



Structuring Food to Improve the Delivery of Bioactives

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Portrait

The National Institute for Agronomic Research

- Set up in 1946
- A public, scientific and technological establishment
- Under the joint authority of the Ministries of Agriculture and Research
- Staff of nearly 11000 and a budget of 700 M€
- Largest European organisation for agricultural research, 2nd largest in the world
- Working on Food, Nutrition, Agriculture and the Environment

140 people
25 PhD students
7 private companies

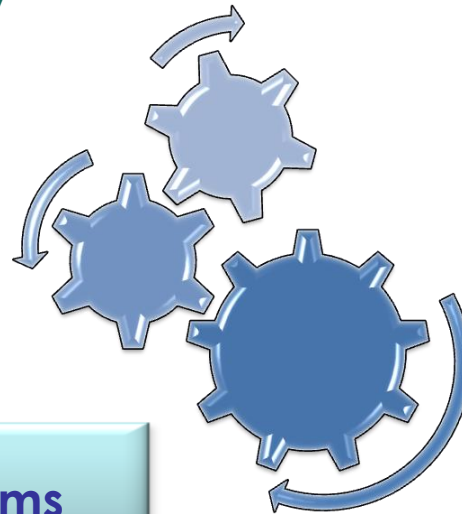


Milk & Egg Science & Technology



Our disciplinary skills

Biochemistry
Microbiology/ Mol Biology
Process & technology



In situ systems

Model systems

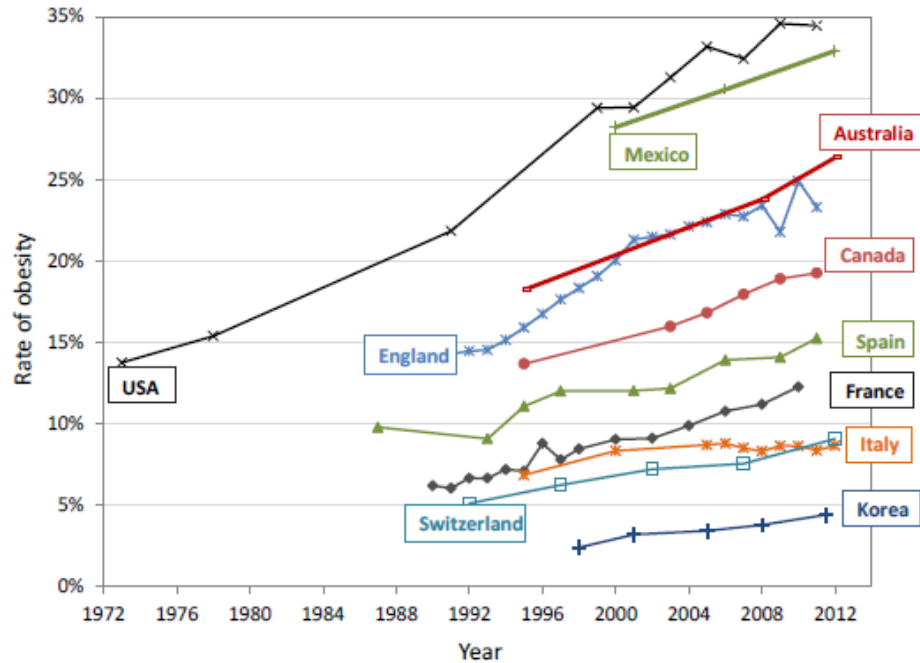
Our facilities

Mass spectrometry
Confocal microscopy, AFM
Quantitative PCR
ITC, Biacore 3000

Technology platform, Spray-drying tower
Biological Resource Centre

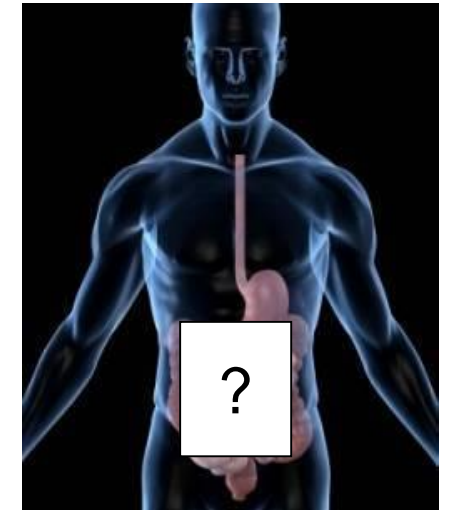


Food and human health: the key role of the digestive process



Diet-related diseases ↑

⇒ Prevent these pathologies rather than cure them



Gut = interface between food and human body

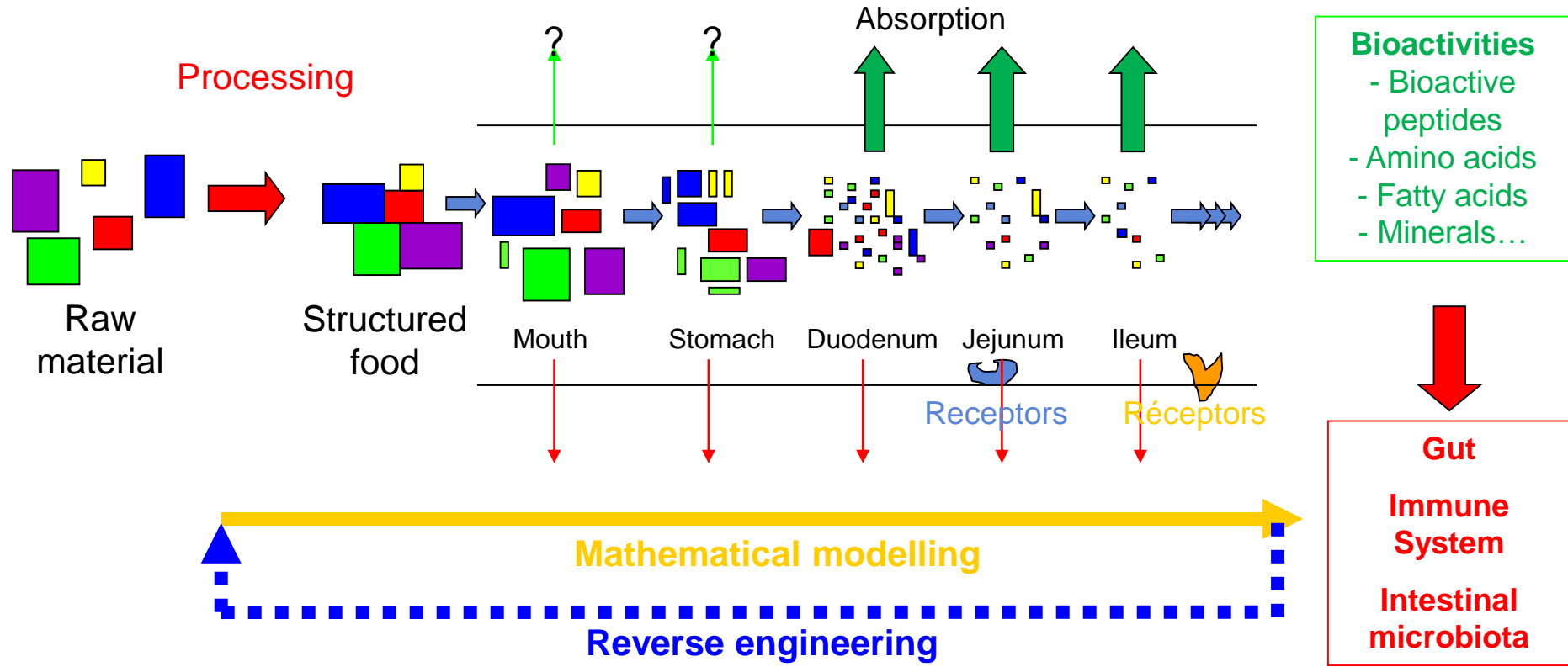
Digestion releases food components that can have a beneficial or a deleterious effect on human health

