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

Didier Dupont

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# 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 food matrix on the bioavailability of food nutrients and bioactive molecules



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**675 scientists - 200 institutes – 53 countries**

# Industry involvement

☞ More than 60 companies are following INFOGEST





# INFOGEST



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Didier Dupont - France

[didier.dupont@inrae.fr](mailto:didier.dupont@inrae.fr)



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[www.cost-infogest.eu](http://www.cost-infogest.eu)

**In vitro  
models of  
digestion  
WG1**

**Food  
interaction –  
meal digestion  
WG2**

**Absorption  
models  
WG3**

**Digestive  
lipases and  
lipid digestion  
WG4**

**Digestive  
amylases and  
starch  
digestion  
WG5**

**In silico  
models of  
digestion  
WG6**



Isidra Recio



Pasquale Ferranti



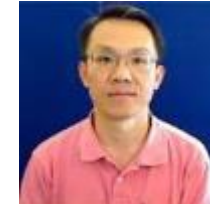
Linda Giblin



Myriam Grundy



Nadja Siegert



Choi-Hong Lai



Andre  
Brodkorb



Lotti Egger



Uri Lesmes



Brigitte Graf



Frederic  
Carriere



Anabel  
Mulet-Cabero



Caroline Orfila



Steven Le Feunteun

## 6 INFOGEST – UNGAP joint Working Groups

1. Drug encapsulation with food structures
2. Application of INFOGEST *in vitro* models in pharmaceutical sciences
3. Building of advanced *in silico* models
4. In vitro gut barrier models to study permeation in different populations
5. Drug effects on GI physiology
6. Imaging (MRI, scintigraphy, ultrasonography)

Paul Smeets  
WUR



Luca Marciani  
Nottingham

# Webinars

15  
Webinars

4000 live  
attendance

15000  
views on  
YOUTUBE

The screenshot shows a web browser window with multiple tabs. The active tab is a YouTube channel page for 'INFOGEST In Vitro and In Vivo food digestion', which has 915 subscribers. The search bar contains the word 'infofest'. The channel's navigation menu includes 'Accueil', 'Vidéos', 'Playlists', 'Communauté', 'Chaînes', and 'À propos'. The 'Vidéos en ligne' section is active, displaying a grid of video thumbnails. The first video is 'Online workshop on "Dynamic in vitro digestion models"' with a duration of 4:01:19 and 693 views. Other videos include 'Food Sustainability and Protein: 15th International...' (55:52), 'MRI imaging and Food Digestion; 14th International...' (1:09:34), 'Gut Microbiota, Bile Acid and Health; 13th International...' (1:00:35), and 'Food Emulsions and Digestion; 12th International INFOGEST...' (1:08:26). The left sidebar of the YouTube interface shows navigation options like 'Accueil', 'Explorer', 'Shorts', 'Abonnements', 'Bibliothèque', 'Historique', 'À regarder plus tard', and 'Vidéos "J'aime"'. At the bottom, there are logos for 'AGRO CAMPUS QUEST', 'INRA SCIENCE & IMPACT', 'STLO', and 'INSTITUT CARNOT QUALIMENT'. The system tray at the very bottom shows the date and time as 09:12.



