

Digestibility of functional foods

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- Introduction to *in vitro* digestion models
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- What foods have been digested?
- What happens after the simulation?



What are *in vitro* digestion models?

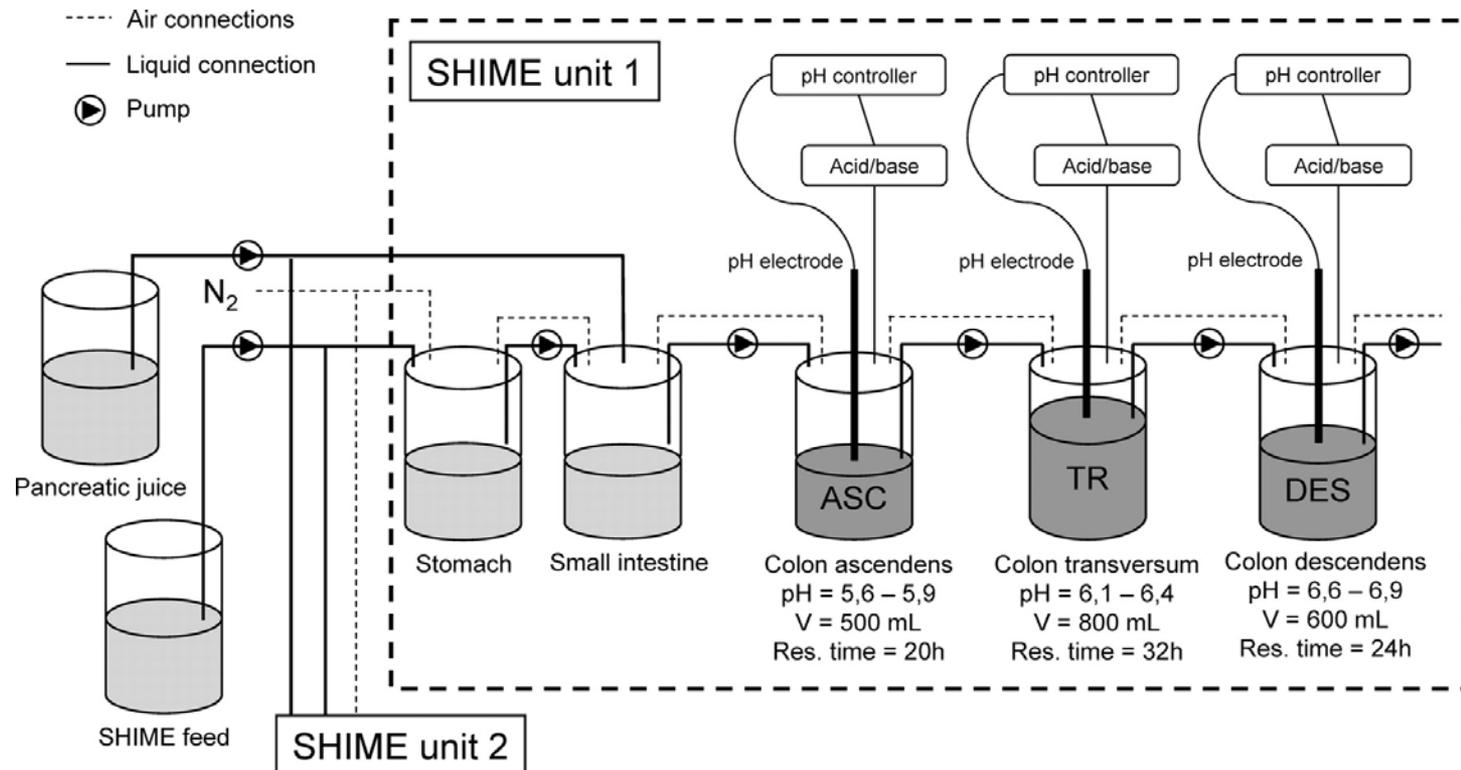
- Physicochemical (mechanical) models simulating the conditions of the human gastrointestinal system

Why are they preferred?

