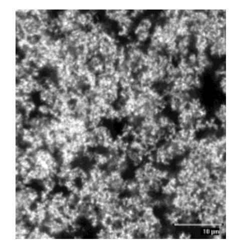
pH 6.6

24h-20°C, GDL 3 % w/w → acid gel



pH 4

24h-20°C, GDL 3 % w/w + mixer 2 min → stirred acid gel



pH 4

Fat-free matrices:

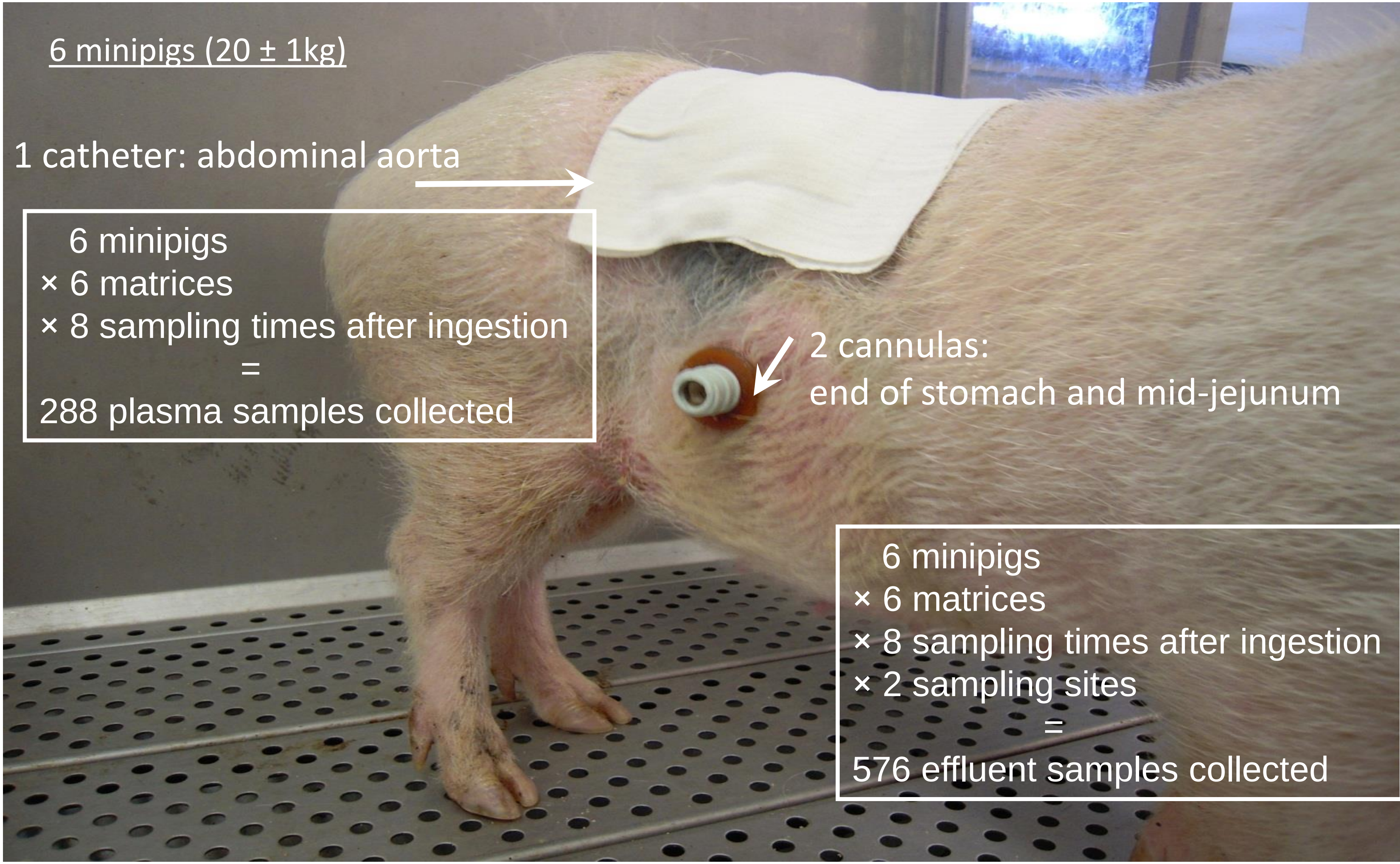
40 g/L caseins, 10 g/L whey proteins,
95 g/L lactose and minerals

+ marker of the meal transit ($Cr^{2+}$-EDTA) → Gastric emptying half-time

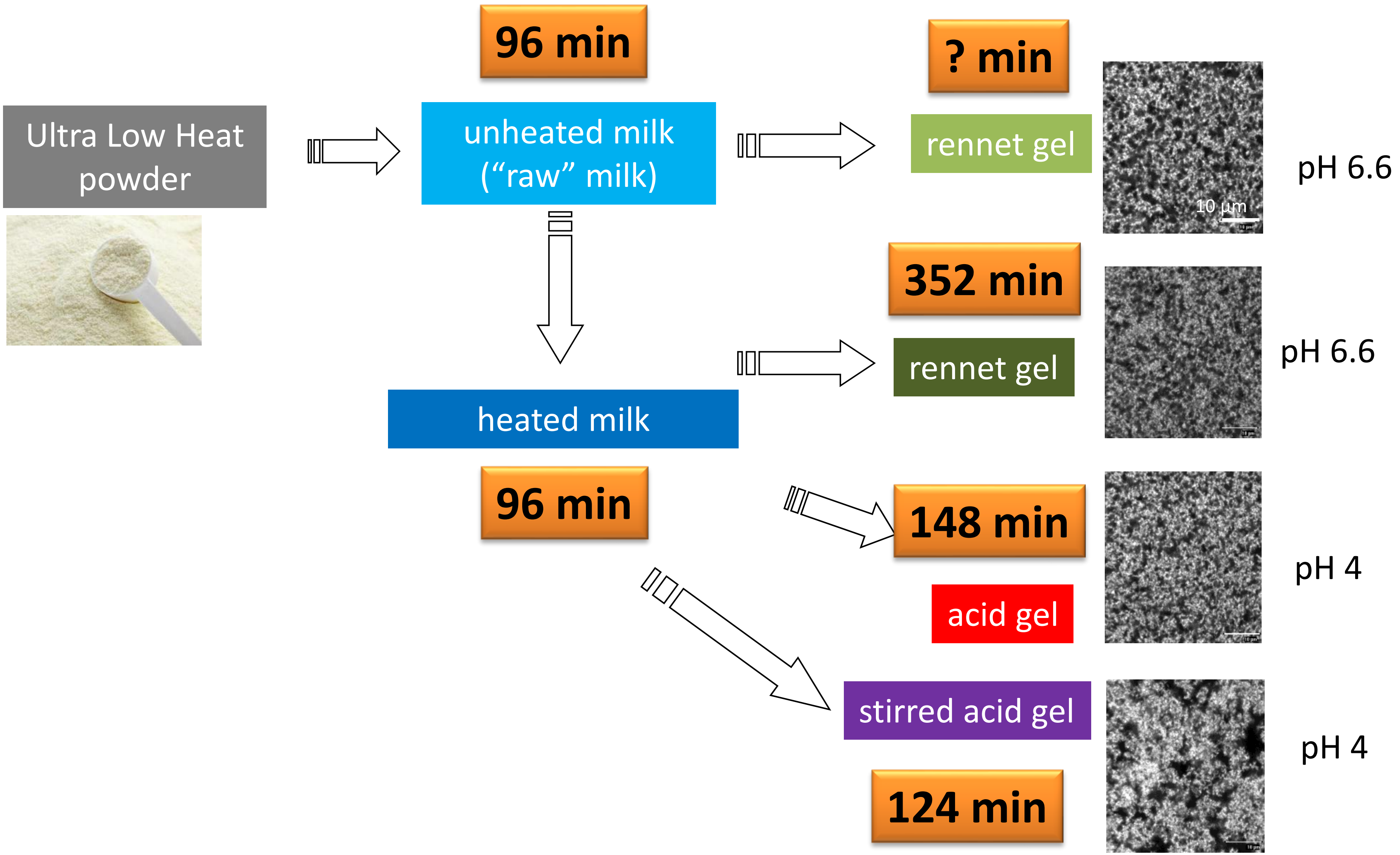
# The multi-canulated mini-pigs

SOLID LIQUID

**Macroscopic scale**



# Gastric emptying half time

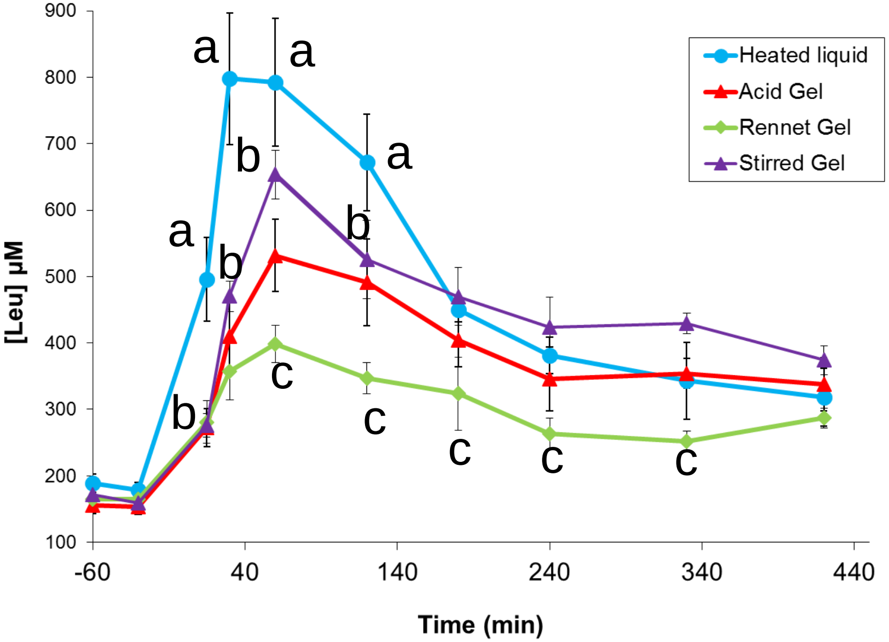
# The liquid-gel transition

**Barbé *et al.* Food Chem 2013**

SOLID LIQUID

**Macroscopic scale**

## Effect on absorption



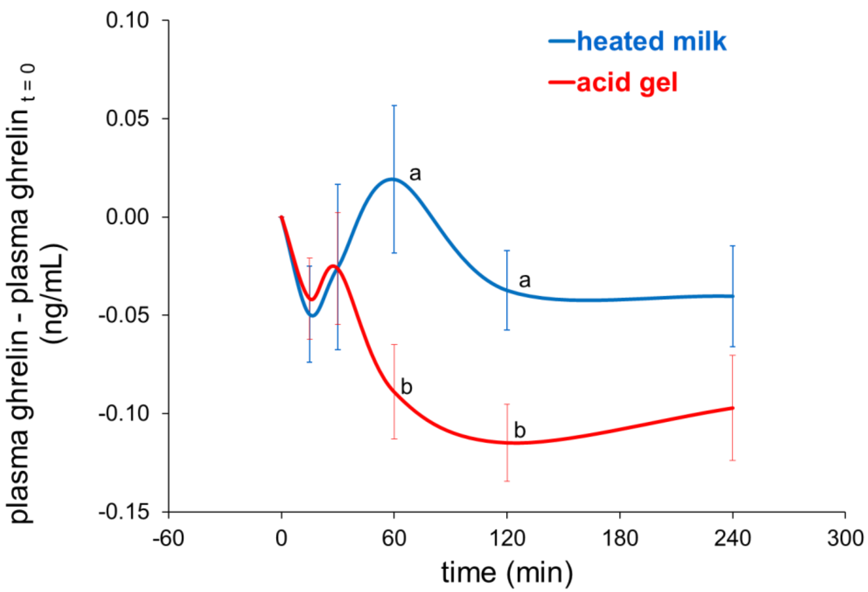

**milk gelation:**

**→ delayed proteins transit → delayed AA absorption**

**↘ maximal AA concentration in the plasma**

## Potential effect on satiety

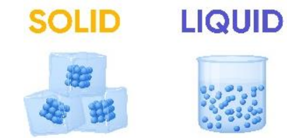
ghrelin (gastrointestinal hormone → appetite stimulation)