# Some important outputs

## Oral phase

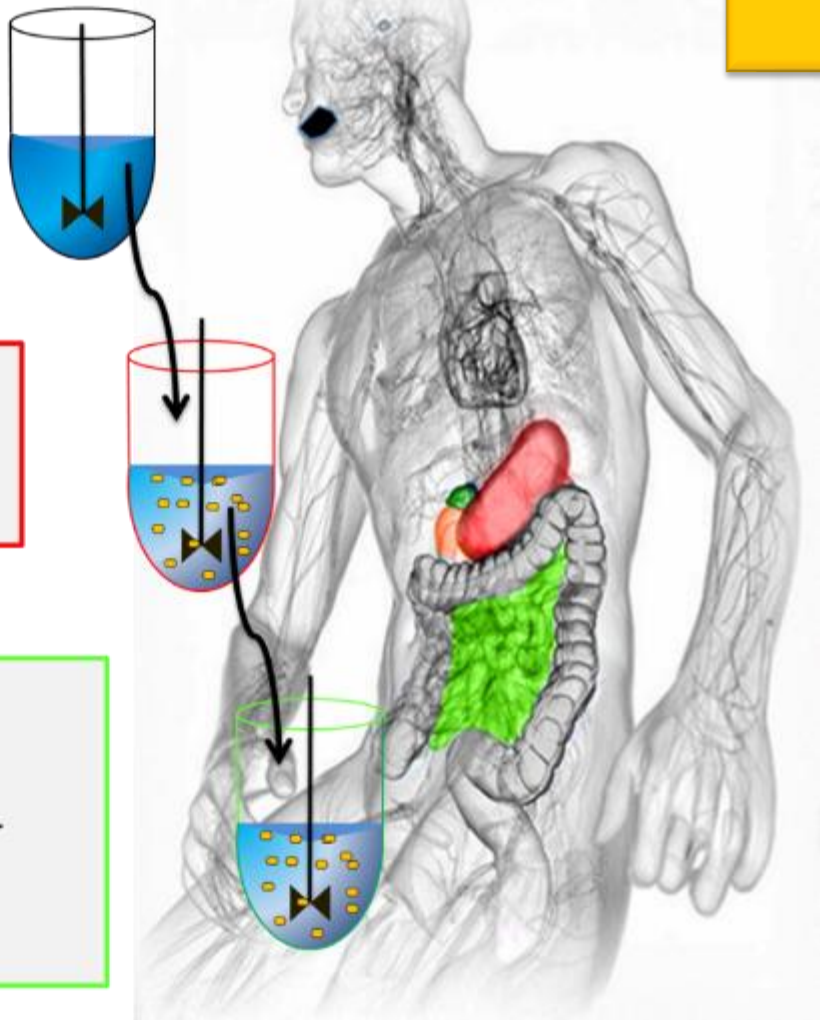
Mix 1:1 with Simulated Salivary Fluid (SSF)  
salivary amylase (75 U/mL)  
2 min, pH 7

## 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



Minekus et al. 2014  
Food & Function  
+2235 citations  
Highly Cited

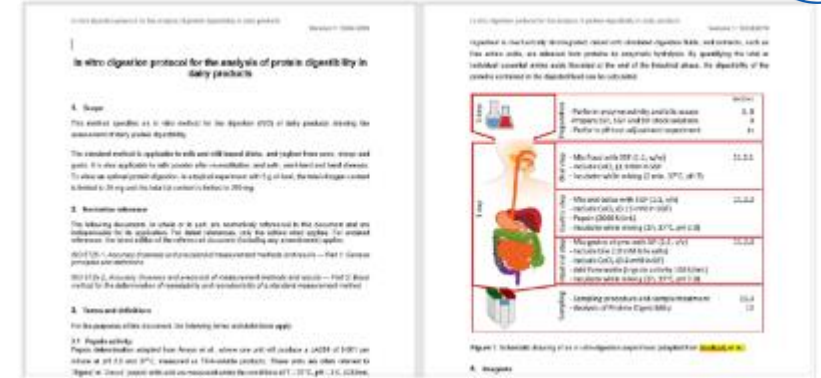
Brodkorb et al. 2019  
Nature Protocols  
+540 citations  
Highly Cited



Training schools in Oslo, Granada and Madrid



# Ringtrial on the use of INFOGEST protocol to determine protein *in vitro* digestibility in dairy products



	Product	Sample Name	Total Nitrogen (g/kg)	Protein (TN*6.38) (g/kg)	Input IVD 1 g Food		Input IVD 5 g Food	
					(mg)	(mL)	(mg)	(mL)
1	Skim milk Powder, INGREDIA	SMP	49.73	317.31	126.1	0.874	630.3	4.370
2	Whole milk Powder, INGREDIA	WMP	38.86	247.91	161.4	0.839	806.8	4.193
3	Gruyère, freeze dried (Agroscope)	Gru	66.71	425.61	94.0	0.906	469.9	4.530
4	Whey protein isolate, INGREDIA	WPI	133.01	848.58	47.1	0.953	235.7	4.764
5	Yogurt, freeze dried (Agroscope)	Yog	50.68	323.37	123.7	0.876	618.5	4.382
6	Cookie (protein free enzyme blank)	Cookie	0.00	0.00	1000.0	0.000	5000.0	0.000



→ **Goal: To demonstrate repeatability and reproducibility of the calculation of the *in vitro* digestibility to be proposed as ISO standard**