... 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

Increasing our knowledge on food digestion to increase our knowledge on the effect of food on human health

Our goals

Healthy Adult/ Neonate/ Elderly



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

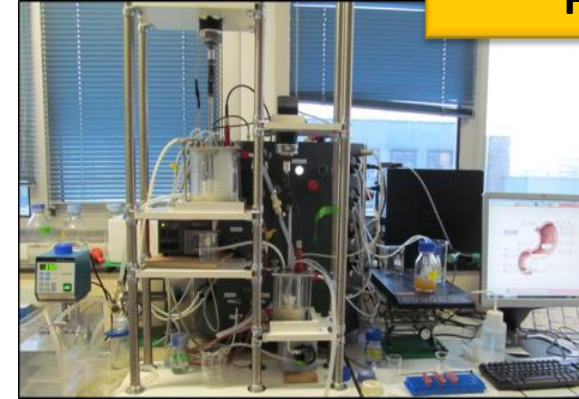
Models available at INRA for simulating digestion

Dupont et al. 2010ab,
Mol Nutr Food Res
Minekus et al. 2014
Food Funct

*In vitro static
models
(infant, adult)*



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

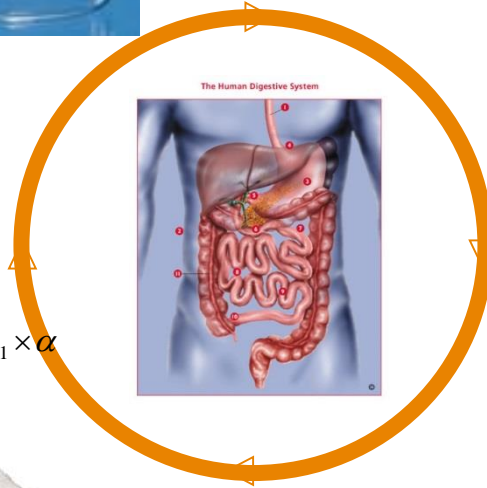


*In vitro dynamic models
(infant, adult, elderly)*

Le Feunteun et al. 2014
Food Bioprocess Tech

*In silico
models*

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



*Human
models*



Animal models



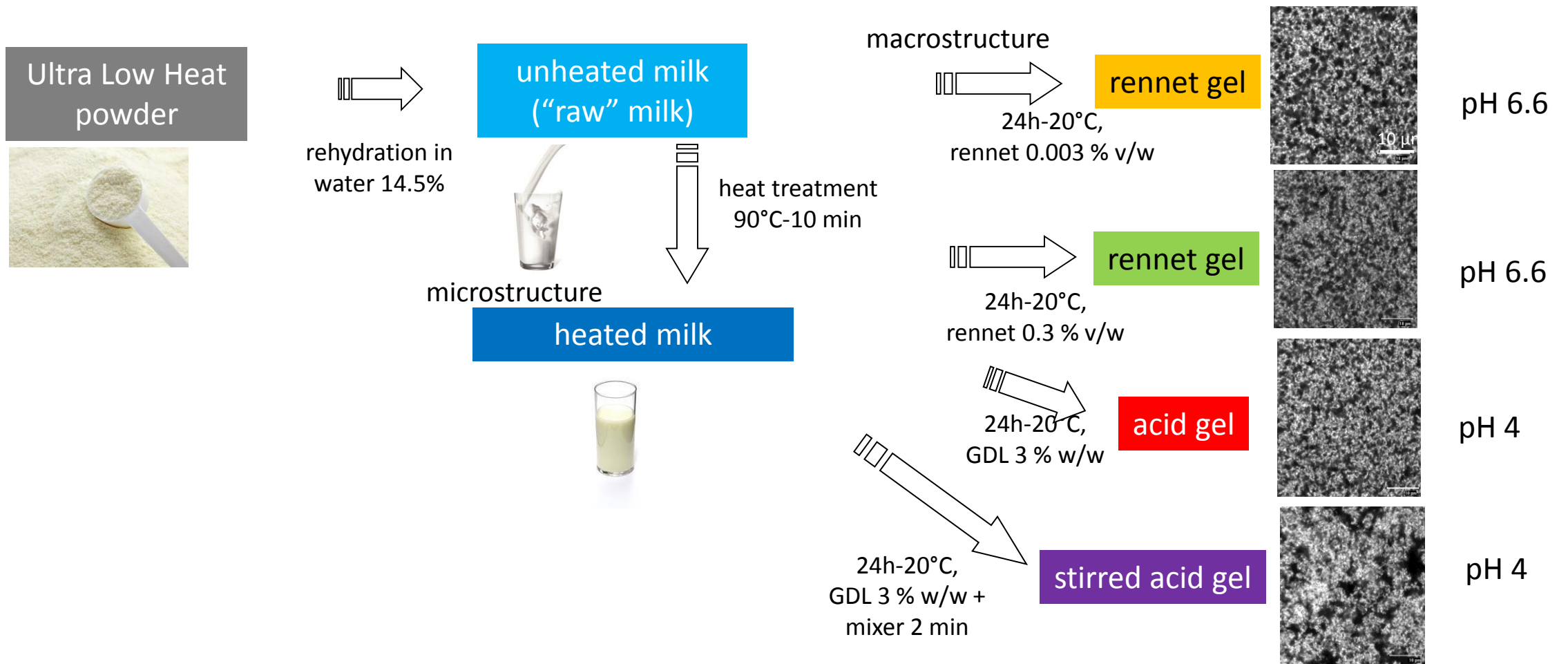
Barbé et al. 2013, 2014
Food Chem
Le Huerou-Luron et al.
2016 Eur J Nutr

