



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

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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



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



Industry involvement

☞ More than 60 companies are following INFOGEST





INFOGEST



Chair
Didier Dupont - France
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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 Siebert



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 with multiple tabs open, including 'Intranet UMR STLO - Accueil', 'teagasc logo - Recherche Google', 'Improving Health Properties of F...', and 'INFOGEST In Vitro and In Vivo food digestion'. The active tab is the YouTube channel page for 'INFOGEST In Vitro and In Vivo food digestion', which has 915 subscribers. The channel's search bar contains the word 'infoGEST'. The left sidebar shows navigation options: Accueil, Explorer, Shorts, Abonnements, Bibliothèque, Historique, À regarder plus tard, and Vidéos "J'aime". Below this are sections for 'ABONNEMENTS' (showing the channel itself) and 'AUTRES CONTENUS YOUTUBE'. The main content area displays a grid of video thumbnails. The first video is 'UNGAP - INFOGEST Online workshop on "Dynamic in vitro digestion models"' with 693 views and a duration of 4:01:19. Other videos include 'Food Sustainability and Protein: 15th International...', 'MRI imaging and Food Digestion; 14th International...', 'Gut Microbiota, Bile Acid and Health; 13th International...', and 'Digestion of Emulsion; 12th International INFOGEST...'. The Windows taskbar at the bottom shows the time as 09:12 and the temperature as 10°C.

Some important outputs

Oral phase

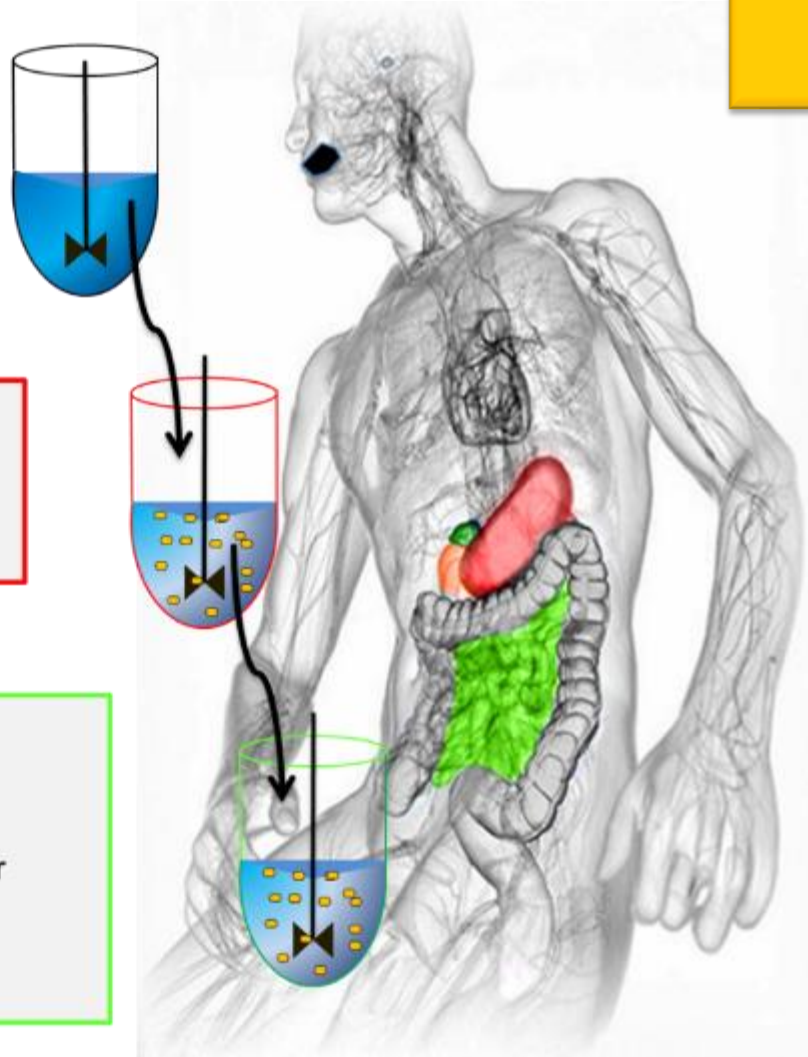
Mix 1:1 with Simulated Salivary Fluid (SSF)
salivary amylase (75 U/mL)
2 min, pH 7