**milk gelation:**

**↘ postprandial ghrelin concentration = ↗ satiety ?**

# Bioactive peptides released during digestion differ from one matrix to another




**Macroscopic scale**

More than 16000 peptides identified by LC-MS-MS in the jejunum

| Protein | Sequence | Activity | Reference | 4 | 20 | 50 | 105 | 165 | 225 | 315 |
|---|---|---|---|---|---|---|---|---|---|---|
| αs1 | 1-23 | EMUL | Shimizu et al. (1984) | | | | | | | |
| αs1 | 23-34 | HYP | Maruyama & Suzuki (1982) | | | | | | | |
| αs1 | 30-45 | MB | Meisel et al. (1991) | | | | | | | |
| αs1 | 40-52 | MB | Adamson & Reynolds (1996) | | | | | | | |
| αs1 | 43-58 | MB | Meisel et al. (1991) | | | | | | | |
| αs1 | 91-100 | STRE | Miclo et al. (2001) | | | | | | | |
| αs1 | 99-109 | MIC | McCann et al. (2006) | | | | | | | |
| αs1 | 167-180 | MIC | Hayes et al. (2006) | | | | | | | |
| αs1 | 180-193 | MIC | Hayes et al. (2006) | | | | | | | |
| αs2 | 1-24 | MB | Miquel et al. (2005) | | | | | | | |
| αs2 | 124-146 | MB | Miquel et al. (2005) | | | | | | | |
| αs2 | 183-206 | TRAN | Kizawa et al. (1996) | | | | | | | |
| αs2 | 183-207 | MIC | Recio & Visser (1999) | | | | | | | |
| αs2 | 189-197 | HYP | Maeno et al. (1996) | | | | | | | |
| αs2 | 190-197 | HYP | Maeno et al. (1996) | | | | | | | |
| β | 1-24 | MB | Bouhallab et al. (1999) | | | | | | | |
| β | 33-52 | MB | Miquel et al. (2005) | | | | | | | |
| β | 60-80 | OPI | Jinsmaa & Yoshikawa (1999) | | | | | | | |
| β | 98-105 | OXI | Rival et al. (2001) | | | | | | | |
| β | 114-119 | OPI | Jinsmaa & Yoshikawa (1999) | | | | | | | |
| β | 132-140 | HYP | Robert et al. (2004) | | | | | | | |
| β | 192-209 | IMM | Coste et al. (1992) | | | | | | | |
| β | 193-202 | IMM | Kayser & Meisel (1996) | | | | | | | |
| β | 193-209 | IMM | Coste et al. (1992) | | | | | | | |
| κ | 18-24 | HYP | Lopez-Exposito et al. (2007) | | | | | | | |
| κ | 106-116 | THR | Jolles et al. (1986) | | | | | | | |
| β–lg | 32-40 | HYP | Pihlanto-Leppala et al. (2000) | | | | | | | |
| β–lg | 92-100 | MIC | Pellegrini et al. (2001) | | | | | | | |
| β–lg | 142-148 | HYP | Mullally et al. (1997) | | | | | | | |

**Acid Gel**

| Protein | Sequence | Activity | Reference | 4 | 20 | 50 | 105 | 165 | 225 | 315 |
|---|---|---|---|---|---|---|---|---|---|---|
| αs1 | 40-52 | MB | Adamson & Reynolds (1996) | | | | | | | |
| αs1 | 43-58 | MB | Meisel et al. (1991) | | | | | | | |
| αs1 | 99-109 | MIC | McCann et al. (2006) | | | | | | | |
| αs1 | 167-180 | MIC | Hayes et al. (2006) | | | | | | | |
| αs1 | 180-193 | MIC | Hayes et al. (2006) | | | | | | | |
| αs2 | 1-24 | MB | Miquel et al. (2005) | | | | | | | |
| αs2 | 189-197 | HYP | Maeno et al. (1996) | | | | | | | |
| β | 33-52 | MB | Miquel et al. (2005) | | | | | | | |
| β | 166-175 | HYP | Hayes et al. (2007) | | | | | | | |
| β | 193-202 | IMM | Kayser & Meisel (1996) | | | | | | | |
| β–lg | 92-100 | MIC | (8)) | | | | | | | |
| β–lg | 142-148 | HYP | (9)) | | | | | | | |

**Rennet Gel**

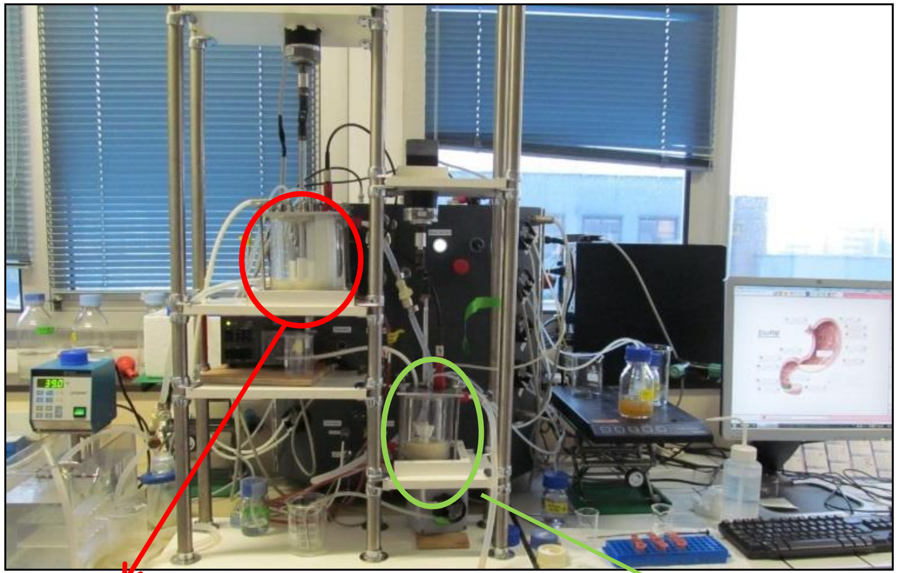
- More bioactive peptides identified during digestion of acid gel than rennet gel
- Nature of peptides is identical (clearly defined by the digestive enzyme specificity)
- Kinetics of release are different

**Barbé et al. 2014**
**Food Res Int**

# Differential behaviour of acid/rennet gels in gastric conditions

- ☞ Acid/Rennet gel: identical composition, similar rheological properties and pore size
- ☞ ≠ Time of residence in the stomach (Acid 148 min /Rennet 352 min)
  - ☞ How can we explain this difference? Dynamic *in vitro* digestion of the 2 gels

**Ménard *et al.* Food Chem 2014**

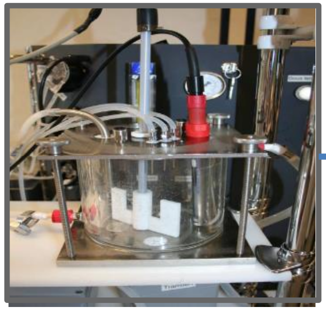


DIDGI®

StoRM® software

**Stomach**

- Pepsine
- Gastric lipase
- Simulated gastric fluid
- HCl



**Emptying : Elashoff's model**

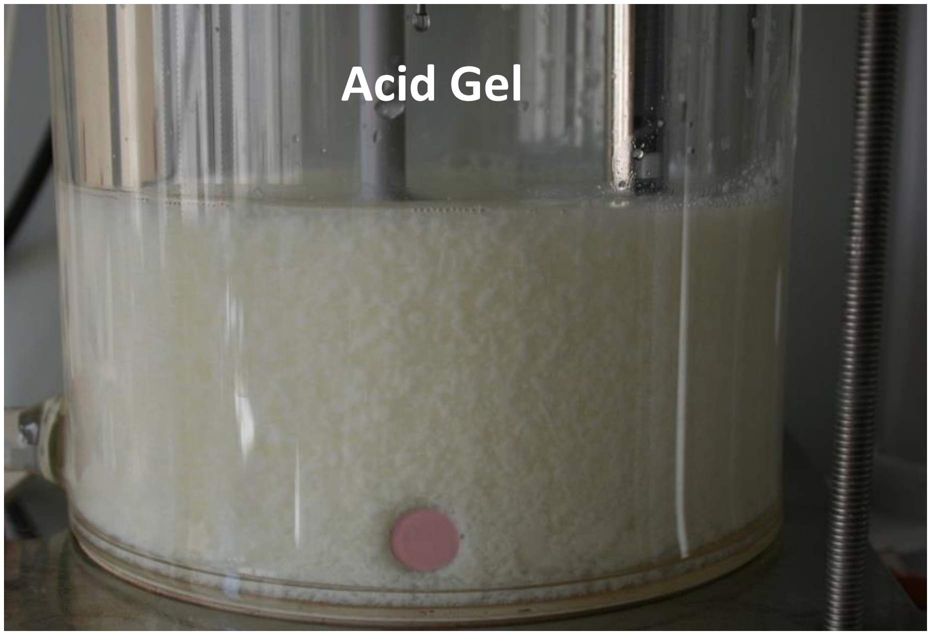
**Small intestine**

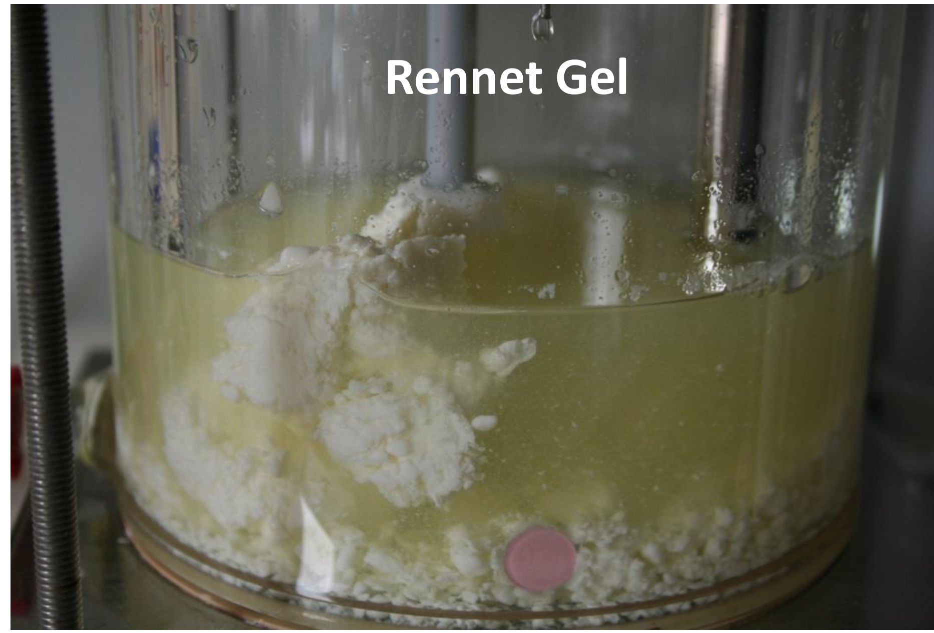
- Pancreatin
- Bile
- Simulated intestinal fluid
- $NaHCO_3$

**Emptying : Elashoff's model**

# Behaviour of acid and rennet gels in the stomach during *in vitro* dynamic digestion

**Barbé et al.**
**Food Chem. 2014**

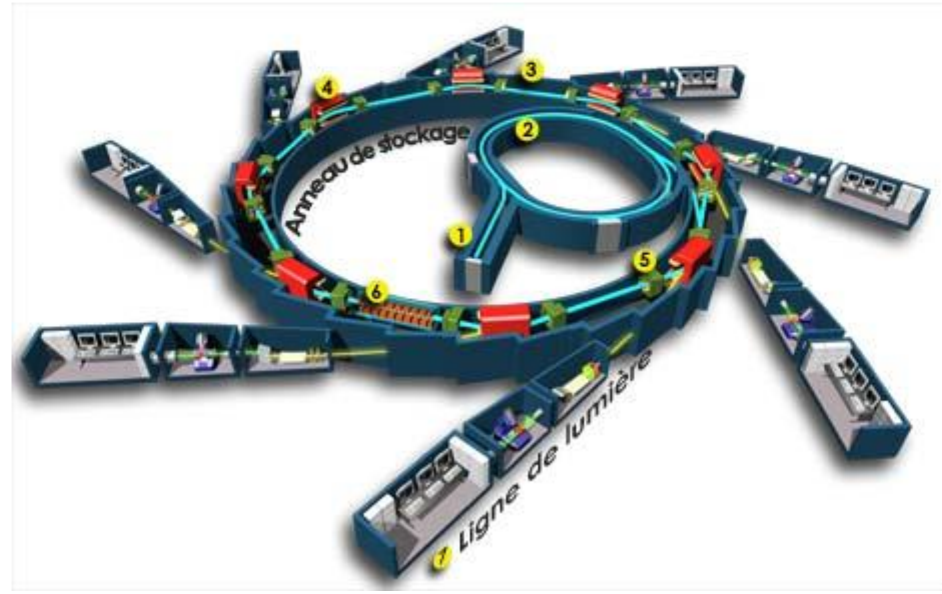



Formation of a strong coagulum with rennet gel → slow down the gastric emptying of caseins