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

Example 1

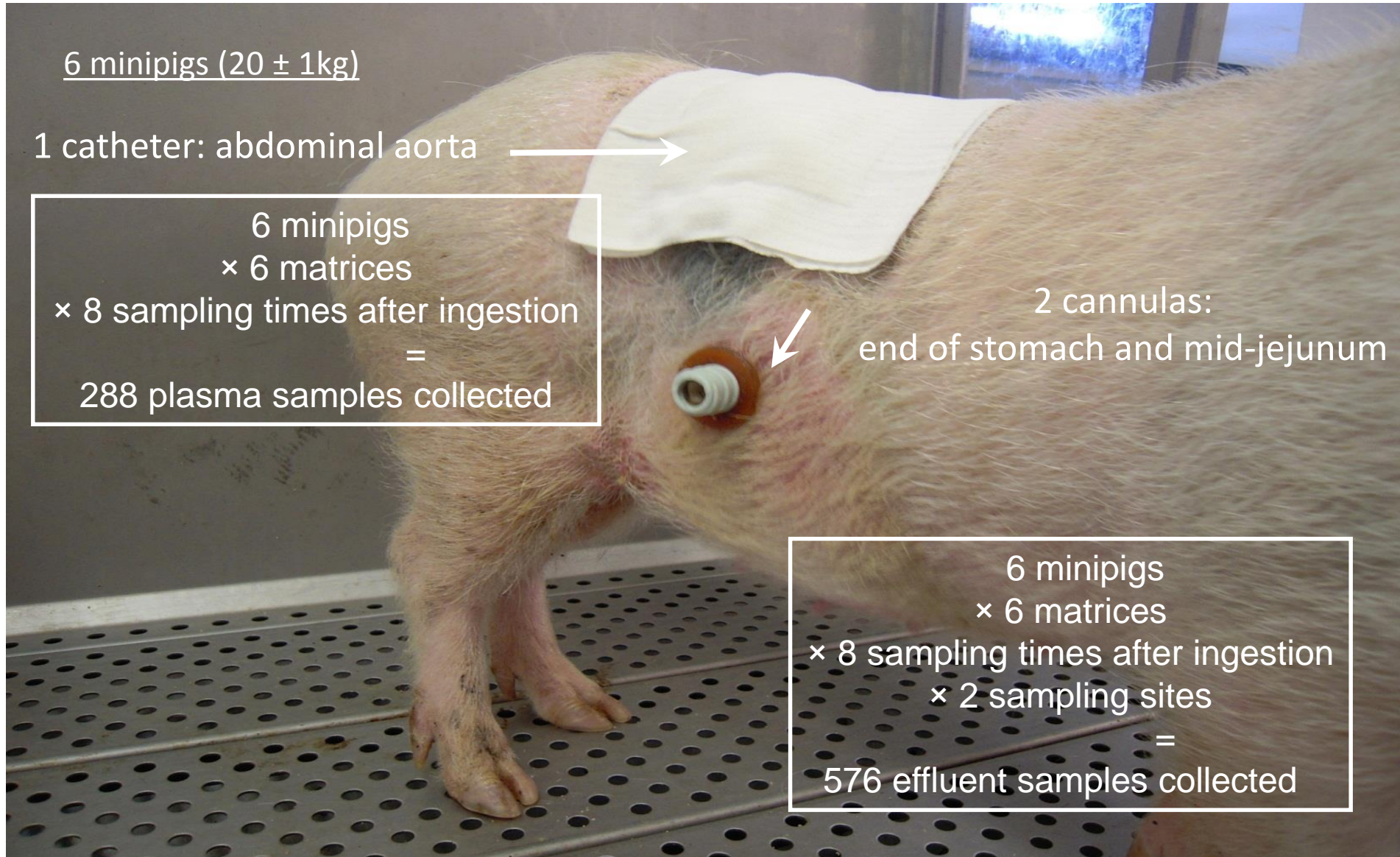
Food structure and delivery of bioactive peptides

The food matrices

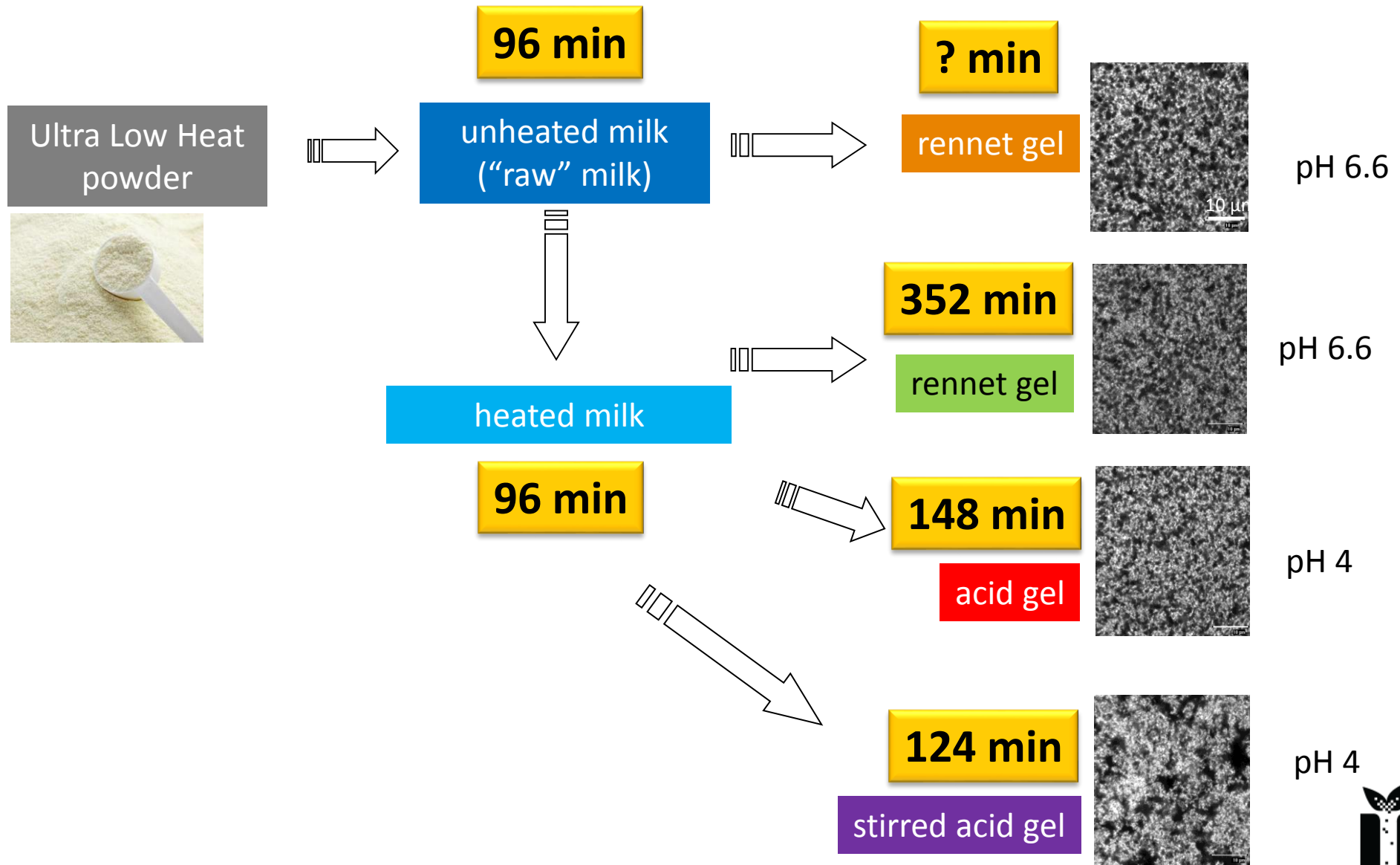


Fat-free matrices: 40 g/L caseins, 10 g/L whey proteins, 95 g/L lactose and minerals + marker of the meal transit (Cr^{2+} -EDTA) → Gastric emptying half-time