- Samples were sent on the 31<sup>st</sup> of May to **32 labs from 18 different countries**
- Digestion in triplicates, SDS-PAGE, TN, OPA and digestibility calculation
- Status: Samples returned from 11 labs and results from 6 labs



## A standardised semi-dynamic *in vitro* digestion method suitable for food – an international consensus†

Cite this: *Food Funct.*, 2020, **11**, 1702

Ana-Isabel Mulet-Cabero, <sup>a</sup> Lotti Egger, <sup>b</sup> Reto Portmann,<sup>b</sup> Olivia Ménard,<sup>c</sup> Sébastien Marze,<sup>d</sup> Mans Minekus,<sup>e</sup> Steven Le Feunteun,<sup>c</sup> Anwasha Sarkar, <sup>f</sup> Myriam M.-L. Grundy, <sup>g</sup> Frédéric Carrière, <sup>h</sup> Matt Golding,<sup>i</sup> Didier Dupont,<sup>c</sup> Isidra Recio, <sup>j</sup> André Brodkorb<sup>k</sup> and Alan Mackie <sup>\*f</sup>

**Mulet-Cabero et al. 2020**  
**Food & Function**  
**84 citations**  
**Highly Cited**

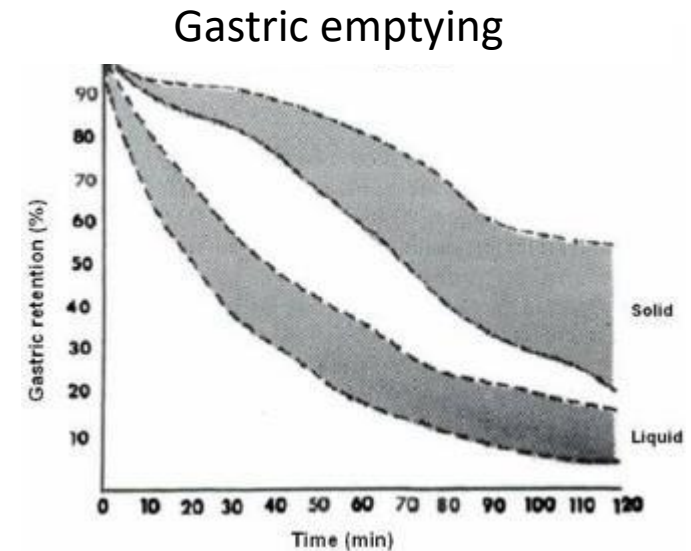
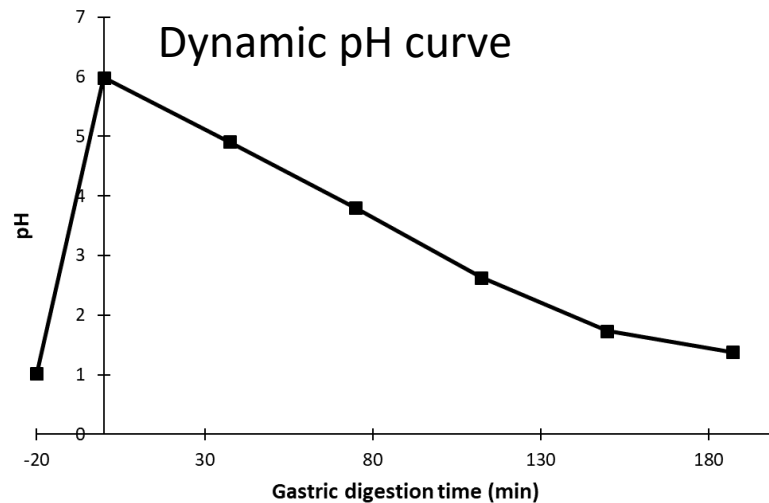
# The Development of Semi-Dynamic *in vitro* Model