**The structure that a food adopts in the stomach is essential to understand its digestion**

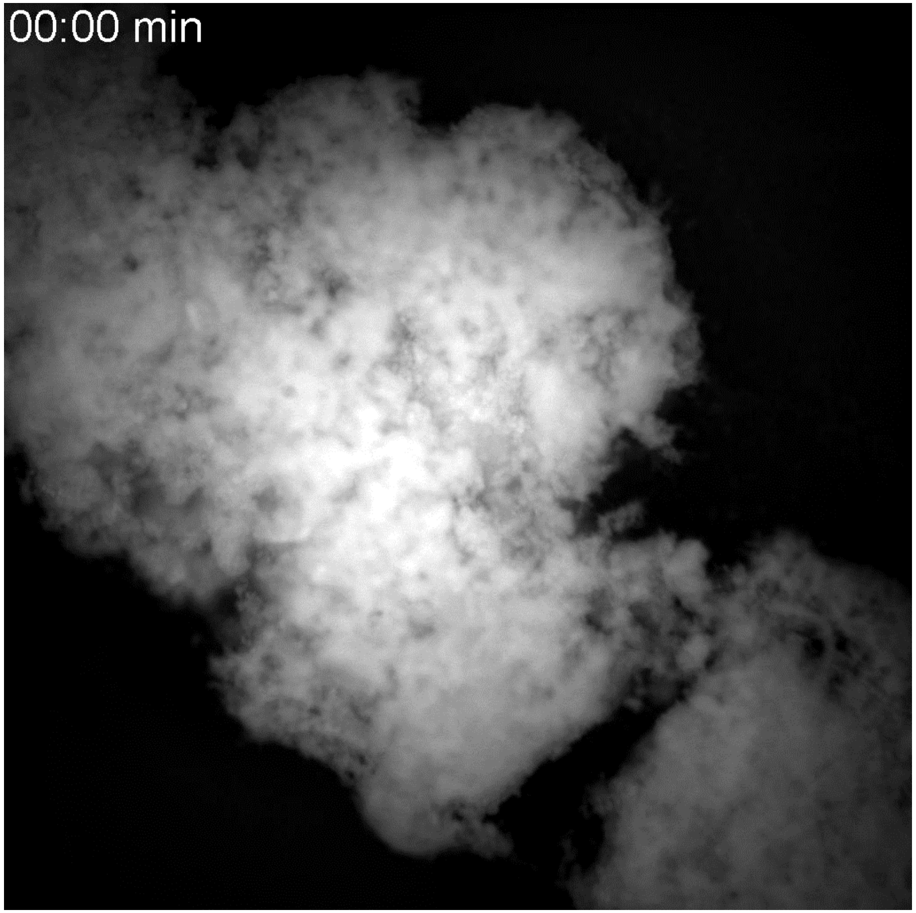
Soleil is a particle (electron) accelerator that produces the synchrotron radiation, an extremely powerful source of light that permits exploration of inert or living matter

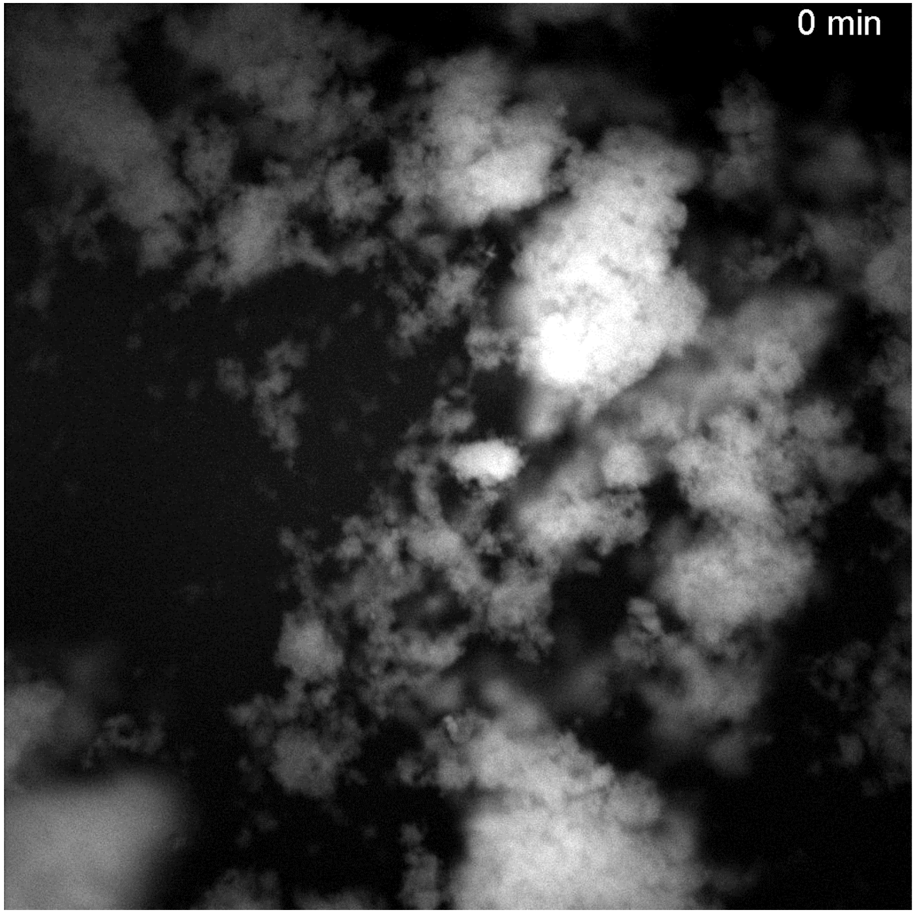



DISCO is a VUV to visible beamline dedicated to biochemistry, chemistry and cell biology. The spectral region is optimized between 60 and 700 nm with conservation of the natural polarization of the light

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

# Kinetics of gel particles disintegration




Rennet Gel

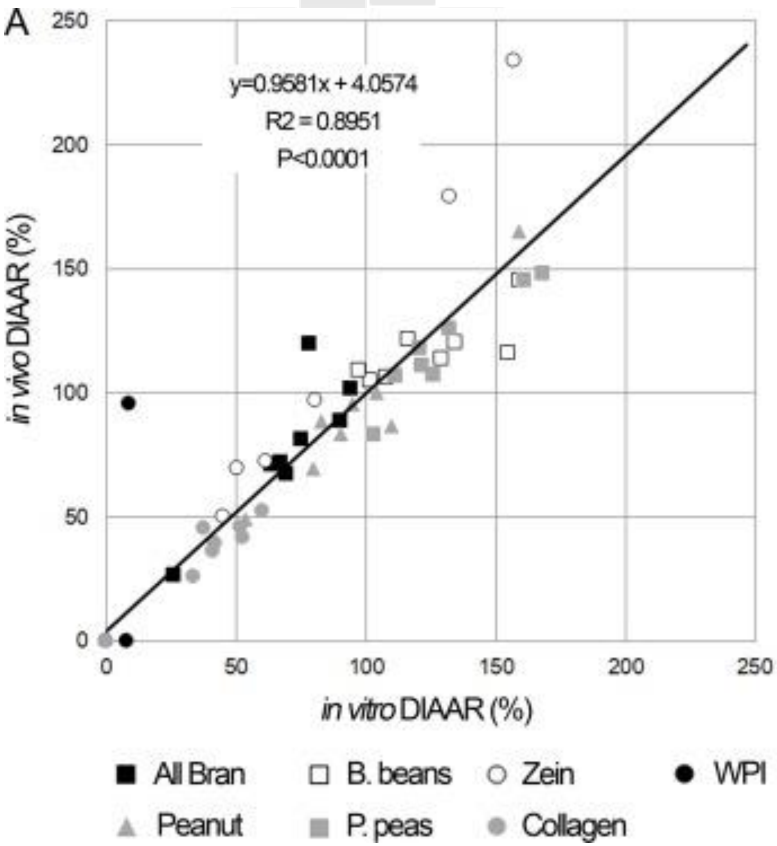
Acid Gel

# Can we estimate plant protein digestibility with in vitro digestion models?

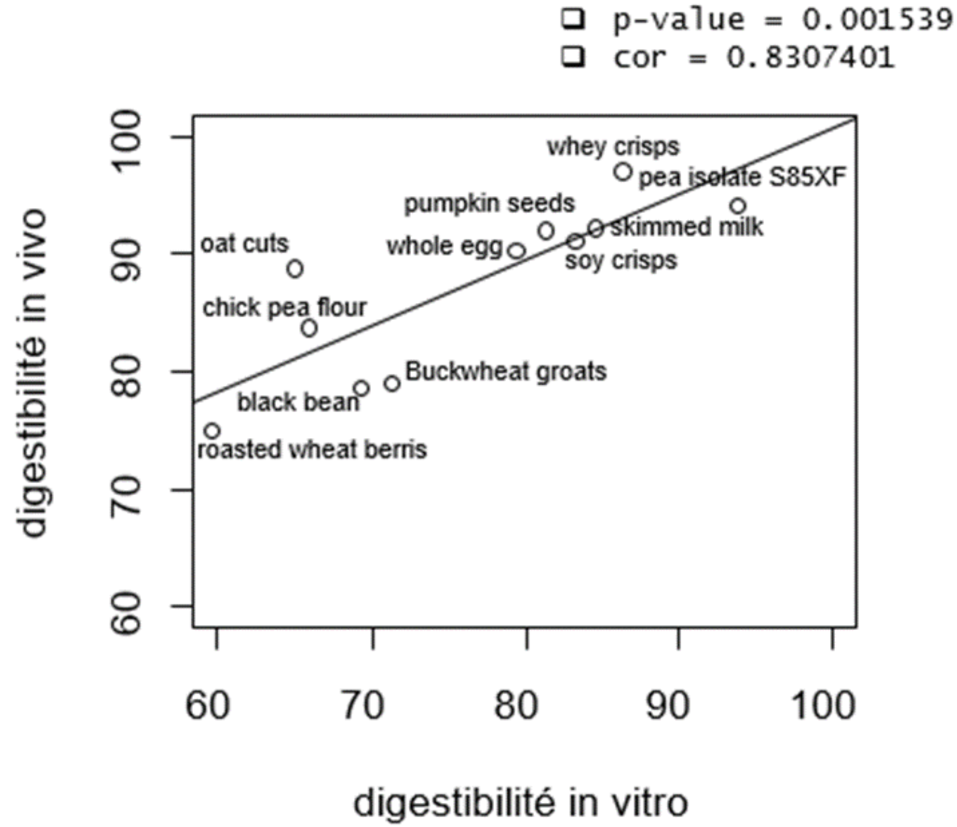
INRA
SCIENCE & IMPACT

Le Feunteun S, Menard O, Dupont D.
INRAE, Rennes, France

# *In vitro/ in vivo* correlation for protein digestibility measurement




Sousa et al. 2023




Nau et al. unpublished

Overall, good correlation are observed but some differences between studies persist

# Protein digestibility with a dynamic *in vitro* digestion model

Study of 4 plant-based foods: 2 solids / 2 liquids

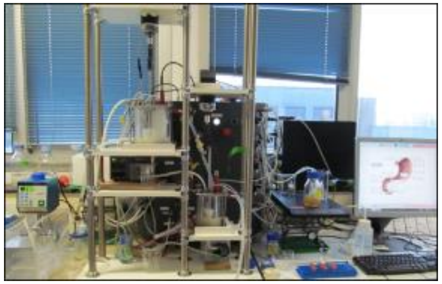
**Reynaud et al. 2021**
**Food Chem. 341**