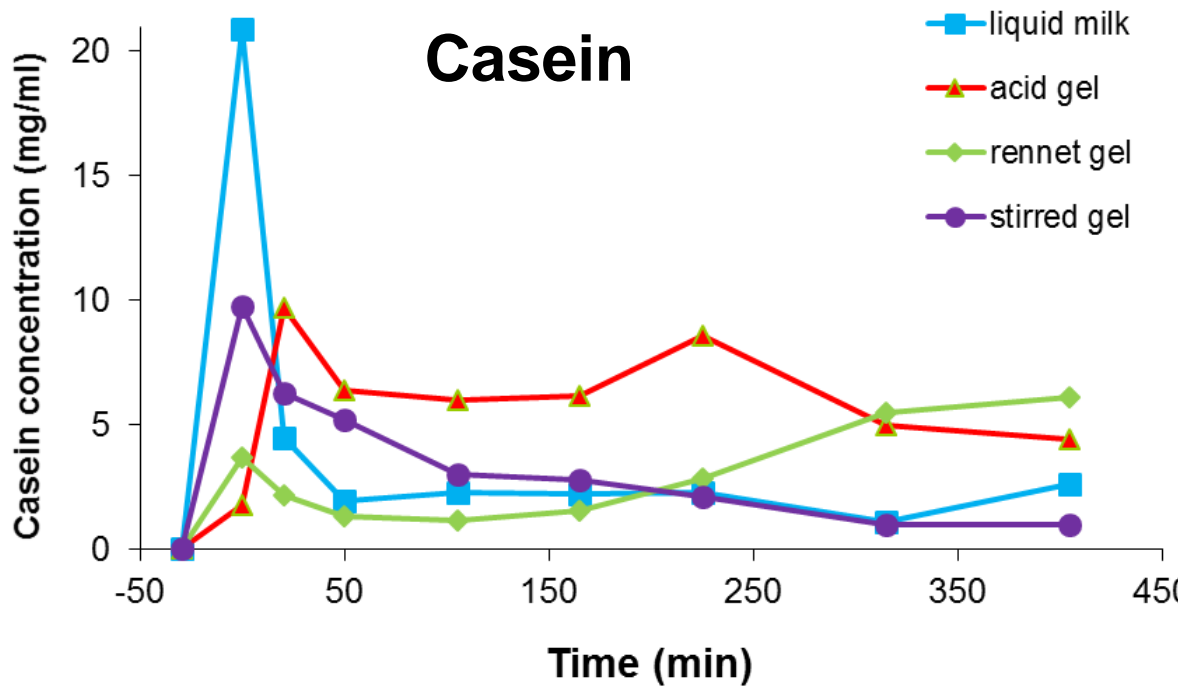
The multi-cannulated mini-pigs



Impact of food structure on gastric emptying half-time



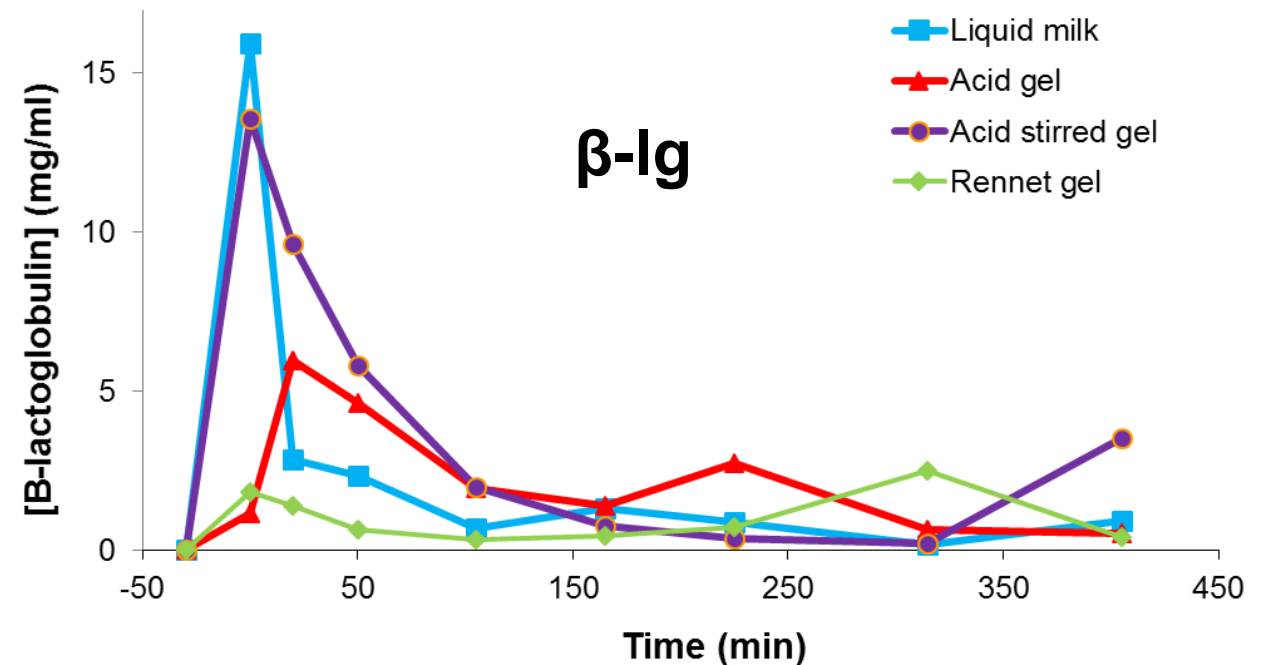
Milk proteins in the duodenum (ELISA)



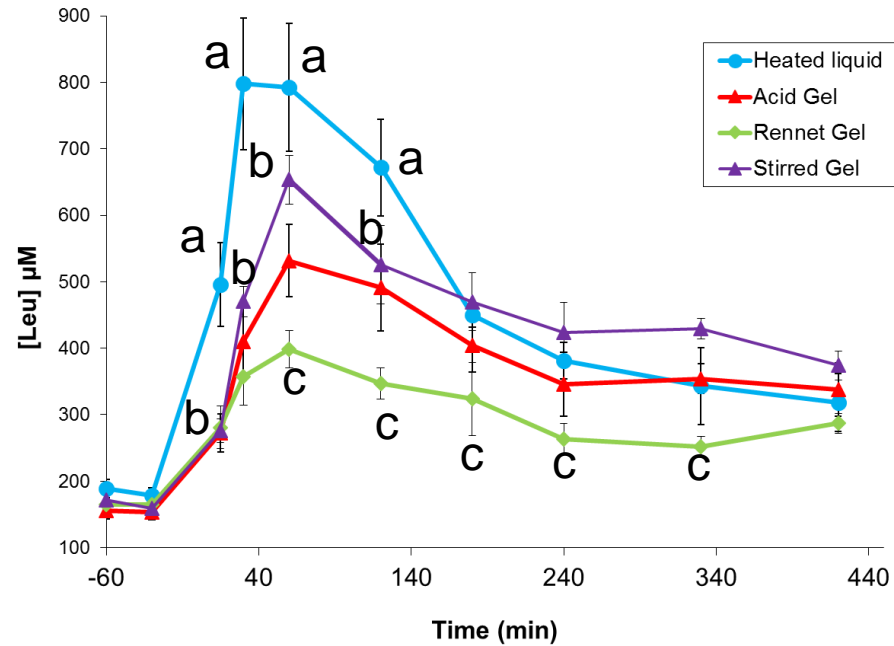
- Intense and early peak with milk/ lower and delayed with gels
- Intermediate behaviour with stirred gel
- Low concentrations with rennet gel but casein release tends to increase over time

- Only traces of milk proteins found in the jejunum
- Dairy products remain highly digestible