# What does it simulate?

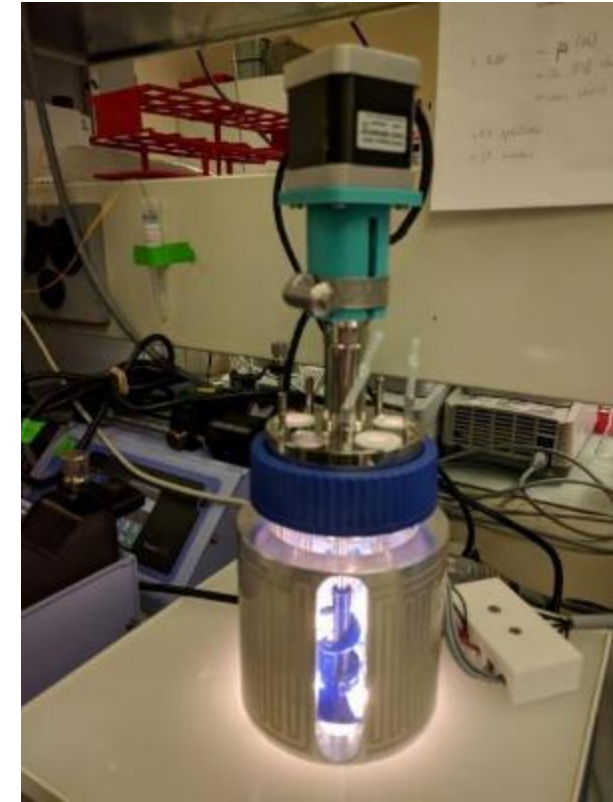
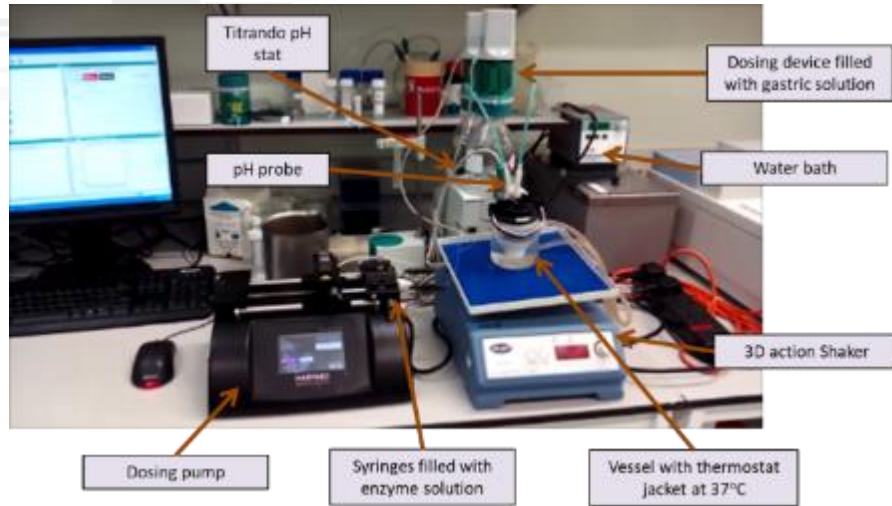


Simulation of:

- ✓ Progressive acidification
- ✓ Gradual enzyme and fluids secretion
- ✓ Continuous emptying



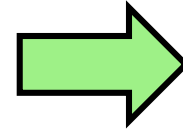
# Semi-Dynamic Gastric Model



# What does it simulate?

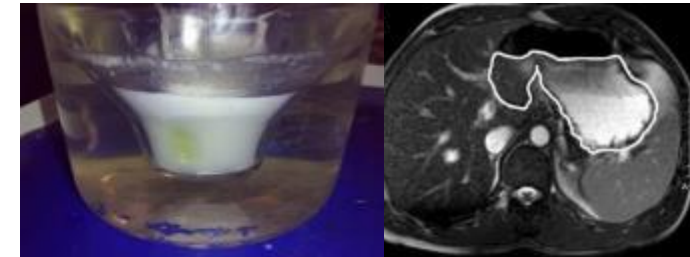
## Simulation of:

- ✓ Progressive acidification
- ✓ Gradual enzyme and fluids secretion
- ✓ Continuous emptying