Tofu

Soymilk

Seitan

Pea Emulsion

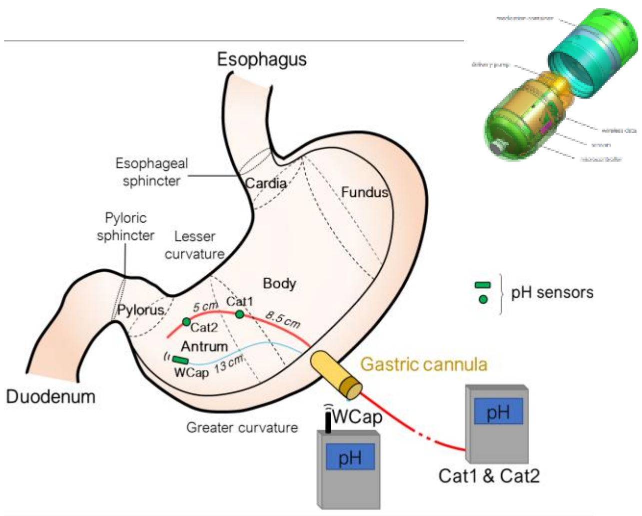


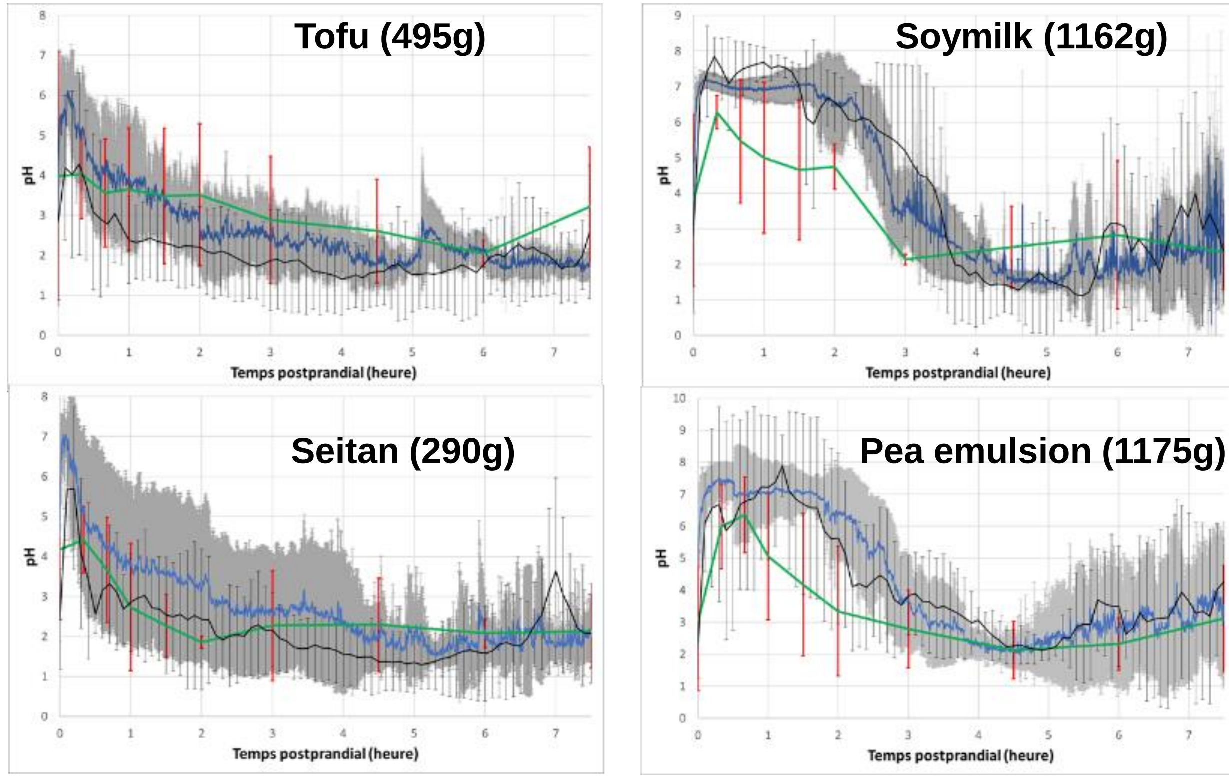
Dynamic *in vitro* digestion DiDGi®

*In vitro*
digestibility
(%)

# *In vivo* data are needed to program the digestion simulator

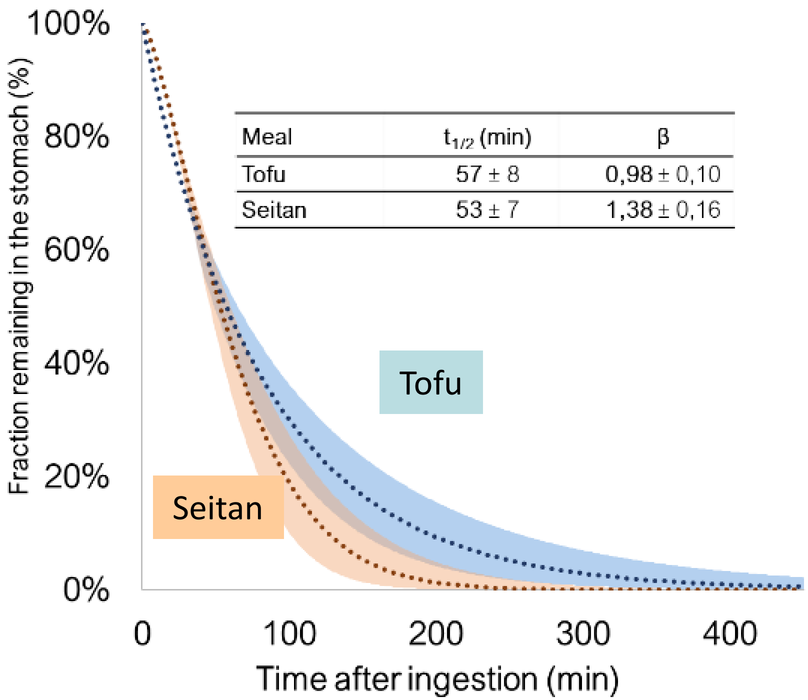
## Evolution of gastric pH



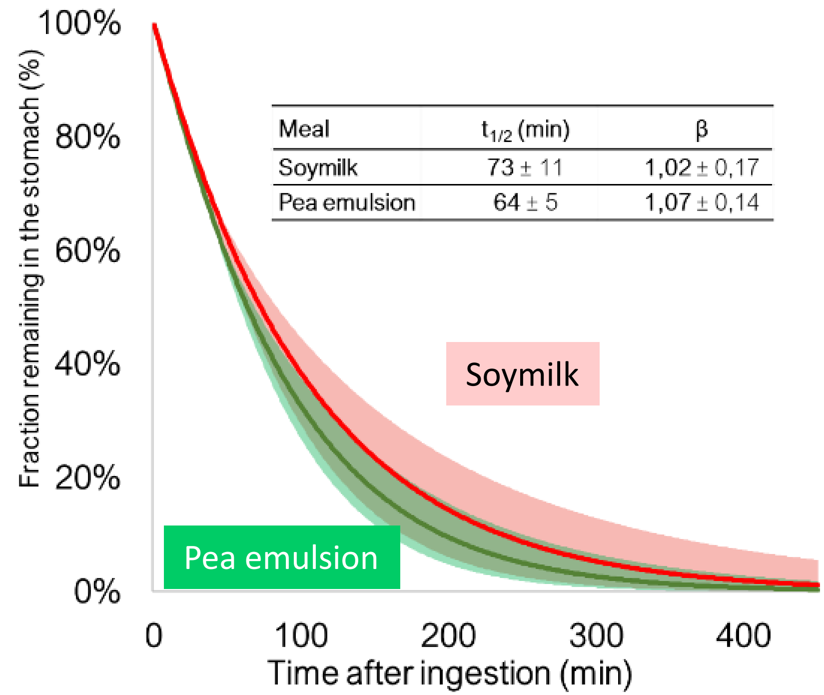



# *In vivo* data are needed to program the digestion simulator

## Gastric emptying




| Meal | $t_{1/2}$ (min) | β |
|---|---|---|
| Tofu | 57 ± 8 | 0,98 ± 0,10 |
| Seitan | 53 ± 7 | 1,38 ± 0,16 |



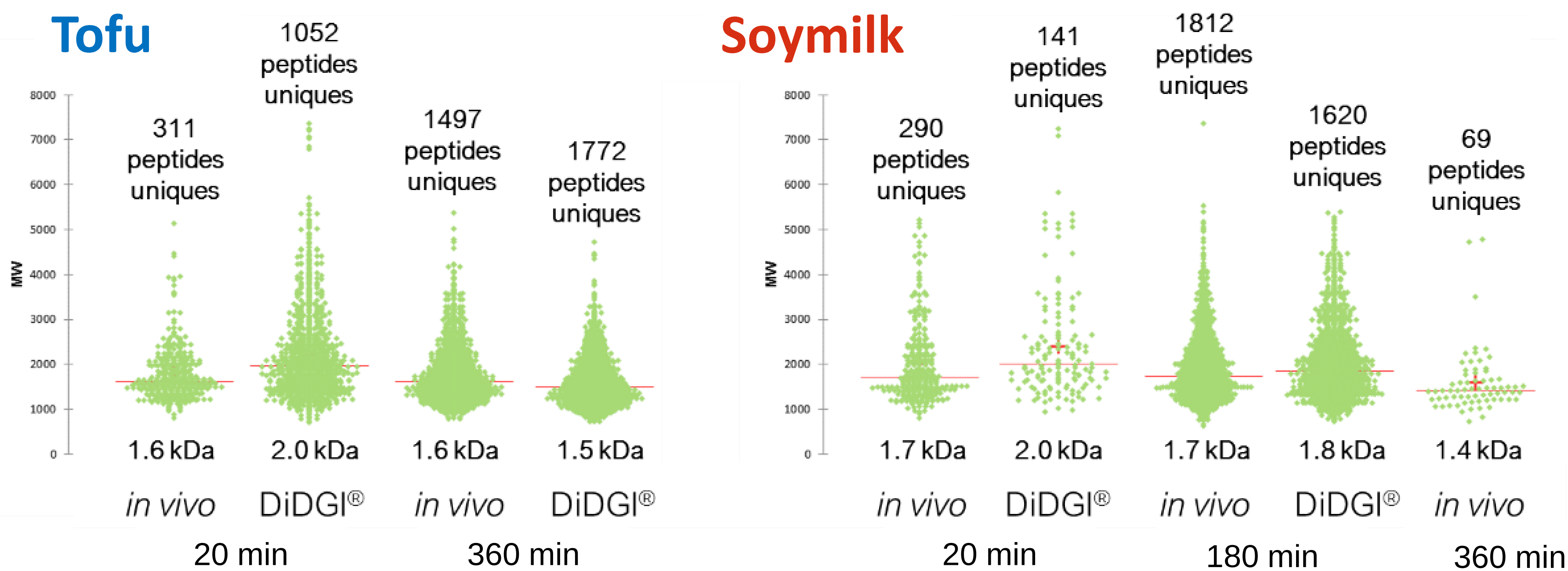

| Meal | $t_{1/2}$ (min) | β |
|---|---|---|
| Soymilk | 73 ± 11 | 1,02 ± 0,17 |
| Pea emulsion | 64 ± 5 | 1,07 ± 0,14 |

**Reynaud et al. 2020**
**Food Res Int, 128**

# Comparison between pig and *in vitro* data

| Model | Digestibility | Tofu | Soymilk |
|---|---|---|---|
| *in vivo* | True | 97.1 ± 4.8% | 99.4 ± 2.2% |
| | **Apparent** | **56.5 ± 7.8%**[b] | **71.3 ± 2.5%**[a] |
| *in vitro* | **Apparent simulated** | **63.7 ± 3.5%**[b] | **72.7 ± 1.4%**[a] |

## Comparison of the gastric peptidome

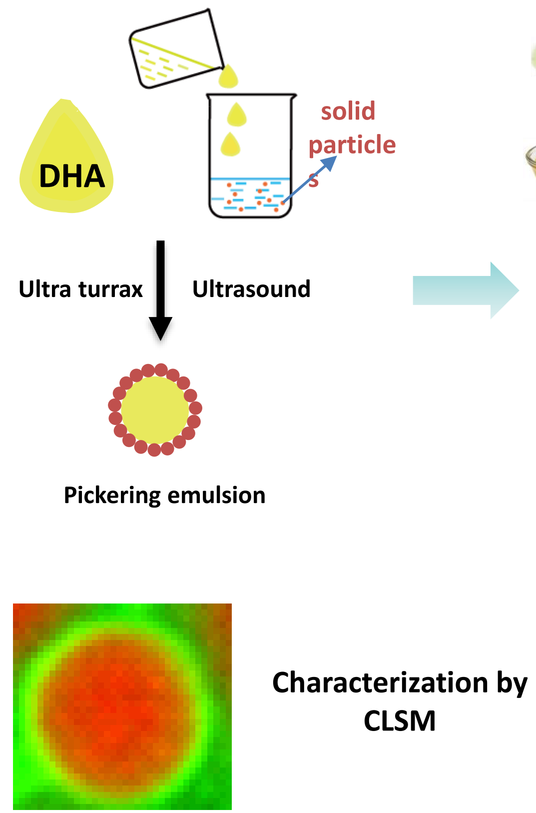


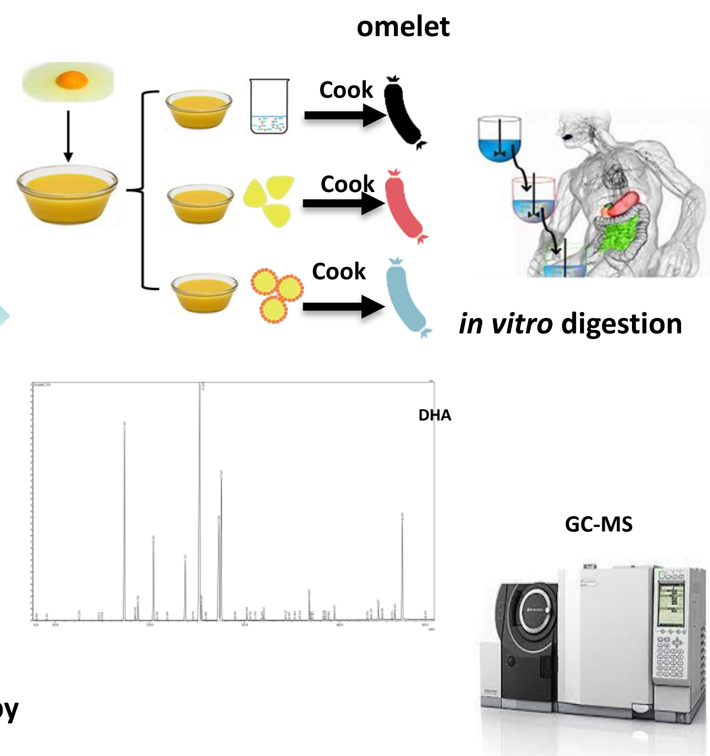
# Improving DHA delivery by encapsulation and design of functional foods