Barbé et al. 2013, 2014
Food Chem



2) effect on absorption

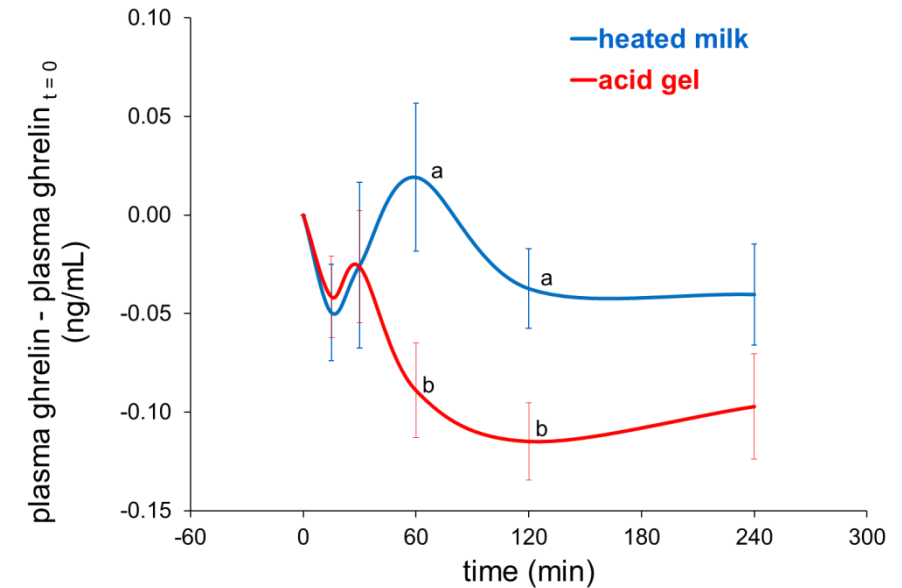


milk gelation: → delayed proteins transit → delayed AA absorption

↘ maximal AA concentration in the plasma

3) potential effect on satiety

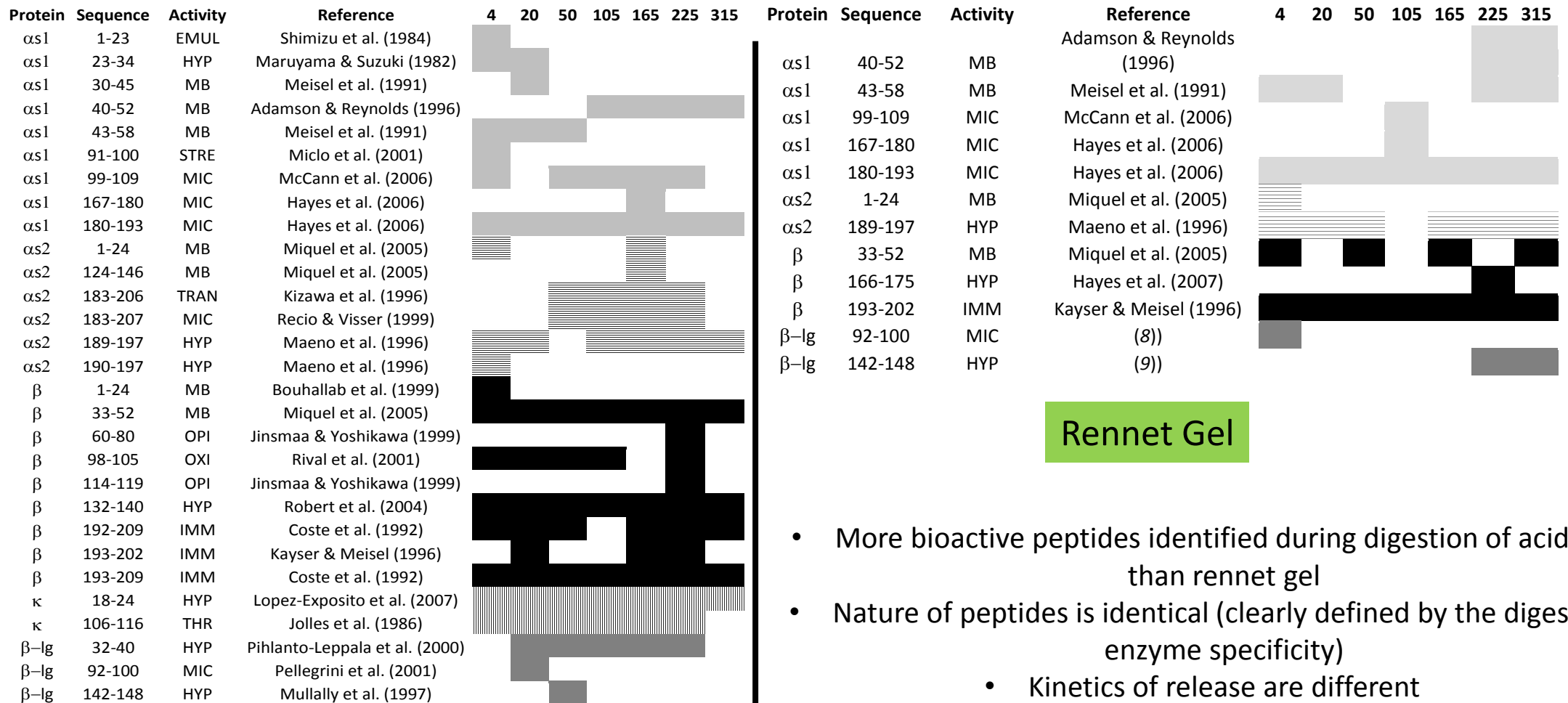
ghrelin (gastrointestinal hormone → appetite stimulation)



milk gelation: ↘ postprandial ghrelin concentration = satiety ?