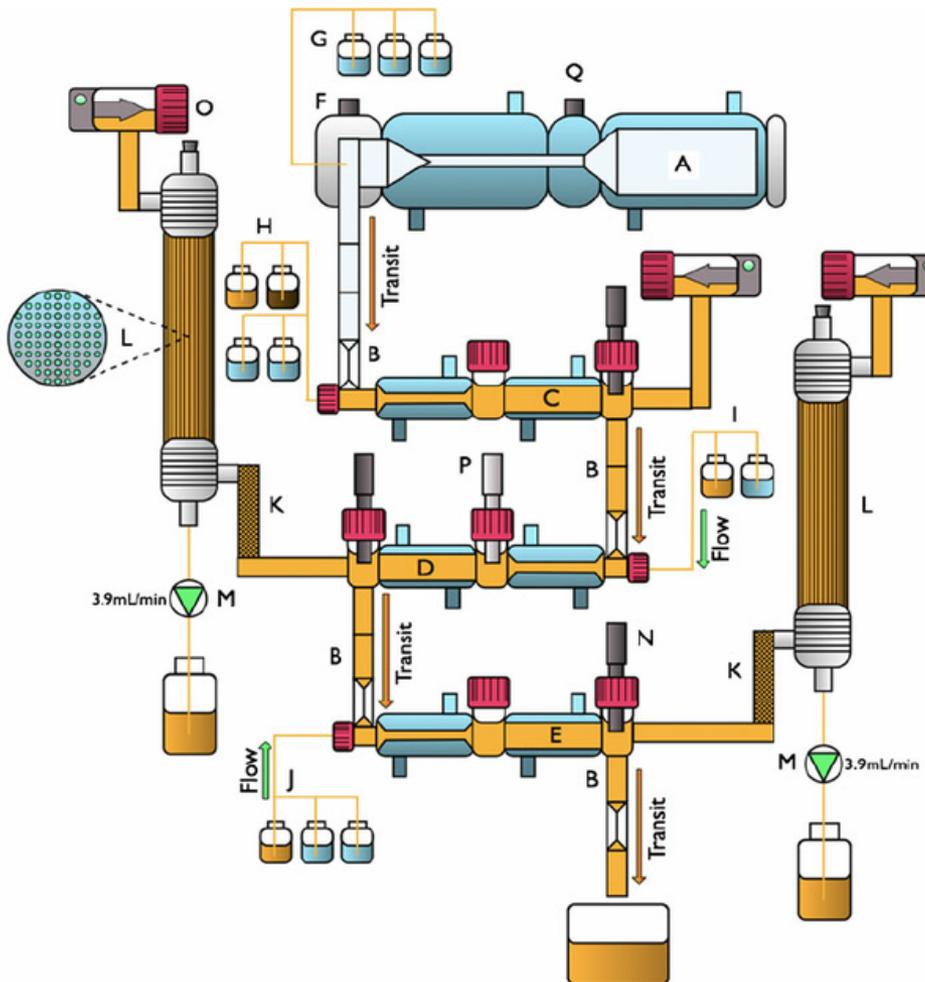
- alternative to *in vivo* clinical studies with humans and laboratory animals
- Examine novel, toxic or unfamiliar compounds
- Ethical constraints, costs and time
- Robust data with high repeatability

Simulator of the Human Intestinal Microbial Ecosystem (SHIME)