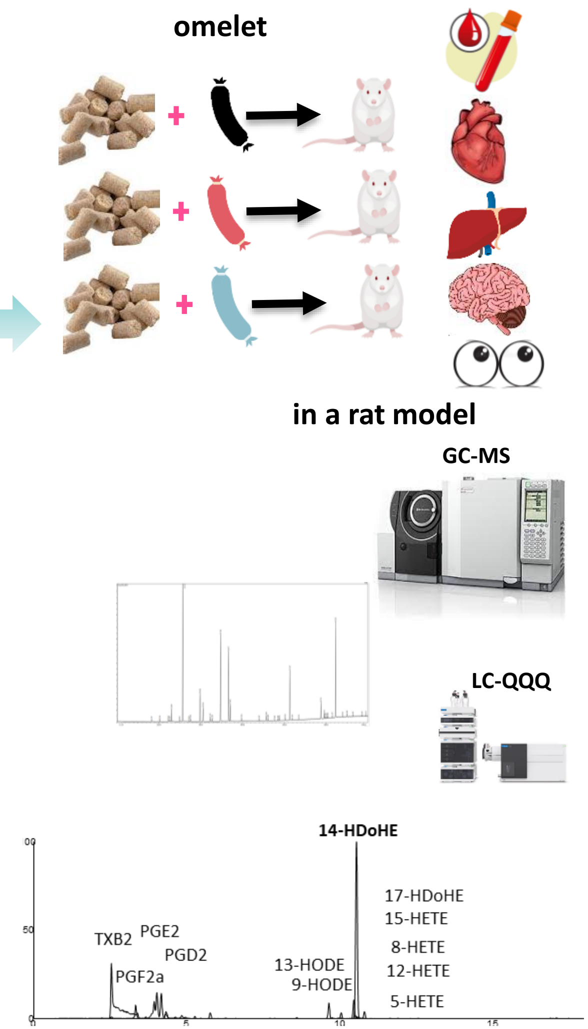
Wang J, Pedrono F, & Dupont D.
INRAE, Rennes, France

# General strategy

**DHA oil encapsulation** | **DHA bioaccessibility** | **DHA bioavailability, accretion and metabolism**



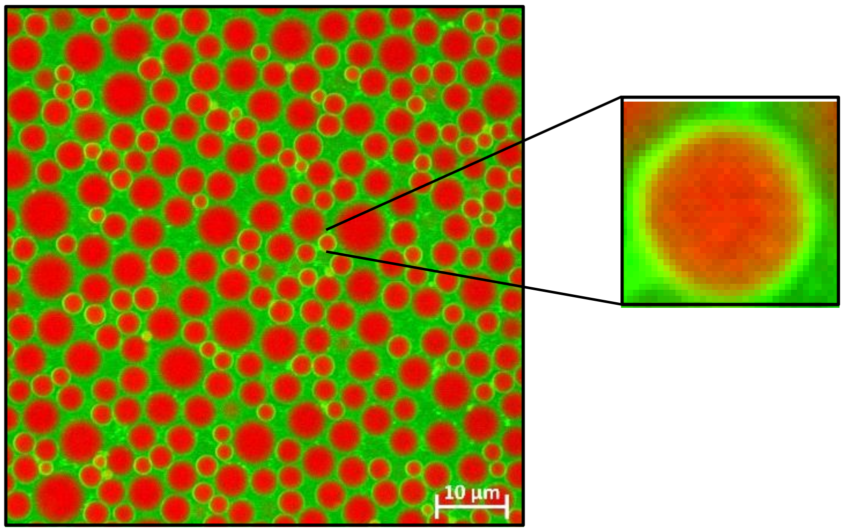

**Wang *et al.*
Food Res Int 2022**

**Wang *et al.*
Frontiers in Nutr 2022**

**Wang *et al.*
Nutrients 2023**

# DHA oil in emulsion and omelet

**In emulsion**

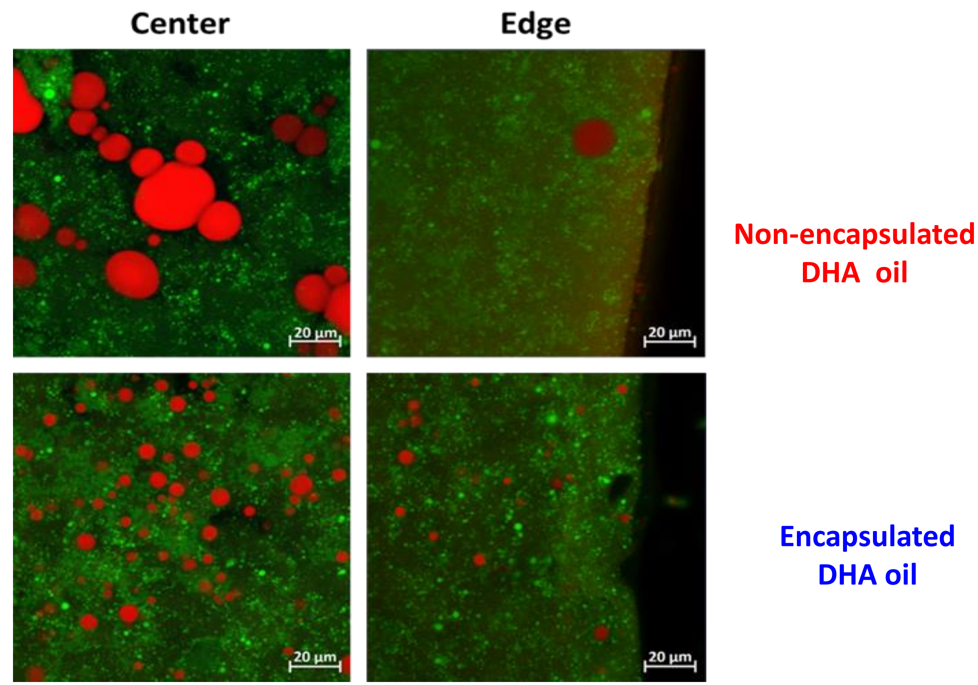



**Encapsulated DHA oil with heat-denatured WPI**

DHA oil stained with Nile Red and proteins stained with Fast Green.

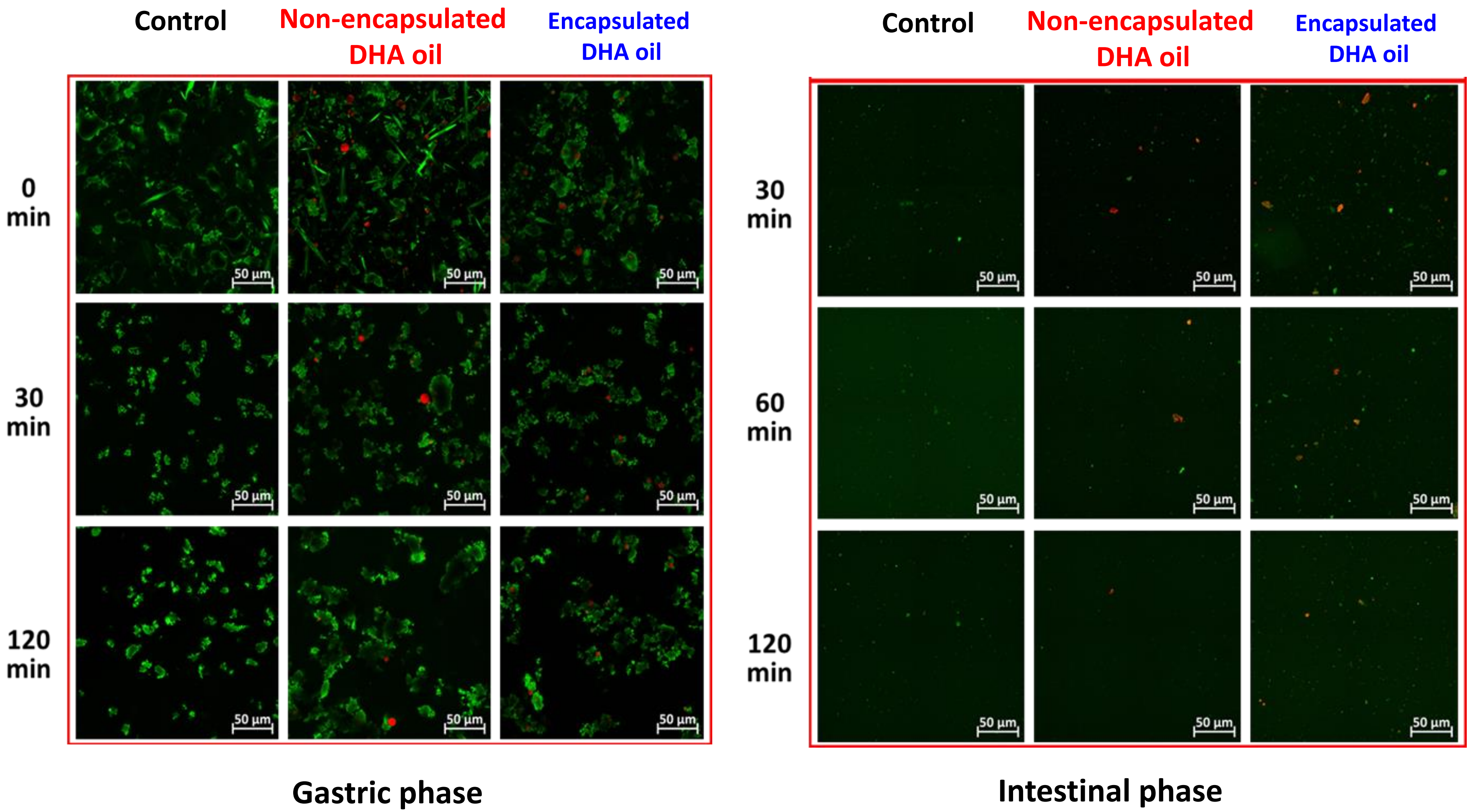
The particle size of heat-denatured WPI on average is 42 nm.

**In omelet**



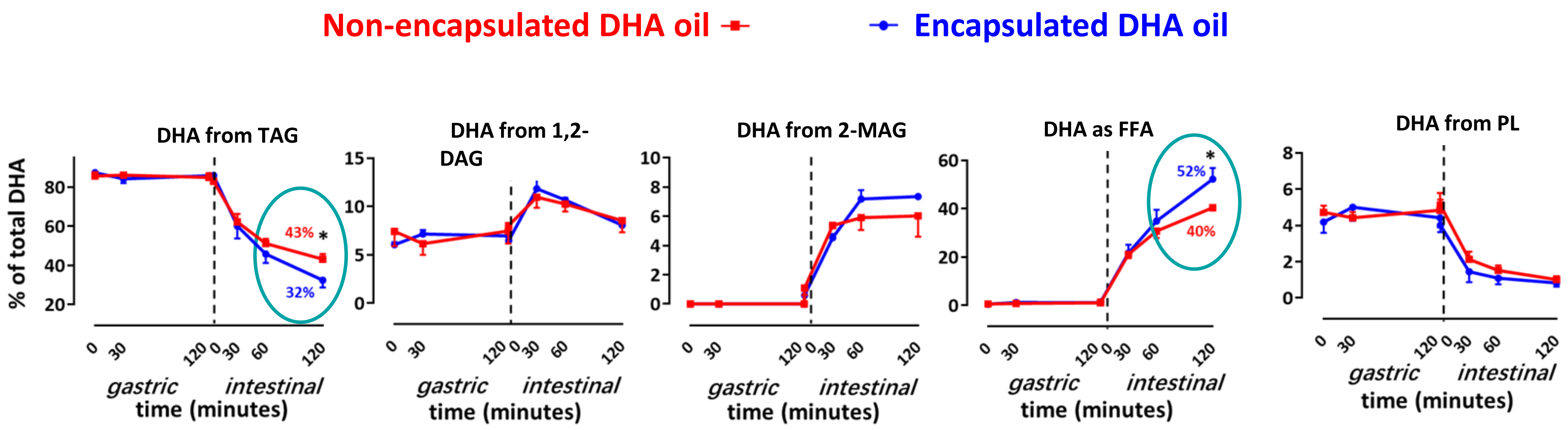

**Distribution of non-encapsulated and encapsulated DHA oil in omelets.**

# DHA oil in omelet during digestion




**DHA oil and proteins were mainly hydrolyzed in intestinal phase**

# The release of DHA from different lipid species during digestion




The evolution DHA from different lipid species during digestion.