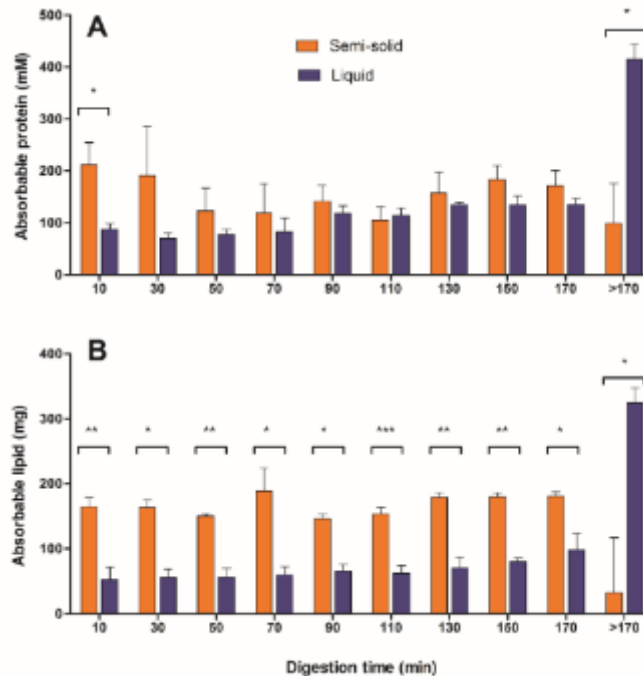
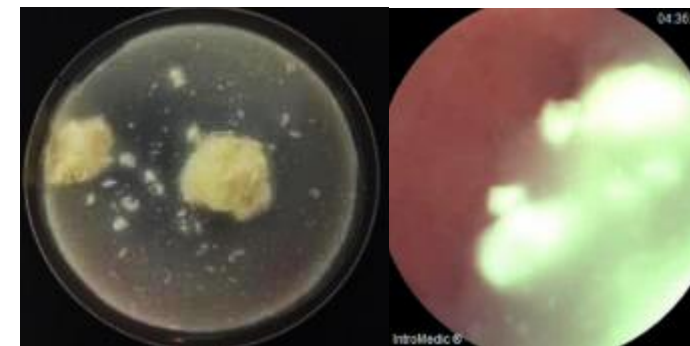


- ✓ Rate of nutrient digestion
- ✓ Structural changes in stomach

## Layering



## Coagulation





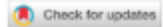
# Ringtrial Semi-Dynamic INFOGEST protocol

Food & Function



PAPER

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A standardised semi-dynamic *in vitro* digestion method suitable for food – an international consensus†

Cite this Food Funct., 2020, 11, 1702

	Product	Sample Name	Total Nitrogen (g/kg)	Protein (TN*6.38) (g/kg)	Carbohydrates (g/kg)	Fat (g/kg)	Dry matter (g/kg)
1	Skim milk Powder, INGREDIA	SMP	49.73	317.31	485.03	<lod	956.9



→ **Goal: Interlaboratory reproducibility. Identification of issues/ problem with SMP before starting more complex foods**

- Digestion of SMP in triplicate with 5 gastric endpoints
- SDS-PAGE, TN and OPA
- **13 laboratories from 12 different countries**
- so far: samples from 7 labs and results from 1 lab

# Lipid digestion and lipases



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Journal of Functional Foods

journal homepage: [www.elsevier.com/locate/jff](http://www.elsevier.com/locate/jff)



INFOGEST inter-laboratory recommendations for assaying gastric and pancreatic lipases activities prior to *in vitro* digestion studies

Myriam M.L. Grundy<sup>a,\*</sup>, Evan Abrahamse<sup>b,c</sup>, Annette Almgren<sup>d</sup>, Marie Alminger<sup>d</sup>, Ana Andres<sup>e</sup>, Renata M.C. Ariëns<sup>f</sup>, Shanna Bastiaan-Net<sup>f</sup>, Claire Bourlieu-Lacanal<sup>g,h</sup>, André Brodkorb<sup>i</sup>, Maria R. Bronze<sup>j,k,l</sup>, Irene Comi<sup>m</sup>, Leslie Couëdelo<sup>n</sup>, Didier Dupont<sup>g</sup>, Annie Durand<sup>o</sup>, Sedef N. El<sup>p</sup>, Tara Grauwet<sup>q</sup>, Christine Heerup<sup>r</sup>, Ana Heredia<sup>e</sup>, Marcos R. Infantes Garcia<sup>q</sup>, Christian Jungnickel<sup>s</sup>, Ilona E. Kłosowska-Chomiczewska<sup>s</sup>, Marion Létisse<sup>o</sup>, Adam Macierzanka<sup>s</sup>, Alan R. Mackie<sup>t</sup>, David J. McClements<sup>u</sup>, Olivia Menard<sup>g</sup>, Anne Meynier<sup>v</sup>, Marie-Caroline Michalski<sup>o</sup>, Ana-Isabel Mulet-Cabero<sup>i,w</sup>, Anette Mullertz<sup>r</sup>, Francina M. Payeras Perelló<sup>x</sup>, Irene Peinado<sup>e</sup>, Mélina Robert<sup>h</sup>, Sébastien Secouard<sup>x</sup>, Ana T. Serra<sup>j,k</sup>, Sandra D. Silva<sup>j</sup>, Gabriel Thomassen<sup>c</sup>, Cecilia Tullberg<sup>d</sup>, Ingrid Undeland<sup>d</sup>, Carole Vaysse<sup>n</sup>, Gerd E. Vegarud<sup>m</sup>, Sarah H.E. Verkempinck<sup>q</sup>, Michelle Viau<sup>v</sup>, Mostafa Zahir<sup>y</sup>, Ruojie Zhang<sup>u</sup>, Frédéric Carrière<sup>z</sup>