Bioactive peptides released during digestion differ from one matrix to another

More than 16,000 milk peptides identified in the gastrointestinal tract of pigs



Acid Gel

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

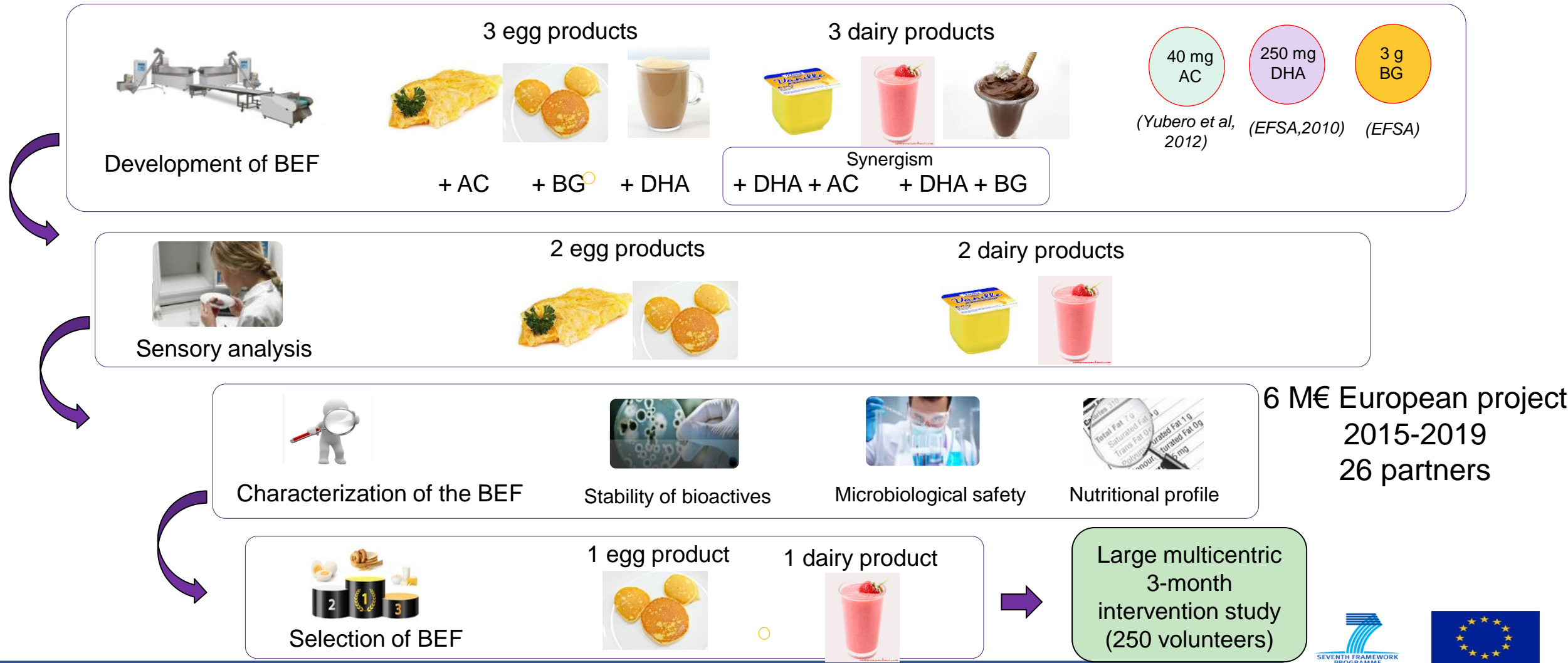
But identifying abioactive peptide in the lumen does not prove that it will exert a biological action!

Example 2

Food structure and delivery of phytochemicals

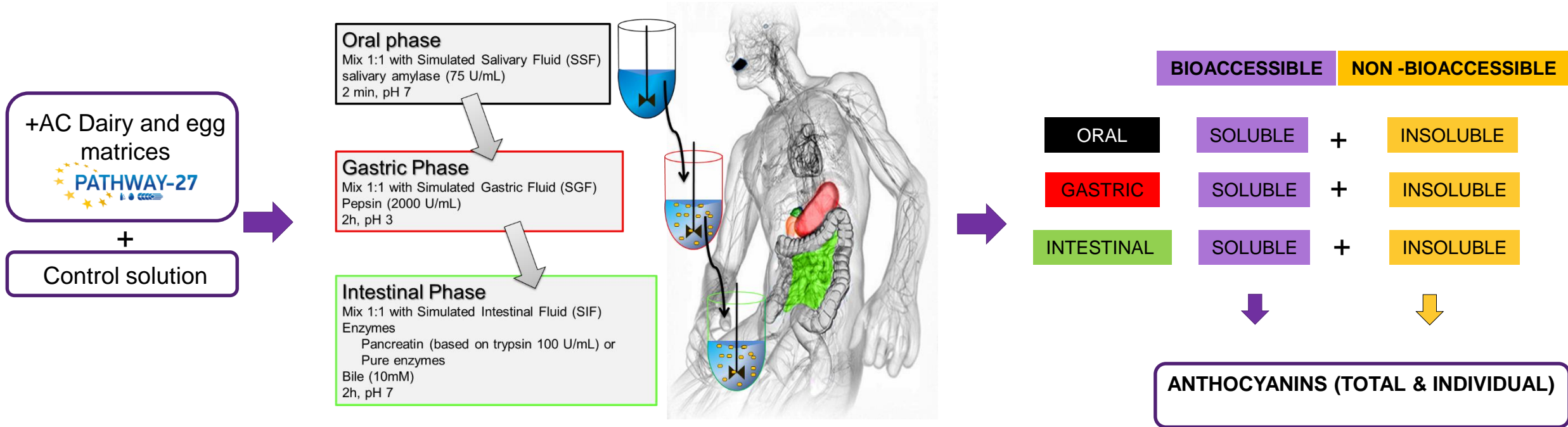


Development of bioactive-enriched food to fight the risk of developing a metabolic syndrome



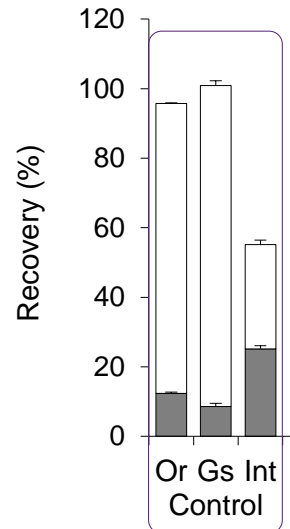




In vitro digestion to determine the effect of the food matrix on the delivery of anthocyanins