**In gastric phase (pepsin and RGE):**

- ☐ DHA oil was not hydrolyzed in gastric phase.

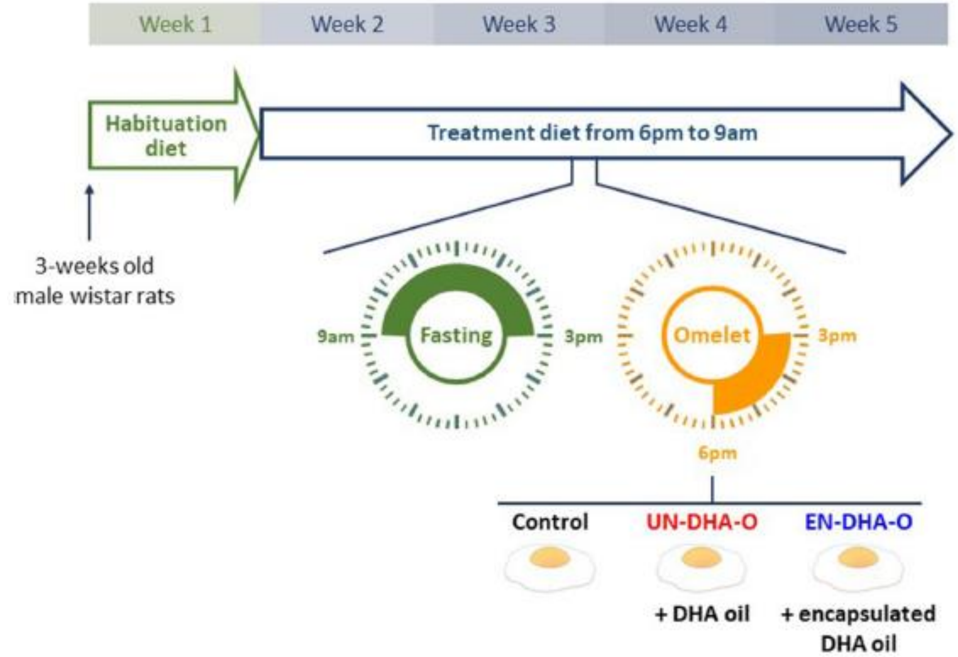
**In intestinal phase (bile salt and pancreatin):**

- ☐ Hydrolyzed TAG and released FFA encapsulation > unencapsulation

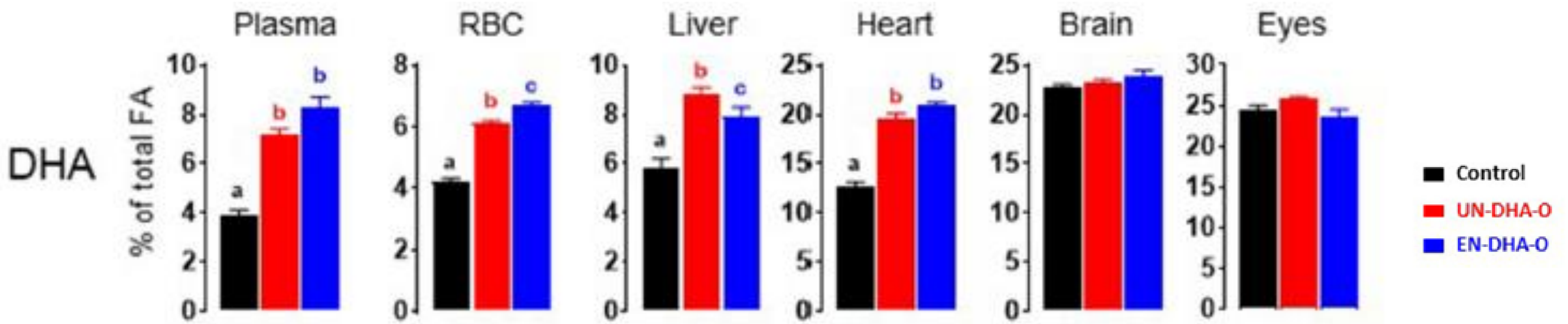
- ☐ **Larger interaction area between DHA oil and pancreatic lipase made by emulsification** *(Maljaars, 2012).*

- ☐ Around **10-25%** and 40-70% of ingested **TAG** can be hydrolyzed **in gastric** and intestinal phase, respectively *(Bauer et al; Carriere et al., 1993).*

# What happens *in vivo*?




Encapsulation increased DHA concentration in plasma and red blood cells




Encapsulation increased oxylipins in heart and brain (precursors of protectins and maresins that limit inflammation and infection)

# Food structure affects the delivery of hydrophilic and lipophilic micronutrients

INRA
SCIENCE & IMPACT

Hiolle M., Dupont D. & Nau F.

INRAE, Rennes, France

# Objective of the study:

Demonstrate the effect of the food macrostructure on the bioavailability of Vit B9, Vit B12, Vit D and lutein

## Development of food matrices

Identical composition on dry matter:
- 17 % proteins
- 30 % lipids
- 52 % carbohydrates

Enriched in micronutrients

Biscuit
DM = 97 %

Sponge cake
DM = 57 %

Pudding
DM = 51 %

Custard
DM = 31 %

**Hiolle *et al.* Food Chem. 2020**

## Characterisation of the matrices

Extensive biochemical characterization

Macrostructure : texture analysis

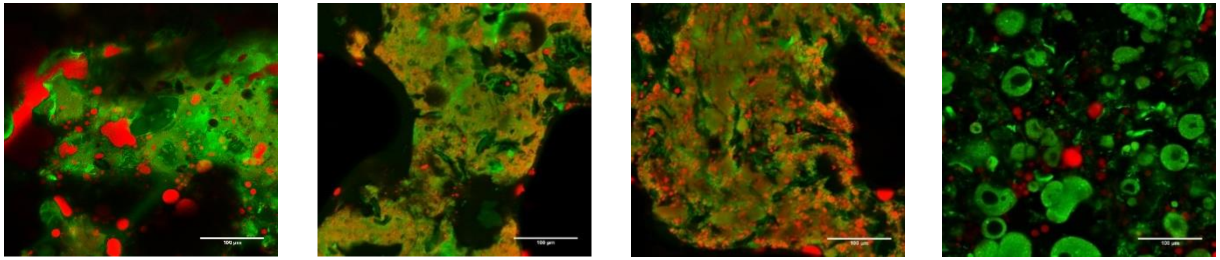
Microstructure : confocal microscopy

## Clinical study

12 healthy volunteers (20-30 y)
Randomized, controlled, crossover study

Postprandial analyses over 8h

Quantification in the plasma :
- Vit B9, B12, D and lutein



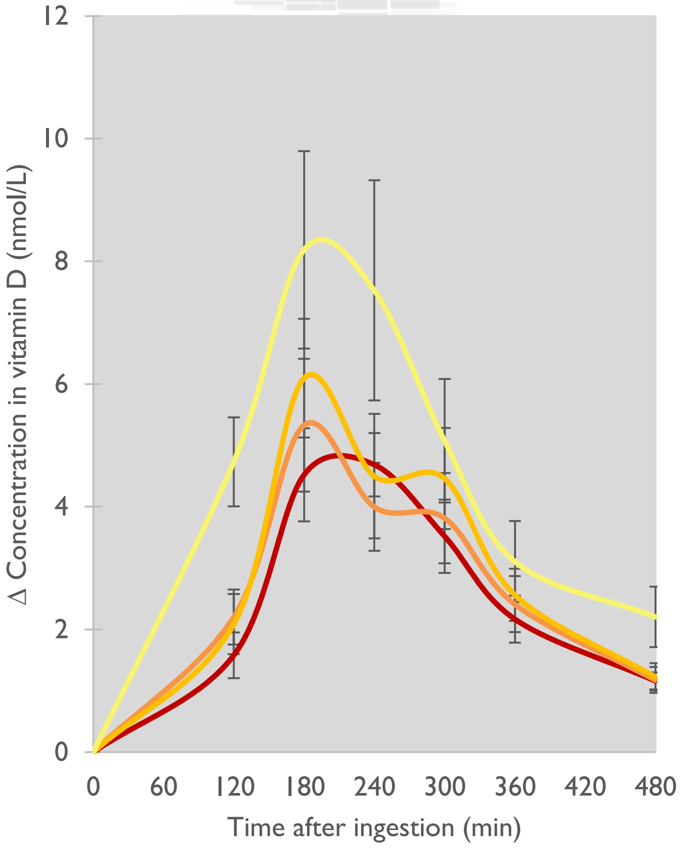
**Biscuit** **Sponge cake** **Pudding** **Custard**

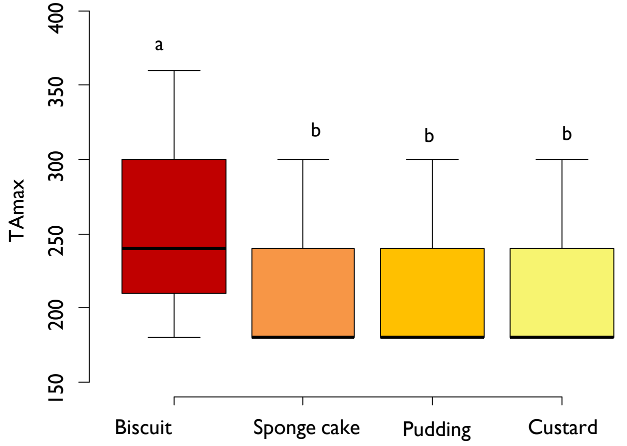
: lipids (Nile Red) : proteins (Fast Green)

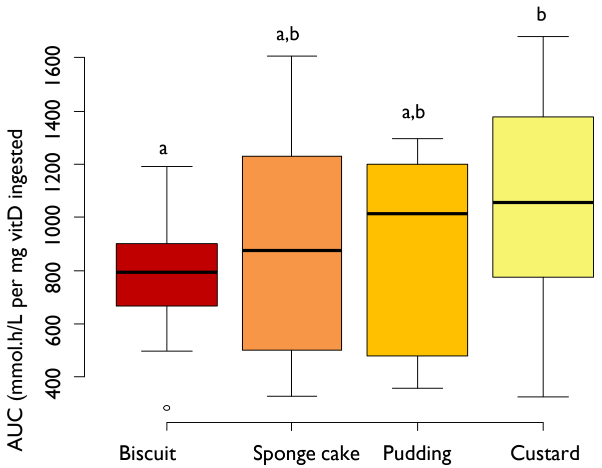
# Food structure affects micronutrient kinetics of release and bioavailability

Vitamin D

Clinical study




**Buffière *et al.* Food Chem. 2020**

Increased AUC for vitamin D when provided via a custard

# Understanding human milk digestion to design new infant formulas that will have the same behaviour in the GI tract

Deglaire A., Menard O., De Oliveira S., Bourlieu C. & Dupont D.

INRAE, Rennes, France

# Human/ bovine milk / Infant Formula

## Lipid globule structure

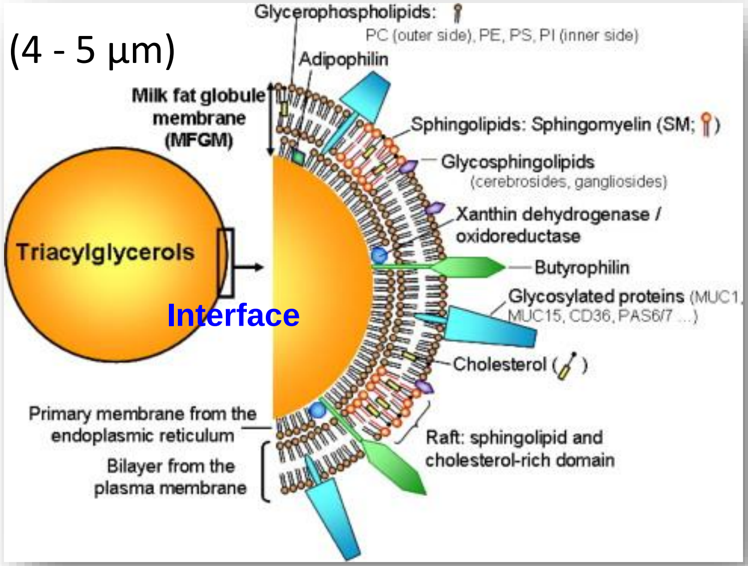
Human milk

Bovine milk

Infant Formula

Native milk fat globule

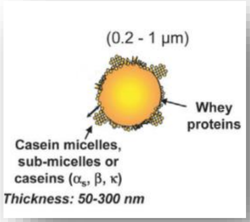
(4 - 5 µm)




(Lopez, 2010)

Lipid droplets

Triacylglycerols

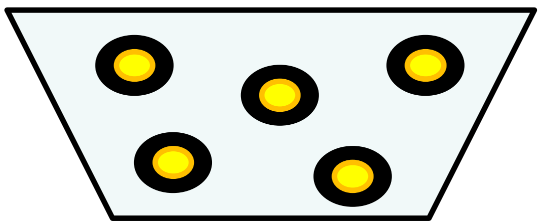



(0,2 - 1 µm)

(Lopez and Briard-Bion, 2007)

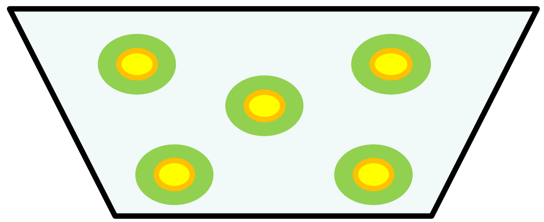
# Infant formulas: can we create lipid structures biomimetic on the native fat globule?