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

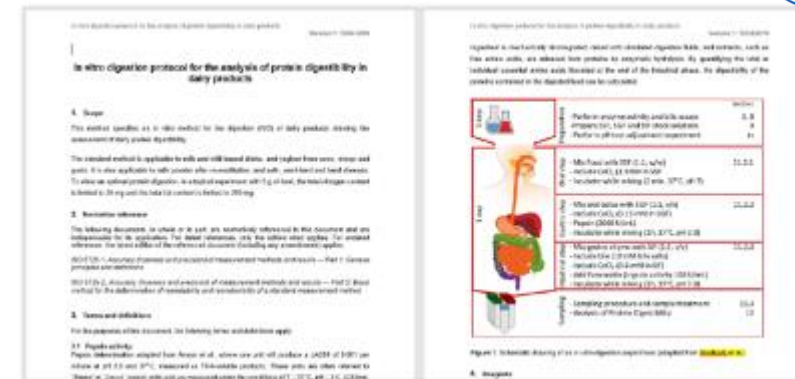
Brodkorb et al. 2019
Nature Protocols
+540 citations
Highly Cited



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	Protein (TN*6.38)	Input IVD 1 g Food		Input IVD 5 g Food	
			(g/kg)	(g/kg)	(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 31st 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†

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

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

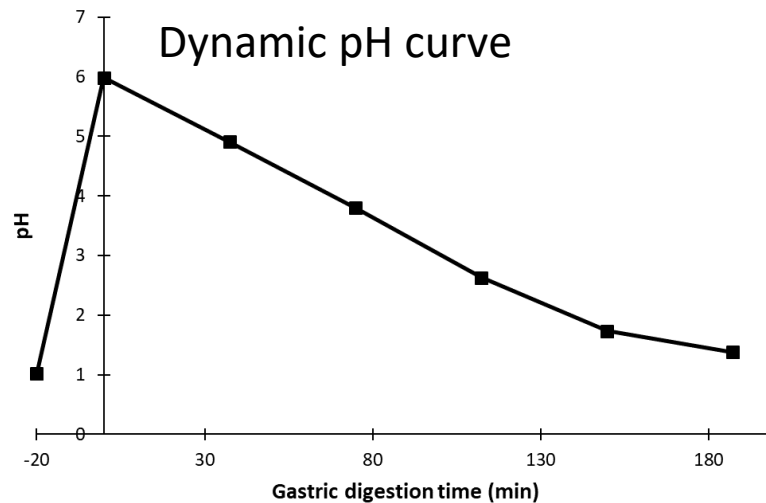
The Development of Semi-Dynamic *in vitro* Model

What does it simulate?

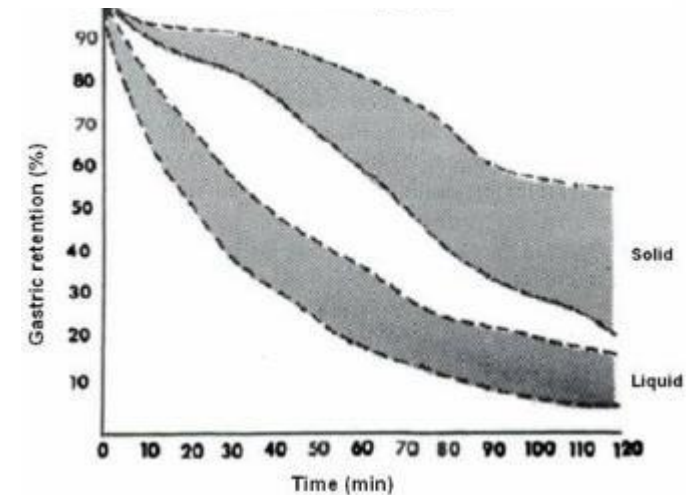


Simulation of:

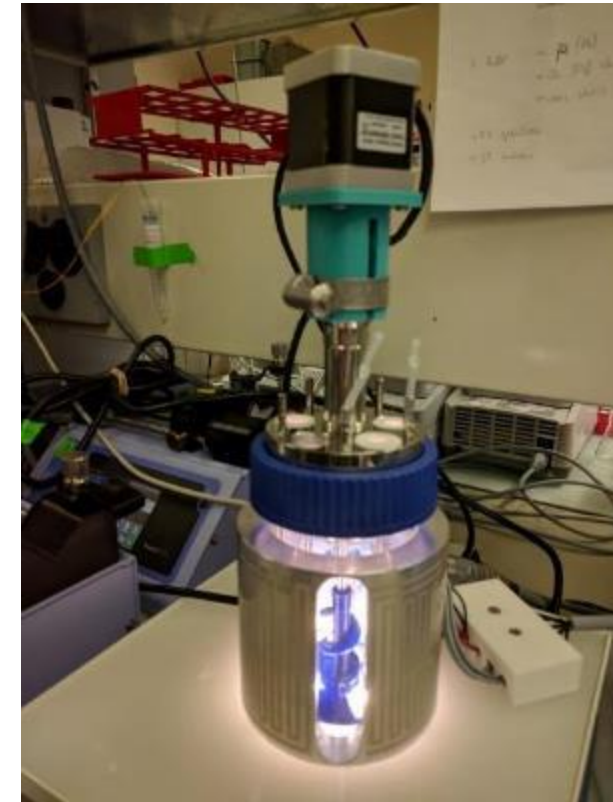
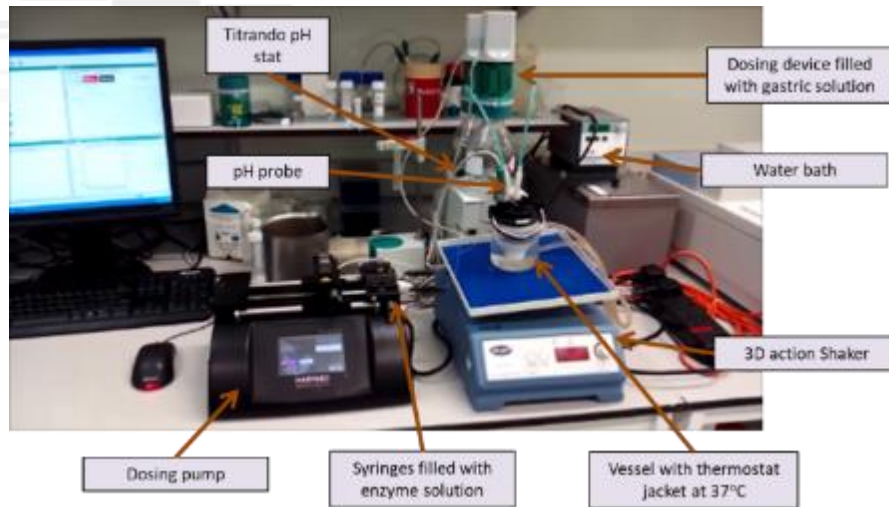
- ✓ Progressive acidification
- ✓ Gradual enzyme and fluids secretion
- ✓ Continuous emptying



Gastric emptying



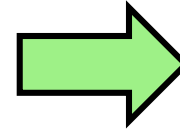
Semi-Dynamic Gastric Model



What does it simulate?

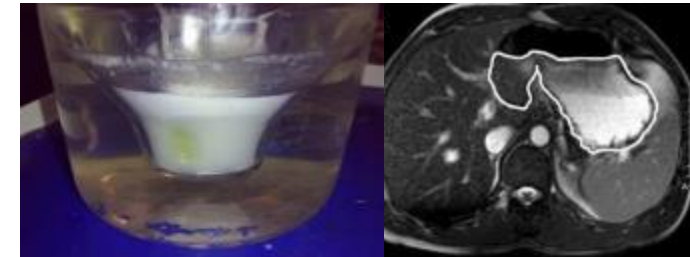
Simulation of:

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

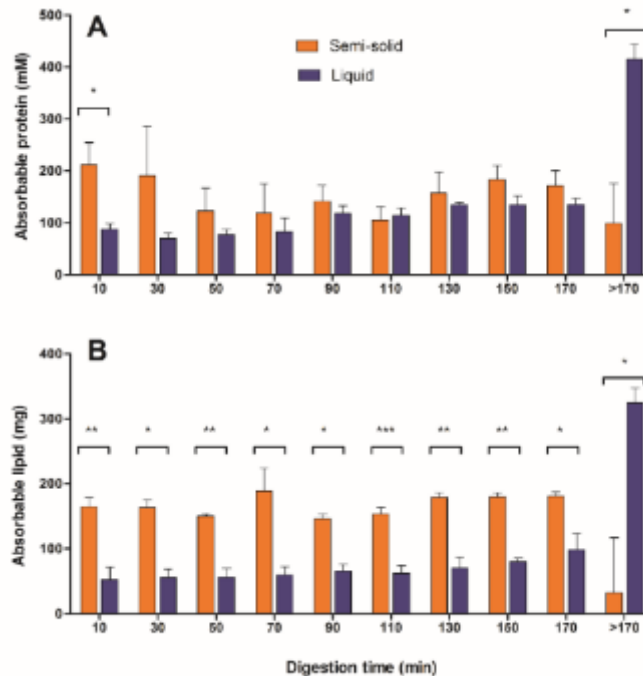
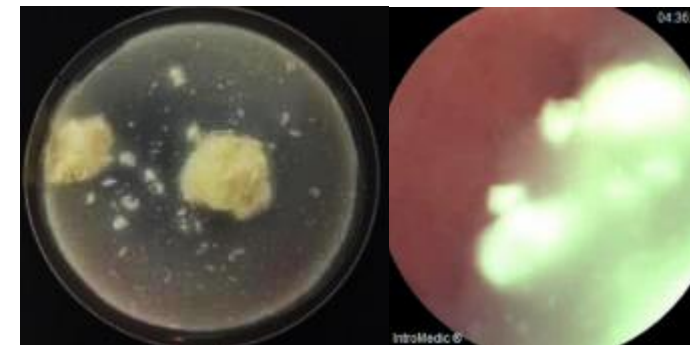