- Molly et al (1993), the 1st multi-stage simulator in the literature



TNO's Intestinal Microsystems (TIM) 1 and 2

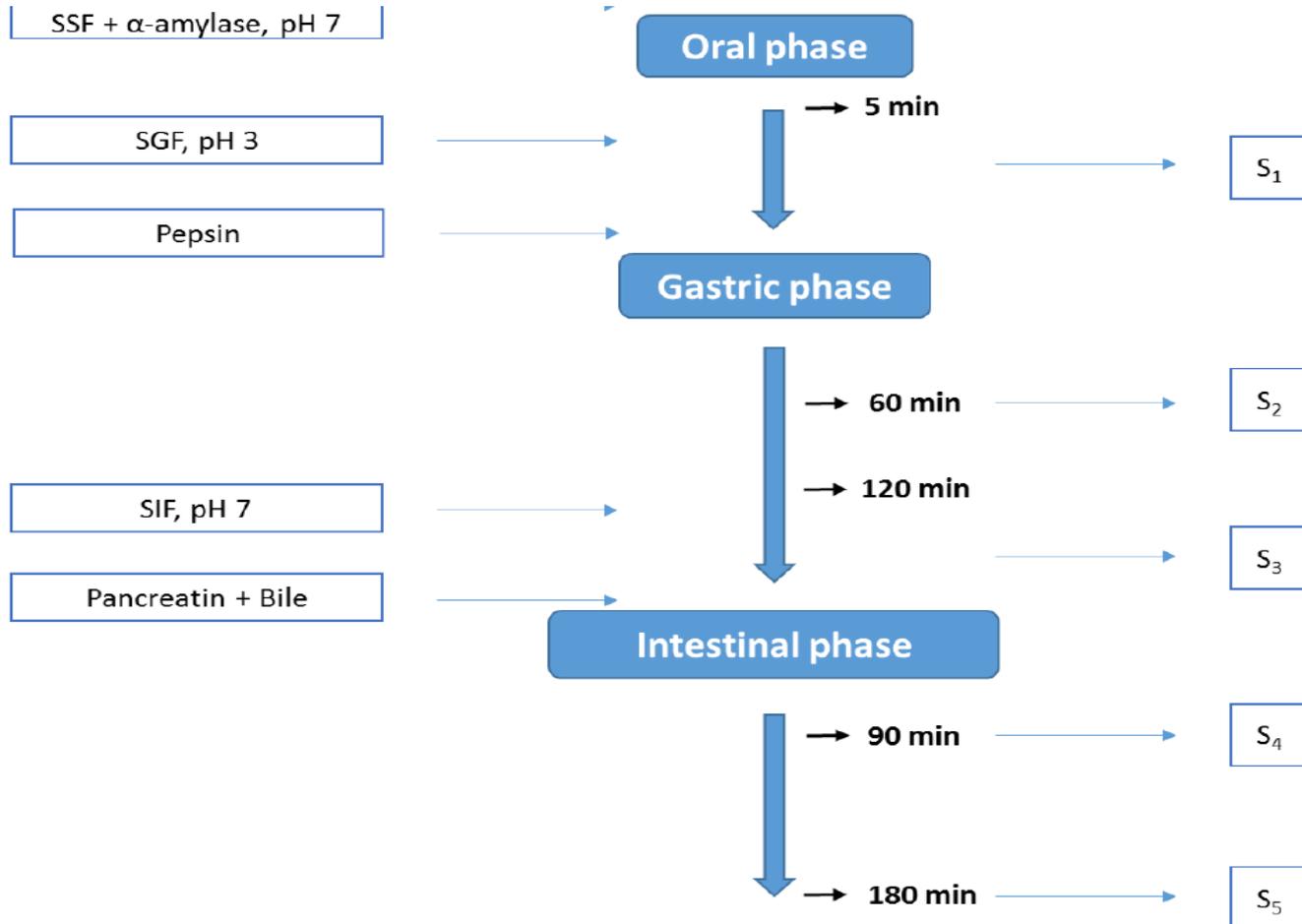


- Havenaar and Minekus (1996)
- 4 computer-controlled chambers, simulation of peristaltic movements

Selective Criteria	Possible Variations	IPUGS
Number of the organs to be simulated	Single/Multiple	Multiple
Nature of the organ conditions to be simulated	Static/Dynamic	Static/Dynamic
Anatomical and geometrical aspects	Consider/Ignore	Considered
Nature of the Building materials	Flexible/Rigid	Flexible
Sequential use of digestive enzymes	Yes/No	Yes
Sequential control of pH	Yes/No	Yes
Physiological residence time	Yes/No	Yes
Anaerobic environment	Yes/No	Yes
Control of temperature	Yes/No	Yes
Appropriate composition of GI secretions	Complex/Simplified	Complex
Sources of the digestive GI enzymes	Human/Other	Fungal/Porcine
Feed-back control of the GI secretion rates	Yes/No	Yes
Delivery of the GI secretions simulated	Pouring/Other	Other*
Simulation of peristaltic motility	Yes/No	Yes
Feed-back control of the GI motility	Yes/No	Yes
Absorption of metabolites and water	Yes/No	N/A
Presence of the mucosal lining	Yes/No	Yes
Immune system	Yes/No	No
Appropriate preparation of the test food	Yes/No	Yes
Appropriate ingestion rate of the test food	Yes/No	Yes
Inoculation of native bacteria in the GI	Yes/No	No
Adsorption of ingested bacteria to the GI walls	Yes/No	N/A (Yes)
Reproducibility of data	High/Low	High
Automation/robustness	Yes/No	Partially
Testing of various substances	Yes/No	Possible