2<sup>nd</sup> ongoing Ring trial

Performing static *in vitro* digestion of a model food (i.e. infant formula) using the Infogest 2.0 including both gastric and pancreatic lipase sources

(10 labs involved)



# Absorption models (L Giblin)

## 7 subgroups:

Sample preparation & détoxification (A. Kondrashina)

Brush border enzyme activity (G. Mamone)

Allergenic sensitization (S. Bastiaan-Net)

Permeability ring-trial (B. Miralles)

Colonic fermentation (L. Tomas)

Cellular bioassays (E. Arranz)

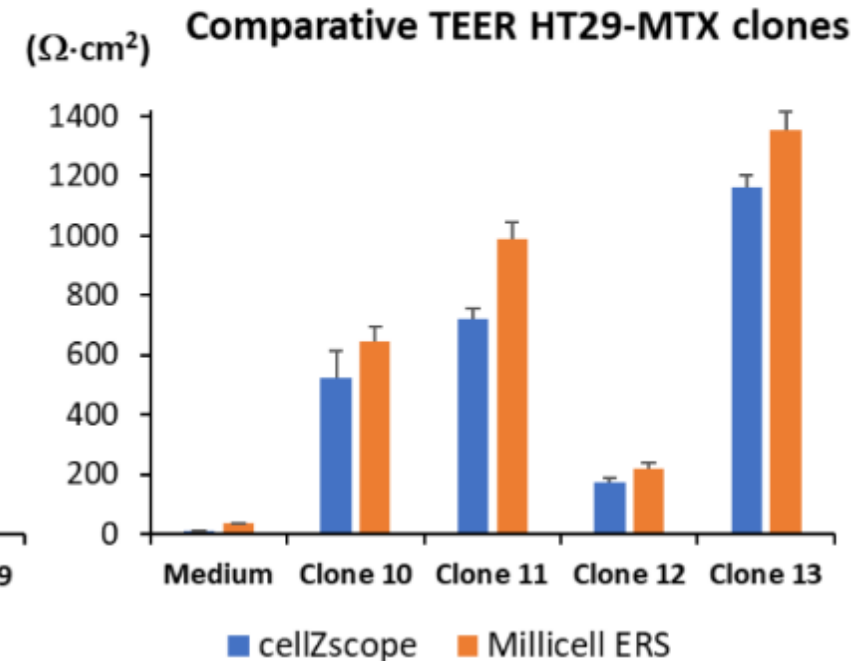
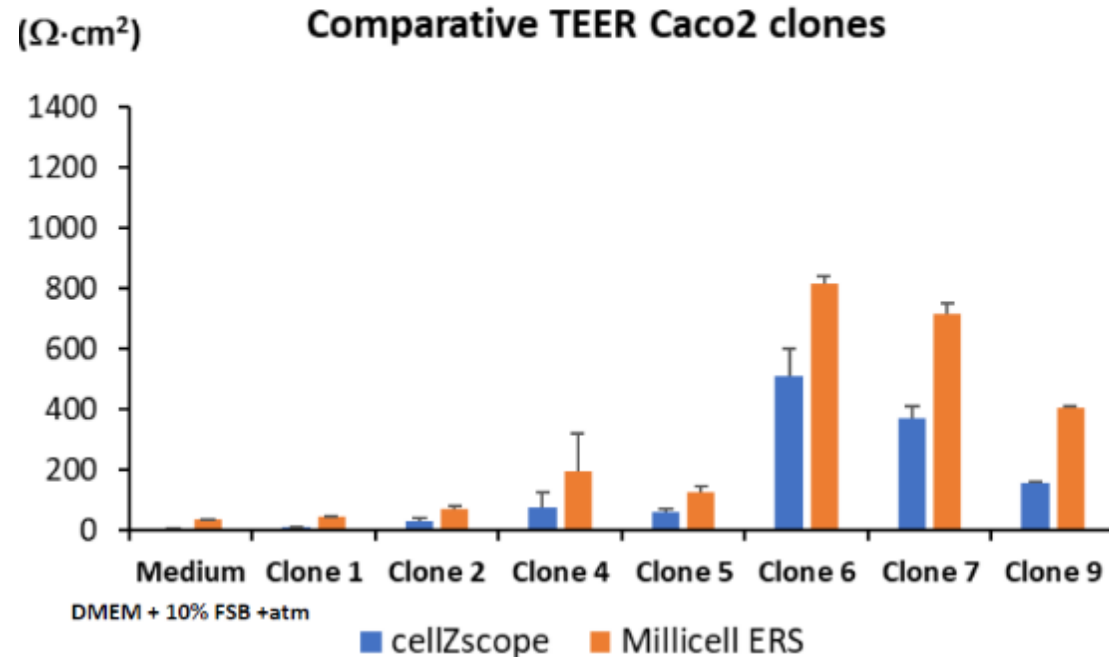
In vivo models of nutrient bioavailability