**Formula T1**



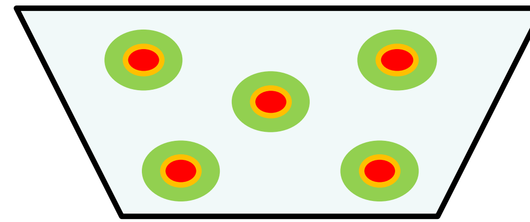
Interface 100 % Proteins
100% vegetable oil

**Formula T2**

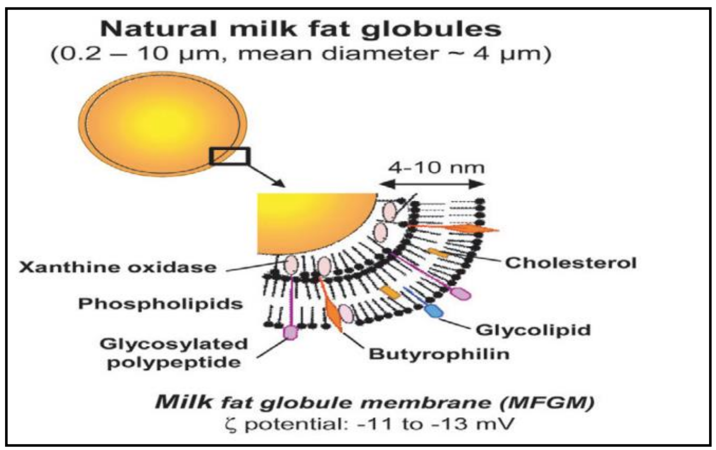


Interface 100 % phospholipids
100% vegetable oil

**Formula T3**

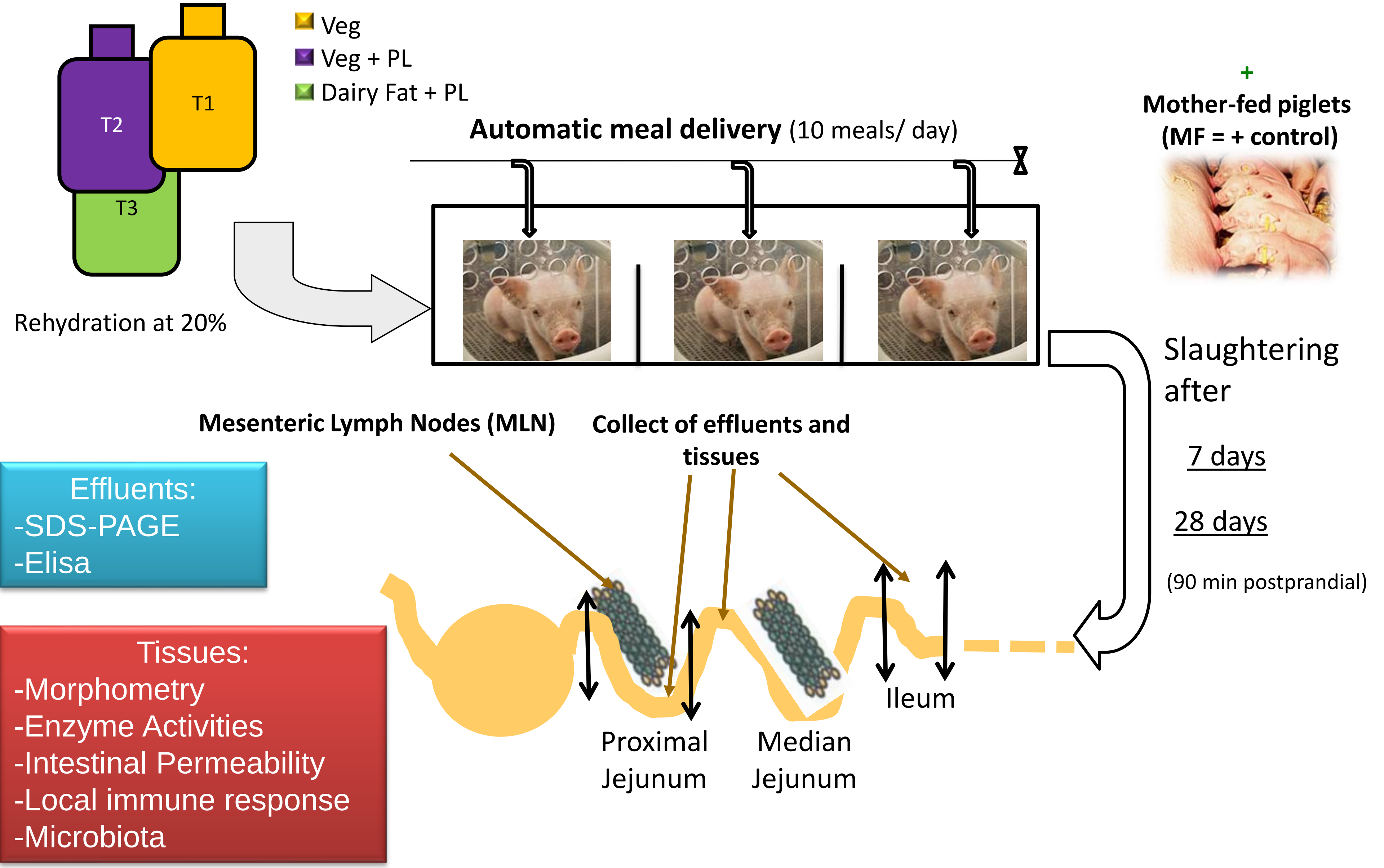


Interface 100 % phospholipides
40% vegetable oil + 60% milk fat



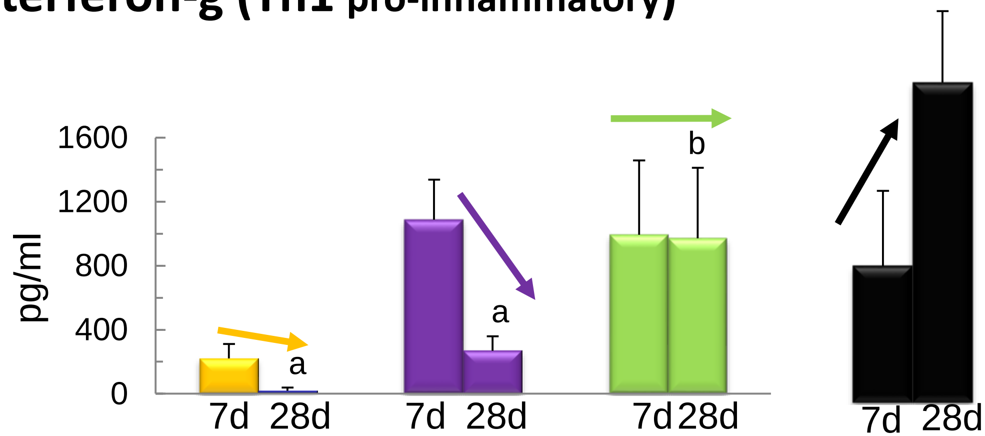

Lopez, (2007)

# Can the composition of infant formula modulate the physiological response of the neonate?

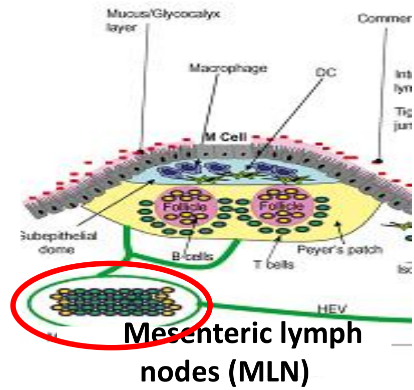


# Secretory activity of MLN

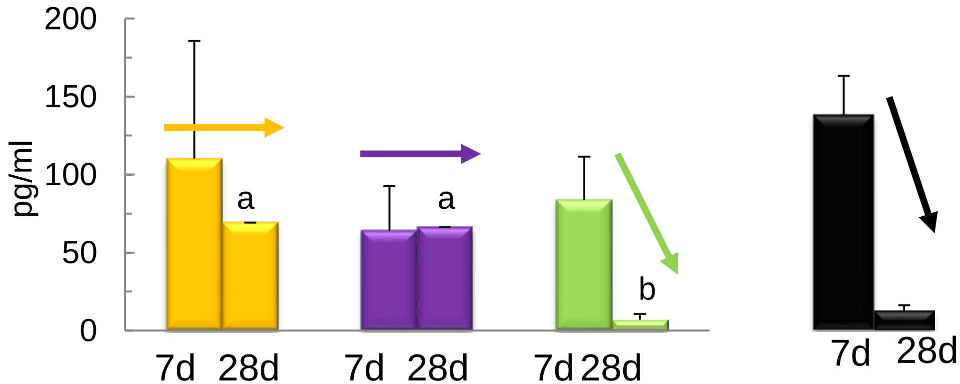
## Interferon-g (Th1 pro-inflammatory)




- Veg
- Veg + PL
- Dairy Fat + PL
- Porcelets SM




## Interleukine-10 (Th2 anti-inflammatory)

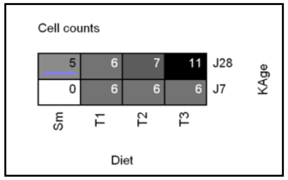



Milk lipids ➔ maturation of the piglet's immune system more similar than with sow's milk