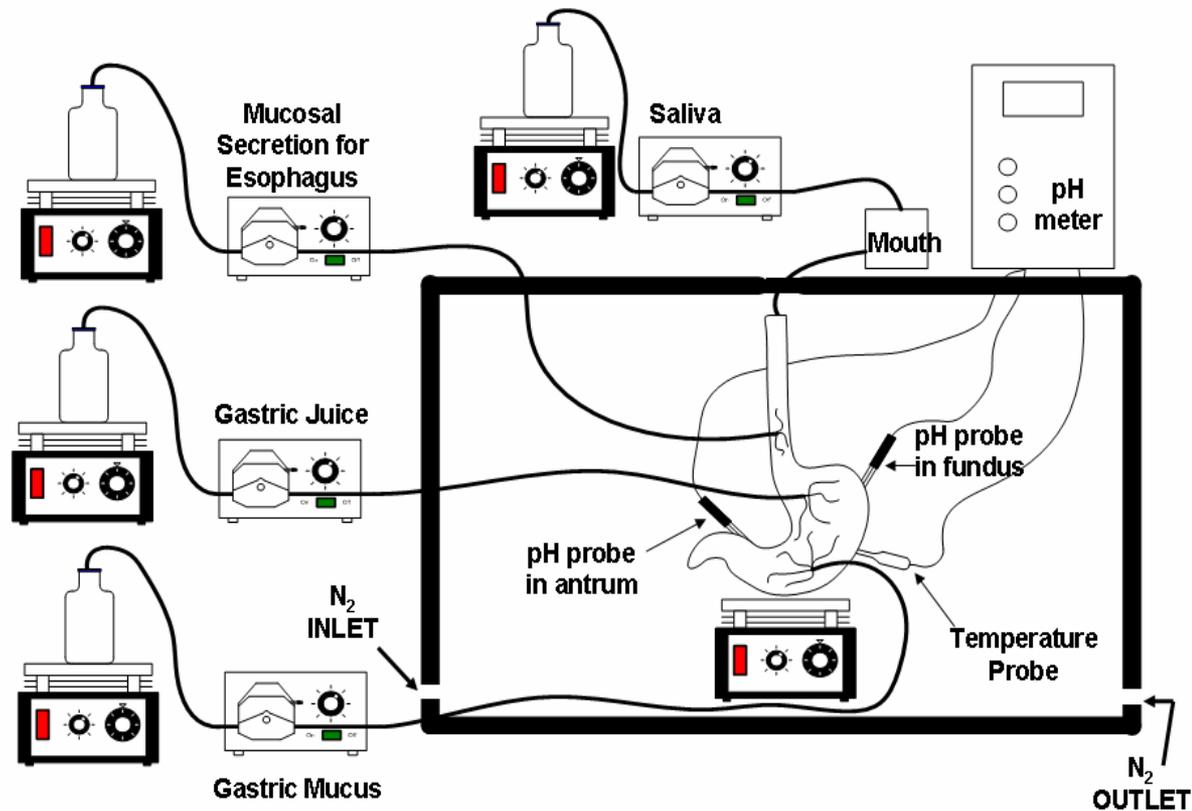
In vitro digestion models @ AUT

- Static



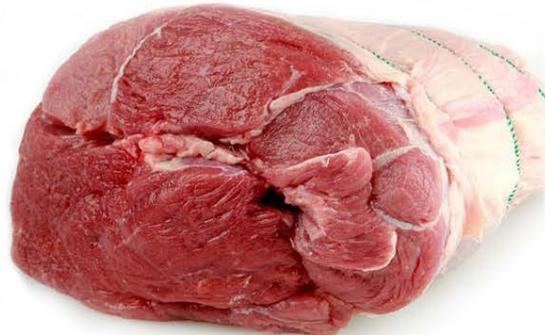
In vitro digestion models @ AUT

- Dynamic, extension of IPUGS



What foods have been digested?