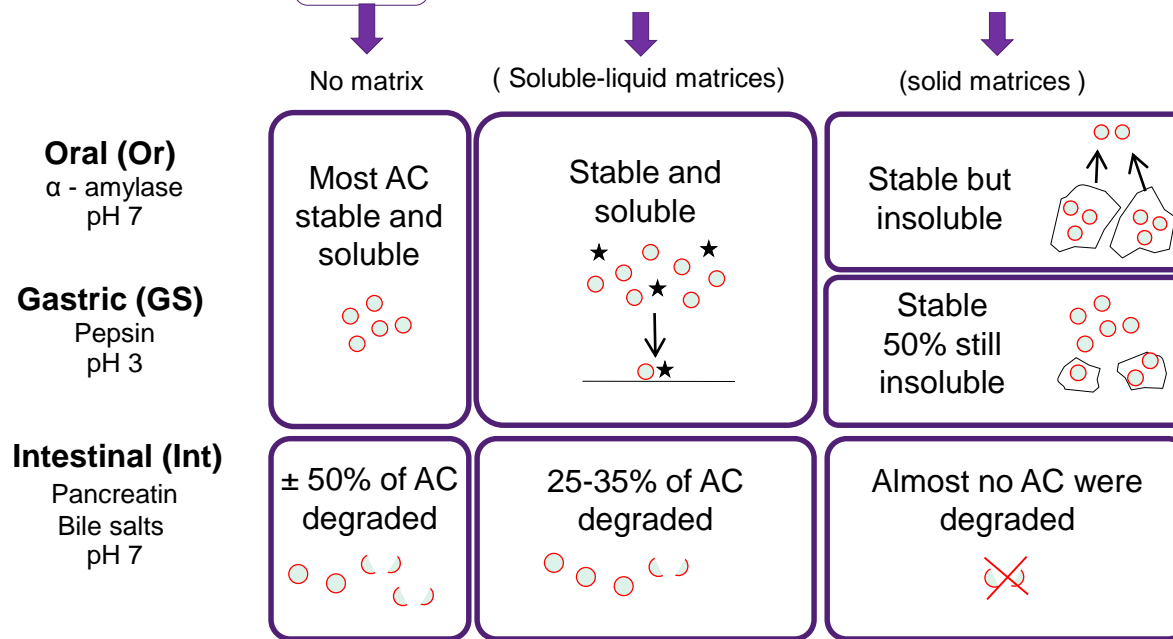


Infogest consensus *in vitro* digestion model

**Pineda-Vadillo et al.
2015
Food Res Int**



 Soluble = Bioaccessible
 Insoluble = Non-bioaccessible



Food matrix affects AC bioaccessibility

Protective effect of the food matrix towards intestinal digestion of AC

Example 3

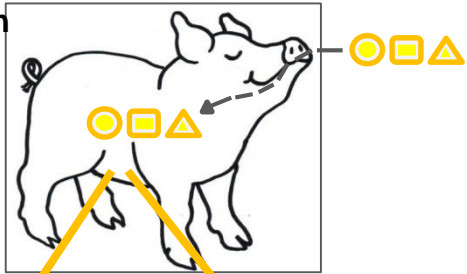
Food structure and delivery of DHA

STRATEGY

3 egg products with identical composition but different structure



In vivo digestion

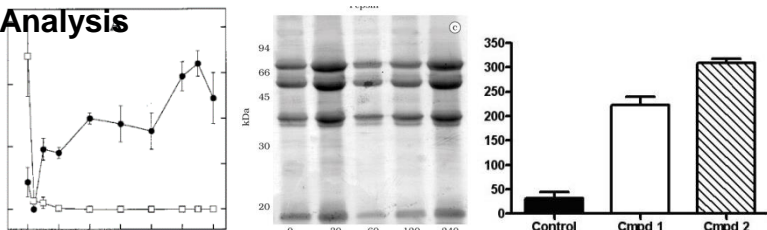


Sampling

Blood
(Bioavailability)

Intestinal effluents
(Bioaccessibility)

Analysis



FOOD MATRICES

Same composition but different structure

OMELETTE: Egg yolk and egg white **MIXED** and **WELL COOKED**

HARD-BOILED EGGS: Egg yolk and egg white **NOT MIXED** and **WELL COOKED**

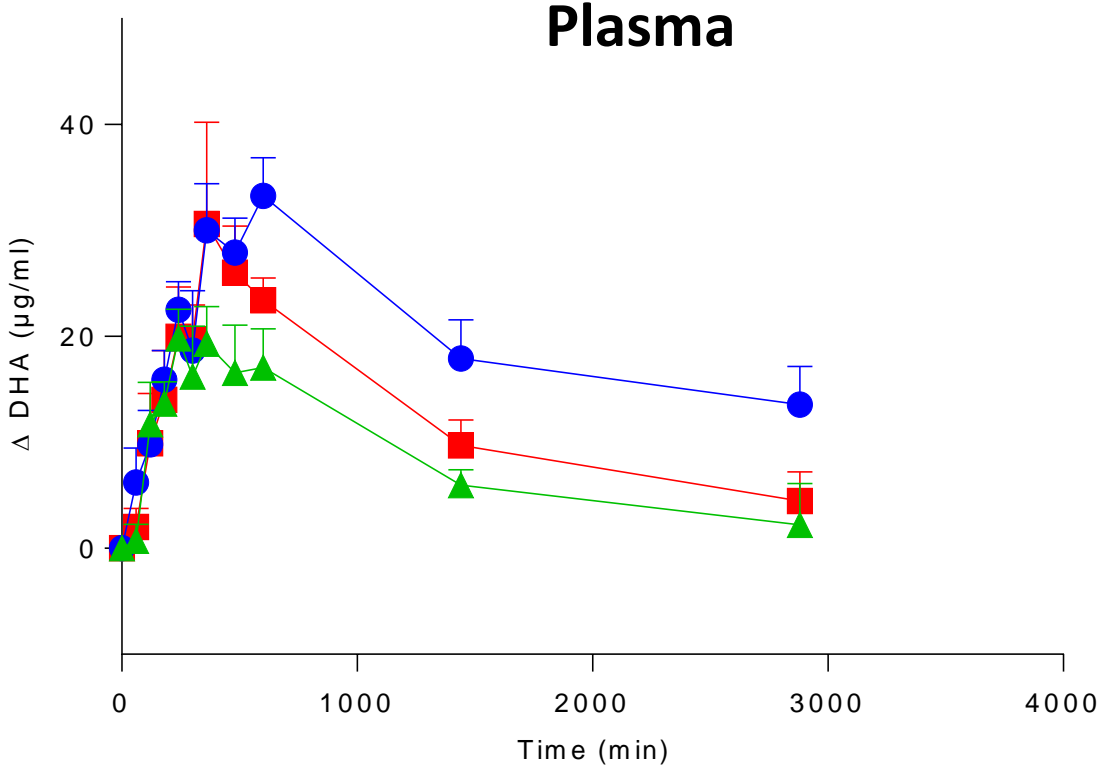
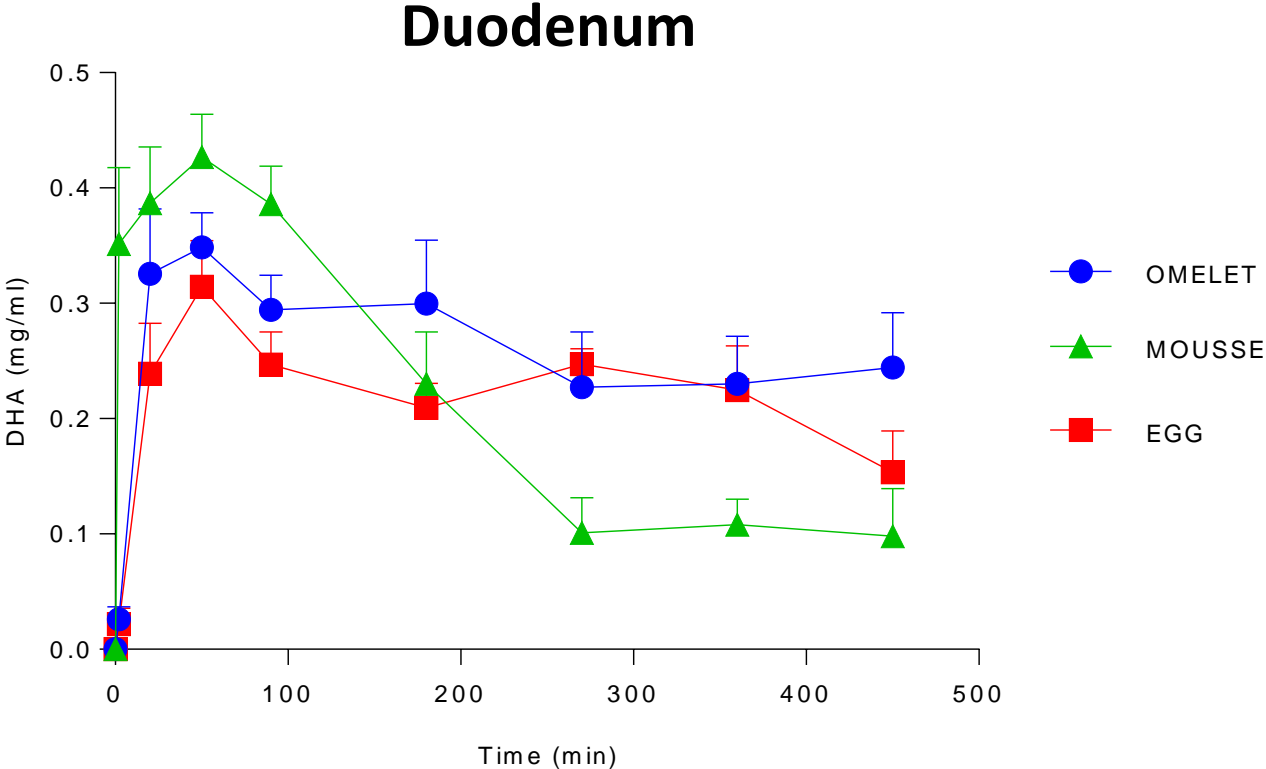
MOUSSE: **FOAMED RAW** Egg white + **RAW** egg yolk. **MIXED**