- ✓ Rate of nutrient digestion
- ✓ Structural changes in stomach

Layering



Coagulation





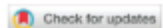
Ringtrial Semi-Dynamic INFOGEST protocol

Food &
Function



PAPER

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Cite this Food Funct., 2020, 11, 1702

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

	Product	Sample Name	Total Nitrogen	Protein (TN*6.38)	Carbohy- drates	Fat	Dry matter
			(g/kg)	(g/kg)	(g/kg)	(g/kg)	(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

Journal of Functional Foods

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

2nd 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)

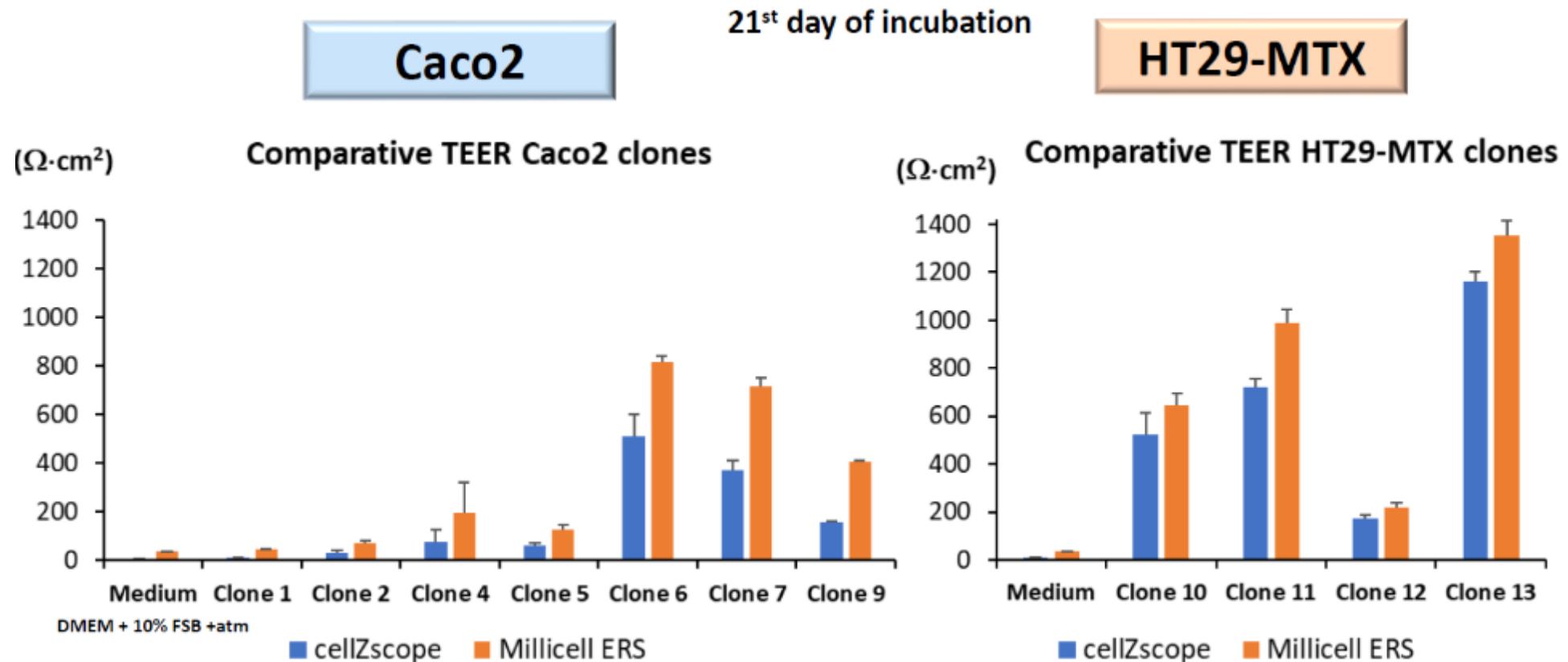
Allergenic sensitization (S. Bastiaan-Net)