(B. Graf)

21<sup>st</sup> day of incubation

Caco2

HT29-MTX



# In silico models of digestion



Contents lists available at [ScienceDirect](#)

Trends in Food Science & Technology

journal homepage: [www.elsevier.com/locate/tifs](http://www.elsevier.com/locate/tifs)



Mathematical modelling of food hydrolysis during *in vitro* digestion: From single nutrient to complex foods in static and dynamic conditions

Steven Le Feunteun<sup>a,\*\*</sup>, Sarah Verkempinck<sup>b,\*</sup>, Juliane Floury<sup>a</sup>, Anja Janssen<sup>c</sup>, Alain Kondjoyan<sup>d</sup>, Sebastien Marze<sup>e</sup>, Pierre-Sylvain Mirade<sup>d</sup>, Anton Pluschke<sup>f</sup>, Jason Sicard<sup>d</sup>, George van Aken<sup>g</sup>, Tara Grauwet<sup>b</sup>

- Publication of 2 important reviews
- Ongoing activities about the possibility of developing/sharing an INFOGEST *in silico* model

*Annual Review of Food Science and Technology*

## Physiologically Based Modeling of Food Digestion and Intestinal Microbiota: State of the Art and Future Challenges. An INFOGEST Review

Steven Le Feunteun,<sup>1</sup> Ahmed Al-Razaz,<sup>2</sup> Matthijs Dekker,<sup>3</sup> Erwin George,<sup>4</sup> Beatrice Laroche,<sup>5</sup> and George van Aken<sup>6</sup>