Egg yolk: egg white proportion as in real eggs
500g /intake **1.74 g of DHA**

Recovery DHA after cooking
Omelet (99.4%) Egg (104%) Mousse (91.7%)

DHA bioaccessibility and bioavailability



DHA bioavailability (Area Under the Curve) : Mousse = Hard-boiled Eggs < Omelette (p<0.005)

The food matrix regulates DHA bioavailability



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

International Network

Dr. Didier DUPONT, Senior Scientist, INRA, France

●
INFOGEST
●



June 2011 – May 2021



350 scientists - 130 institutes – 38 countries



Chair
Didier Dupont - France



Vice-chair
Alan Mackie - UK



In vitro/in vivo
correlations
WG1



Didier Dupont

In vitro semi-
dynamic
model of
digestion
WG2



Alan Mackie

Models for
specific
populations
WG3



Uri Lesmes

Digestive
lipases and
lipid digestion
WG4



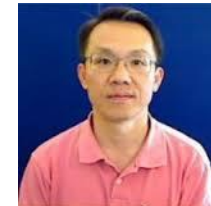
Myriam Grundy

Digestive
amylases and
starch
digestion
WG5



Nadja Siegert

In silico
models of
digestion
WG6



Choi-Hong Lai

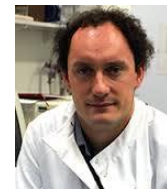
The "Mind-
the-Gap"
group



Guy Vergeres



Frederic Carriere



Fred Warren



Steven Le Feunteun



We are pleased to announce the next
6th International Conference on Food Digestion



in Granada, Spain, April 2019

Key Takeaways

- ▶ Understanding the mechanisms of food digestion is a necessary step to strengthen our knowledge on the relationships between food and human health
- ▶ The effect of food structure on bioactive and nutrient bioavailability can only be demonstrated by comparing foods with identical composition (but different structure)
- ▶ Food structure drives the kinetics of nutrient/bioactive release in the GI tract and the bioavailability. Gastric emptying can be a key parameter.
- ▶ An international effort is needed to harmonize the digestion models used by the scientific community

The Bioactivity & Nutrition team

Head

Didier DUPONT - Senior Scientist

Scientists

Rachel BOUTROU – Junior Scientist

Amélie DEGLAIRE – Lecturer

Juliane FLOURY – Lecturer

Catherine GUERIN - Lecturer

Joëlle LEONIL – Senior Scientist

Françoise NAU – Professor

Frédérique PEDRONO – Lecturer

Jonathan THEVENOT – Post-doc



PhD students

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Linda LEROUX (2016-2019)

Manon HIOLLE (2016-2019)

Yohan REYNAUD (2016-2019)

Masters students

Technicians

Gwenaële HENRY

Yann LE GOUAR

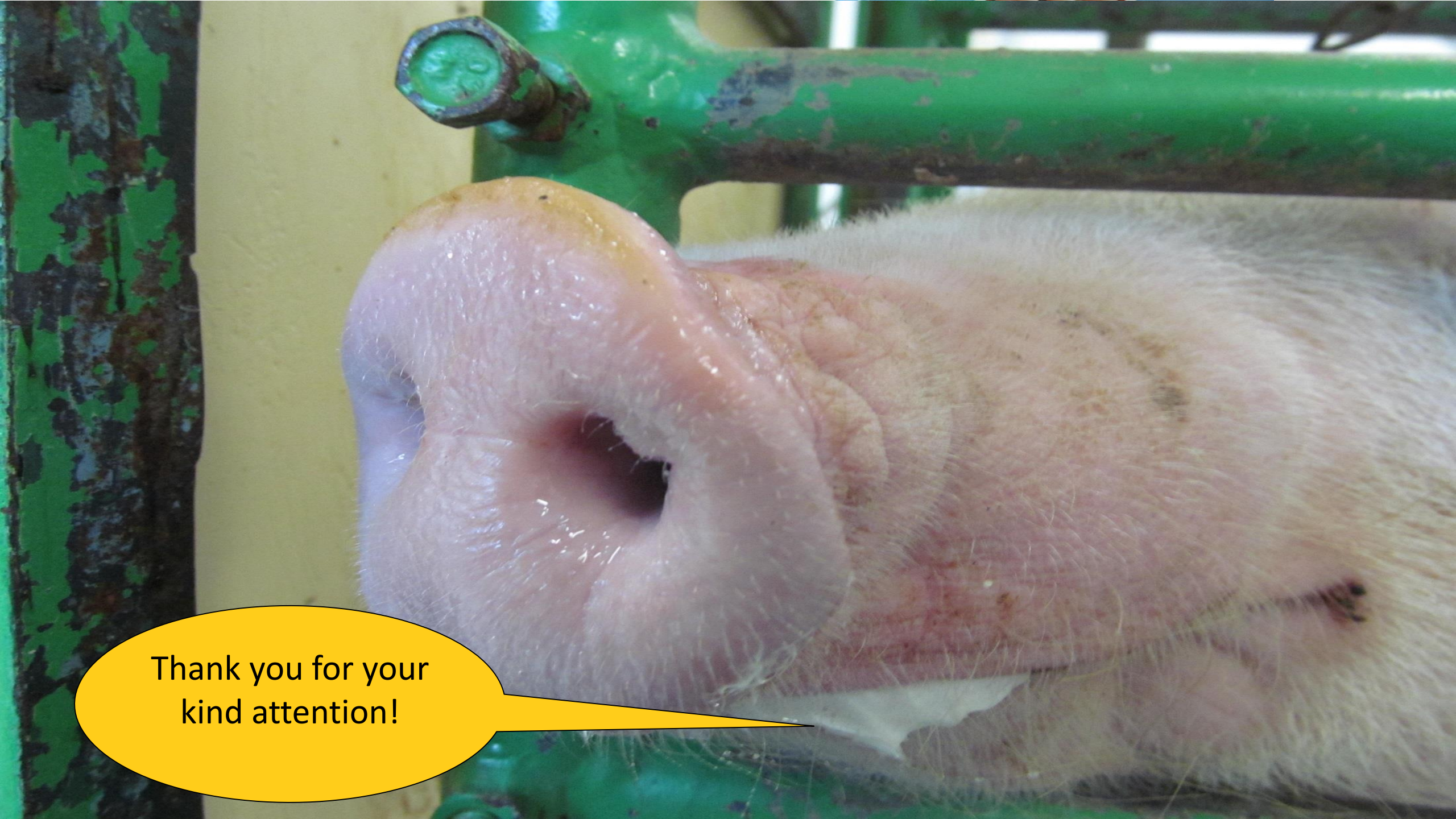
Nathalie MONTHEAN

Engineers

Julien JARDIN

Olivia MENARD

Jordane OSSEMOND



Thank you for your
kind attention!