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
675 scientists - 200 institutes – 53 countries
Industry involvement

More than 60 companies are following INFOGEST
INFOGEST

Chair
Didier Dupont - France
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Vice-chair
Alan Mackie - UK

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

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Lotti Egger
Andre Brodkorb

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
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

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\textsuperscript{st} 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

<table>
<thead>
<tr>
<th>Product</th>
<th>Sample Name</th>
<th>Total Nitrogen (g/kg)</th>
<th>Protein (TN*6.38) (g/kg)</th>
<th>Input IVD 1 g Food (mg)</th>
<th>Input IVD 5 g Food (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skim milk Powder, INGREDIA</td>
<td>SMP</td>
<td>49.73</td>
<td>317.31</td>
<td>126.1</td>
<td>630.3</td>
</tr>
<tr>
<td>Whole milk Powder, INGREDIA</td>
<td>WMP</td>
<td>38.86</td>
<td>247.91</td>
<td>161.4</td>
<td>806.8</td>
</tr>
<tr>
<td>Gruyère, freeze dried (Agroscope)</td>
<td>Gru</td>
<td>66.71</td>
<td>425.61</td>
<td>94.0</td>
<td>469.9</td>
</tr>
<tr>
<td>Whey protein isolate, INGREDIA</td>
<td>WPI</td>
<td>133.01</td>
<td>848.58</td>
<td>47.1</td>
<td>235.7</td>
</tr>
<tr>
<td>Yogurt, freeze dried (Agroscope)</td>
<td>Yog</td>
<td>50.68</td>
<td>323.37</td>
<td>123.7</td>
<td>618.5</td>
</tr>
<tr>
<td>Cookie (protein free enzyme blank)</td>
<td>Cookie</td>
<td>0.00</td>
<td>0.00</td>
<td>1000.0</td>
<td>5000.0</td>
</tr>
</tbody>
</table>
A standardised semi-dynamic *in vitro* digestion method suitable for food – an international consensus†

Ana-Isabel Mulet-Cabero, Lotti Egger, Reto Portmann, Olivia Menard, Sébastien Marze, Hans Minekus, Steven Le Feunteun, Anwesha Sarkar, Myriam M.-L. Grundy, Frédéric Carrière, Matt Golding, Didier Dupont, Isidra Recó, André Brodkorb and Alan Mackie
What does it simulate?

Simulation of:

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

Dynamic pH curve

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

<table>
<thead>
<tr>
<th>Product</th>
<th>Sample Name</th>
<th>Total Nitrogen</th>
<th>Protein (TN*6.38)</th>
<th>Carbohydrates</th>
<th>Fat</th>
<th>Dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Skim milk Powder, INGREDIA</td>
<td>SMP</td>
<td>49.73</td>
<td>317.31</td>
<td>485.03</td>
<td>&lt;lod</td>
<td>956.9</td>
</tr>
</tbody>
</table>

→ 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

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


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**

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

Steven Le Feunteun²,³, Sarah Verkemipnck⁴,⁵, Juliane Flouri³, Anja Janssen⁶, Alain Kondjojan⁴, Sebastien Marze⁴, Pierre-Sylvain Mirade⁴, Anton Pluschke⁴, Jason Sicard⁴, George van Aken⁵, Tara Grauwet⁴

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

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**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

Scientific Review Panel

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And all the TEAGASC members!

Linda Giblin

Andre Brodkorb