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What happens after the simulation?

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- Samples are collected at least three times
 - Oral phase
 - Gastric phase
 - Intestinal phase
- Analysis of nutrient breakdown
 - Carbohydrates and starch and monosaccharides
 - Proteins and amino acids
 - Fats and fatty acids

Take an egg as an example

	Prior to digestion		Gastric Phase		Intestinal Phase	
	raw	cooked	raw	cooked	raw	cooked
ALA	1.431±0.027	1.289±0.008	60.886±1.043	48.380±0.323	276.040±0.638	358.020±0.471
GLY	0.000±0.000	0.000±0.000	34.946±1.016	26.515±0.347	257.581±0.108	394.422±0.315
VAL	1.445±0.011	0.000±0.000	31.489±0.168	25.110±0.206	223.466±0.921	486.599±0.155
LEU	0.742±0.006	0.968±0.010	121.479±0.142	146.958±1.006	807.463±1.503	1011.899±0.917
THR	0.000±0.000	0.000±0.000	25.582±0.297	22.180±0.361	129.294±0.977	341.612±0.560
ILE	-	-	14.258±0.225	19.942±0.334	117.358±0.564	198.364±0.428
SER	4.332±0.078	7.577±0.072	56.076±0.779	73.987±0.699	177.348±1.128	207.183±1.159
PRO	0.000±0.000	1.376±0.011	11.612±0.575	12.210±0.042	38.726±0.413	78.293±0.498
ASN	3.444±0.056	3.343±0.071	35.587±0.295	40.755±0.569	112.787±0.723	315.705±0.497
ASP	4.513±0.030	4.315±0.081	7.683±0.286	5.271±0.094	22.502±0.240	69.457±0.942
MET	1.248±0.035	1.181±0.007	29.922±0.177	24.771±0.832	266.811±1.501	455.116±0.739
GLU	0.000±0.000	0.000±0.000	10.962±0.563	17.204±0.657	58.173±0.776	98.209±0.936
PHE	1.253±0.004	1.683±0.013	137.751±0.706	65.788±0.844	562.442±0.543	693.875±0.693
AAA	4.058±0.047	7.902±0.010	13.474±0.567	20.517±0.802	45.684±0.412	65.936±0.319
GLN	7.795±0.142	12.831±0.713	37.752±0.438	49.348±0.796	262.870±1.509	344.612±0.258
ORN	1.433±0.030	1.682±0.064	12.999±0.489	15.928±1.097	24.635±1.066	58.977±0.885
LYS	1.468±0.053	1.440±0.028	47.985±0.792	58.758±0.441	406.976±1.939	726.334±0.504
HIS	1.514±0.028	0.000±0.000	16.386±1.080	22.623±0.266	189.606±2.030	305.466±0.467
TYR	1.068±0.048	1.162±0.029	39.021±0.363	45.923±0.786	409.896±0.871	703.617±0.538
TRP	0.000±0.000	0.817±0.009	14.733±0.948	37.321±0.783	198.226±0.235	290.250±0.881
Total FAAs	35.743	47.566	760.582	779.489	4587.884	7203.946

Digestibility of Cooked and Raw Egg Protein in Humans as Assessed by Stable Isotope Techniques^{1,2,3}

Pieter Evenepoel, Benny Geypens, Anja Luypaerts, Martin Hiele, Yvo Ghooos⁴
and Paul Rutgeerts

Department of Medicine, Division of Gastroenterology and Gastrointestinal Research Centre, University Hospital Leuven, B-3000 Leuven, Belgium

“The true ileal digestibility of cooked and raw egg protein amounted to 90.9 ± 0.8 and $51.3 \pm 9.8\%$, respectively”

	raw	cooked
Total FAAs (mg)	4587	7203
Total proteins (mg)	9550	8950
% digestibility	48.03	80.49



Take home messages

- Close simulation of digestion is possible using an *in vitro* digestion model
- Processing methods do make a difference in digestibility
- It is important to study the digestibility to fully understand the functionality of your food product