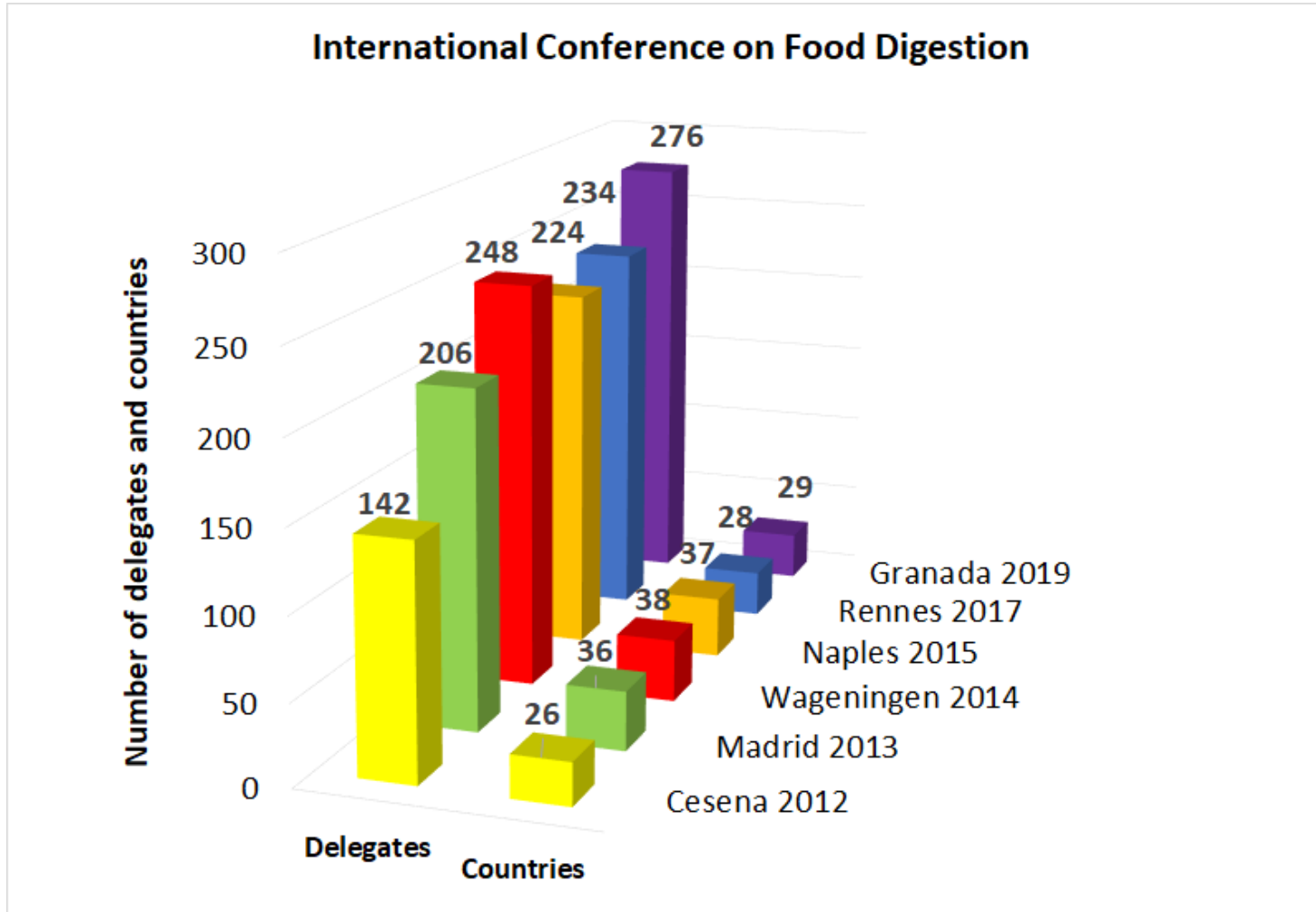
# What's next?

- ☞ INFOGEST 2.0 recognized as an **ISO/IDF Standard** (2022-23)
- ☞ Ongoing discussion with the **Bridge2Food network** in the plant-based foods and alternative proteins sector. Strong interest from **EFSA** as well!
- ☞ Development of international consensus for *in vitro* digestion models of specific populations (elderly within the EAT4AGE project)
- ☞ Dynamic *in vitro* digestion models, what can we share? Can we define **large categories of foods** (liquids, gels, solids) in order to validate the existing systems towards in vivo data
- ☞ **Ring trial with the UNGAP** network in order to evaluate *in vitro* digestion models (static, semi-dynamic, dynamic) to evaluate drug-food interactions
- ☞ Organization of a **Training School in 2023**? Some volunteers to host it? Webinars every 2-3 months mainly dedicated to PhD student pre-defence

We need to see each other more often if the sanitary conditions allow it. **Organization of 1-2 workshops** every year connected to a conference of interest. Any proposition?

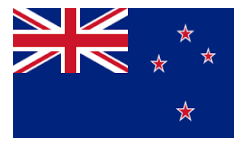
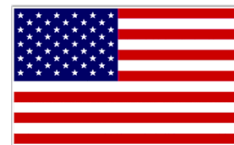


# The International Conference on Food Digestion



The Conference has been created by INFOGEST and is now an event regularly followed by 200 scientists

**ICFD7 = 250 Delegates**



# Special Issue in Food Research International

Impact Factor 2021 = 6.475

- Launched within a week or two
- Open for people who presented an oral conference or a poster
- Deadline for submitting manuscripts: **28th of September 2022**



# Acknowledgments

## Thank you to Our Sponsors



## Prize Sponsors:



## Scientific Review Panel

Dr Didier Dupont  
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*University Of Leeds, United Kingdom*

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Linda Giblin



Andre Brodkorb

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