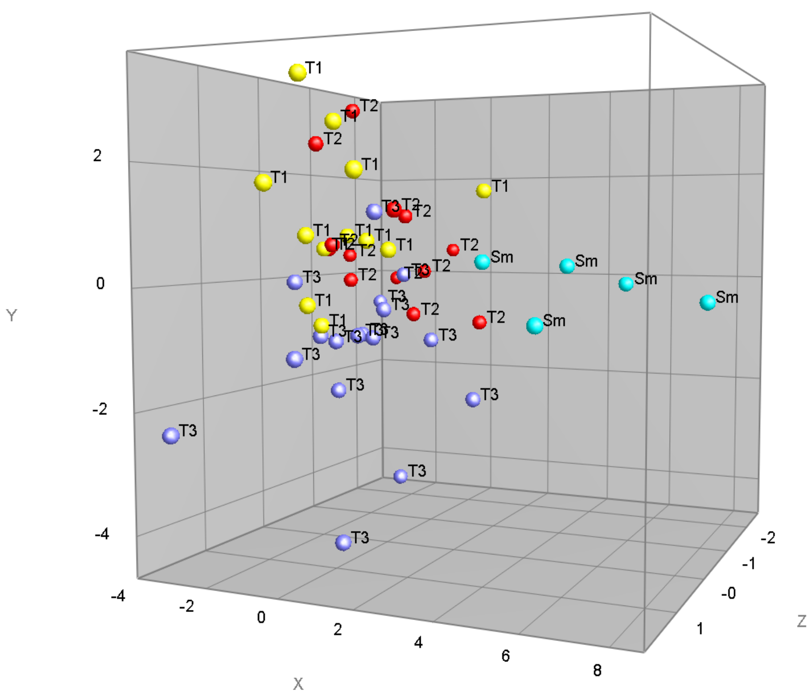
Le Huerou et al.
Eur J Nutr 2017

AGRO CAMPUS OUEST INRA SCIENCE & IMPACT STLO INSTITUT CARNOT QUALIMENT

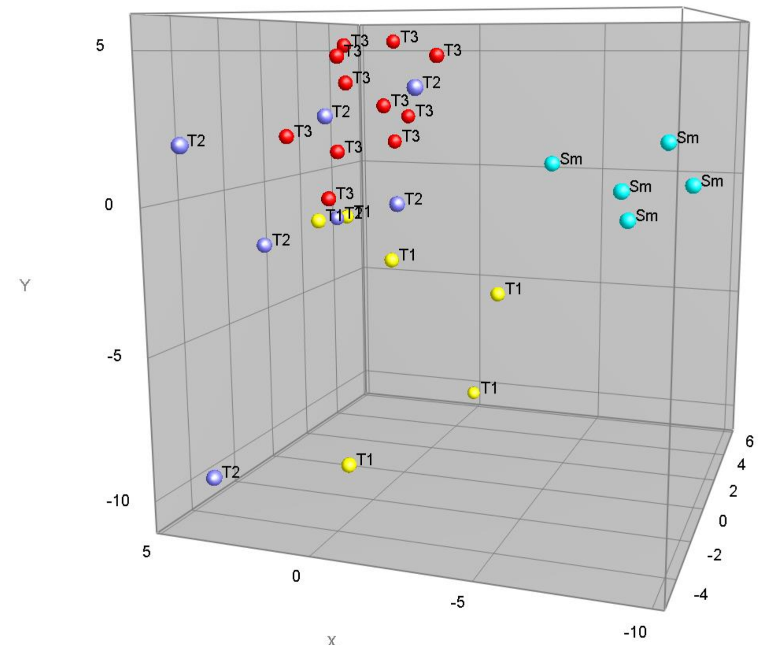
# Microbiota by DHPLC

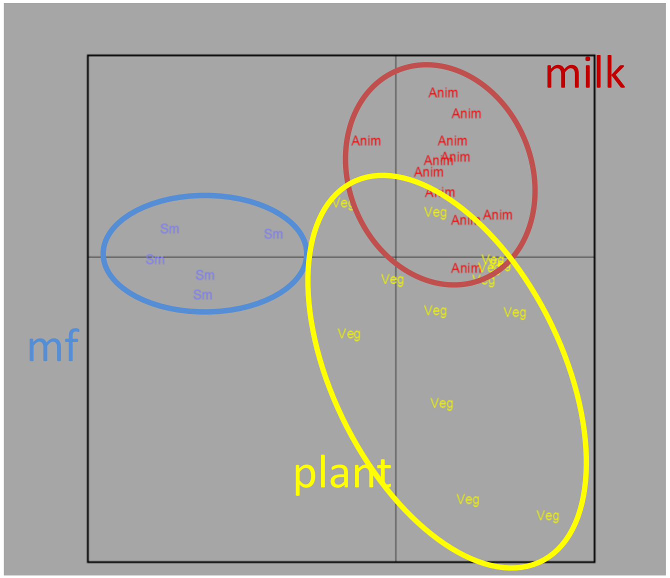


## D7 & D28



## D28



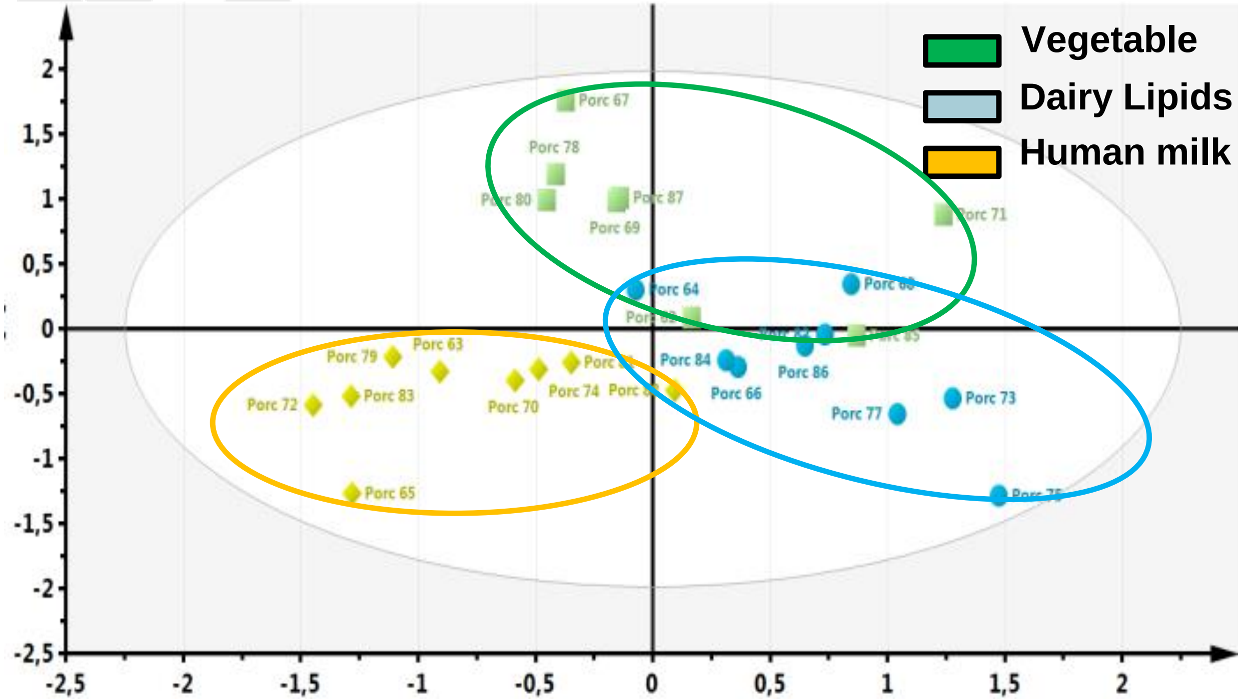



The composition/structure of the infant formula « orientates » the microbiota

More Proteobacteria with milk fat / More Firmicutes with plant oil

Bourlieu et al. Eur J Lipid Sci Technol 2016

# What happens when they become older (140 d)?




If animals are submitted to a nutritional stress (high fat/sugar diet), some differences remain in:

* the microbiota composition
* the fecal metabolome with different metabolites (including propionate)
* the immune system with a reduced susceptibility to inflammation with milk lipids

# Conclusion

The structure/composition of food regulate the kinetics of protein digestion and the release of amino acids in the bloodstream

Gastric emptying rate will highly depend on the structure that the product will adopt in the stomach cavity.

Understanding the mechanisms of food particle breakdown in the stomach is critical to control the structure a food will adopt in gastric conditions

Being able to design food structures for controlling the kinetics of hydrolysis of macronutrients will allow to obtain food particularly adapted to specific population

# The Bioactivity & Nutrition team at INRA Rennes

**Head**
Didier DUPONT- Senior Scientist

**Scientists**
Amélie DEGLAIRE – *Lecturer*
Juliane FLOURY – *Lecturer*
Catherine GUERIN - *Lecturer*
Steven LE FEUNTEUN – *Senior Scientist*
Joëlle LEONIL – *Senior Scientist*
Martine MORZEL – *Senior Scientist*
Françoise NAU – *Professor*
Frédérique PEDRONO – *Lecturer*

Xiaoxi YU – *Post-doc*
Guilherme FURTADO – *Post-doc*

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Amira HALABI *(2017-2020)*
Jun WANG *(2018-2021)*
Lea SALLELES *(2018-2021)*
Elise CHARTON *(2019-2022)*
Lucile CHAUVET *(2019-2022)*
Ousmane SUWAREH *(2019-2022)*

**Technicians**
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Yann LE GOUAR
Nathalie MONTHEAN

**Engineers**
Julien JARDIN
Olivia MENARD
Jordane OSSEMOND

**Masters students**

# Improving health properties of food by sharing our knowledge on the digestive process

International Network

Dr. Didier DUPONT, Senior Scientist, INRAE, France

INFOGEST

# Main objective: understanding the mechanisms of food digestion

- Develop new *in vitro*, *in vivo* and *in silico* digestion models including some for specific populations (infant, elderly)
- Harmonize the methodologies and propose guidelines for performing experiments
- Validate *in vitro* models towards *in vivo* data (animal and/or human)
- Identify the beneficial/deleterious components that are released in the gut during food digestion
- Determine the effect of the matrix structure on the bioavailability of food nutrients and bioactive molecules


767 scientists - 280 institutes – 60 countries

# Industry involvement

☞ ~ 60 private companies are following INFOGEST

Chair
Didier Dupont - France
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# INFOGEST

Vice-chair
Alan Mackie - UK

**www.cost-infogest.eu**

| WG1 | WG2 | WG3 | WG4 | WG5 | WG6 |
|---|---|---|---|---|---|
| In vitro models of digestion | Food interaction – meal digestion | Absorption models | Digestive lipases and lipid digestion | Digestive amylases and starch digestion | In silico models of digestion |

Isidra Recio

Pasquale Ferranti

Linda Giblin

Myriam Grundy

Daniela Freitas

Choi-Hong Lai

Andre Brodkorb

Lotti Egger

Uri Lesmes

Brigitte Graf

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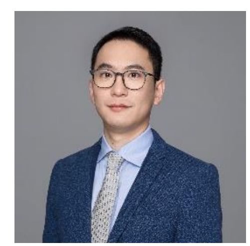
Anabel Mulet-Cabero



Bin Zhang

Steven Le Feunteun

# Some outputs

*In vitro* gastrointestinal digestion
Consensus INFOGEST protocol

Minekus et al. 2014
Food & Function, 5, 1113-1124
**3125 citations**

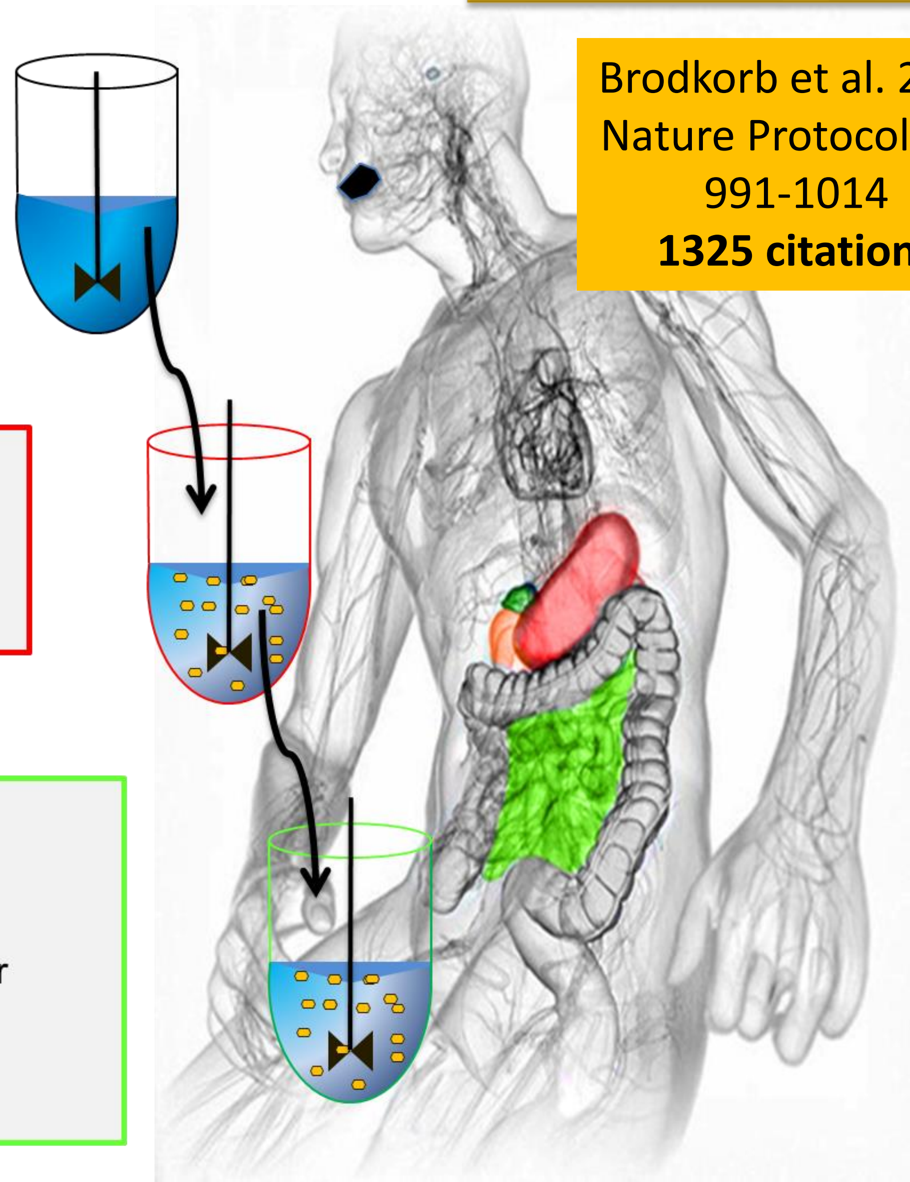
Brodkorb et al. 2019
Nature Protocol, 14, 991-1014
**1325 citations**

## Oral phase
Mix 1:1 with Simulated Salivary Fluid (SSF)
salivary amylase (75 U/mL)
2 min, pH 7

## Gastric Phase
Mix 1:1 with Simulated Gastric Fluid (SGF)
Pepsin (2000 U/mL)
2h, pH 3

## Intestinal Phase
Mix 1:1 with Simulated Intestinal Fluid (SIF)
Enzymes
- Pancreatin (based on trypsin 100 U/mL) or
- Pure enzymes

Bile (10mM)
2h, pH 7



INFOGEST
International Conference

**Porto, Portugal**
**2024**

We are pleased to announce the next

## 8th International Conference on Food Digestion

**in Porto, Portugal, 9-11 April 2024**