Permeability ring-trial (B. Miralles)

Colonic fermentation (L. Tomas)

Cellular bioassays (E. Arranz)

In vivo models of nutrient bioavailability
(B. Graf)



In silico models of digestion



Contents lists available at [ScienceDirect](#)

Trends in Food Science & Technology

journal homepage: 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^{a, **}, Sarah Verkempinck^{b, *}, Juliane Floury^a, Anja Janssen^c, Alain Kondjoyan^d, Sebastien Marze^e, Pierre-Sylvain Mirade^d, Anton Pluschke^f, Jason Sicard^d, George van Aken^g, Tara Grauwet^b

- 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,¹ Ahmed Al-Razaz,² Matthijs Dekker,³ Erwin George,⁴ Beatrice Laroche,⁵ and George van Aken⁶

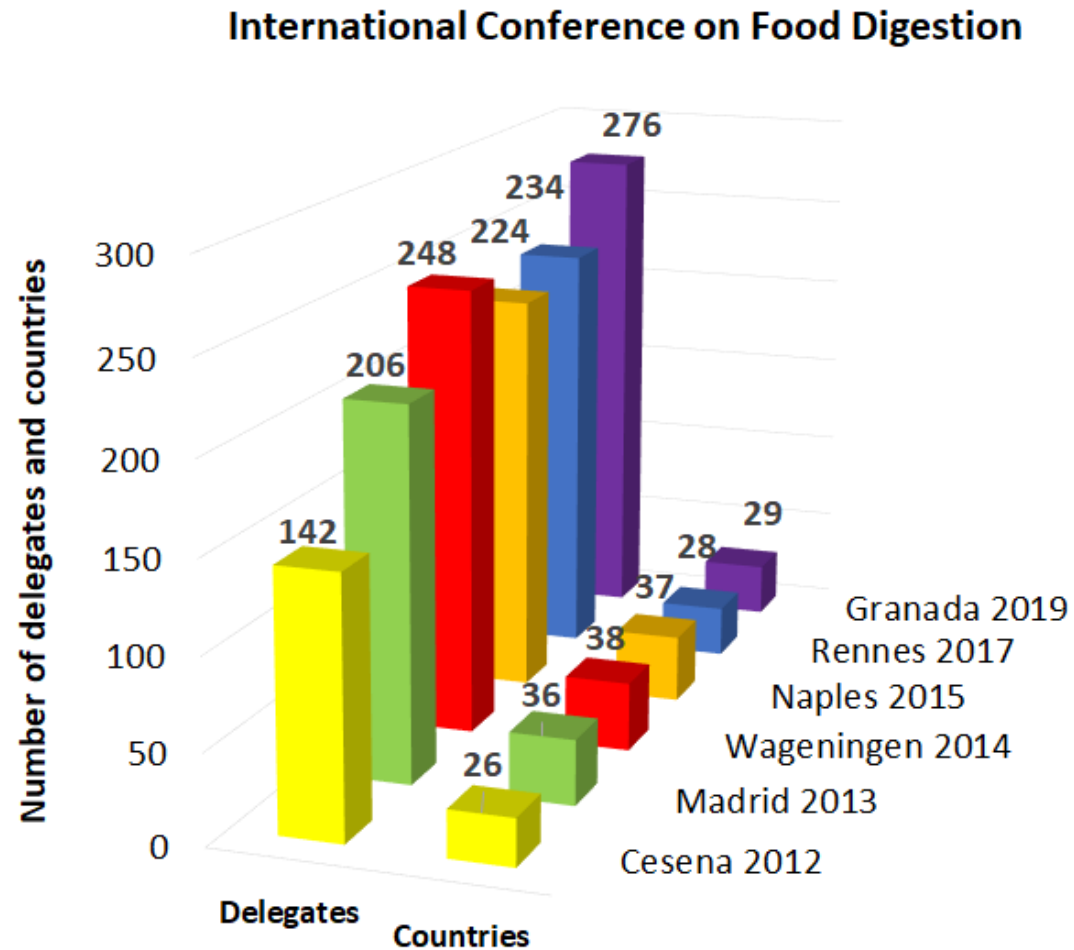
What's next?

- ☞ 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



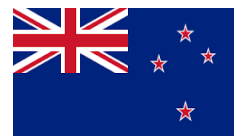
We need to see each other more often if the sanitary conditions allow it. **Organization of 1-2 workshops** every year connected to a conference of interest. Any proposition?

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



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Linda Giblin



Andre Brodkorb

And all the
TEAGASC
members!

