An INFOGEST international consensus static in vitro digestion model adapted to the general older adult population and its application to dairy products

Didier Dupont, Anaïs Lavoisier, Olivia Ménard, Stefano Nebbia, Martine Morzel

Static *in vitro* digestion model adapted to the general older adult population: an INFOGEST international consensus

Anais Lavoisier, Olivia Menard, Stefano Nebbia, Martine Morzel, Didier Dupont

Postdoctoral researcher
Science & Technology of Milk & Eggs (STLO)
Rennes, FRANCE
anais.lavoisier@inrae.fr

8th International Conference on FOOD DIGESTION
9 - 11 APRIL 2024 | PORTO PORTUGAL

"*Ageing leads to changes in the functionality of the digestive tract*"

But the impact of ageing on digestion, and absorption of nutrients is still unclear

1. Exhaustive literature review

Oro-gastrointestinal tract physiological parameters

Healthy older adults ≤ 65 y.

In vivo data

2. Consensus static *in vitro* digestion model

Adaptation of the INFOGEST 2.0 digestion method

Brodkorb et al. *INFOGEST static in vitro simulation of gastrointestinal food digestion.* Nat Protoc 14, 991–1014 (2019)

EAT4AGE consortium & International workshop

WP 3: *In vitro* digestibility and nutrient bioaccessibility of age-tailored food products

ICFD 2022
CORK 3-5 MAY 2022

Oral phase

Similar to young adults

Ionic composition of saliva

Very poorly documented, data available only for at-rest saliva

Salivary amylase activity

Data are scarce, and not easy to compare when determined with different assays

pH

1 study measured a slight increase (up to pH 8), 3 others no significant differences

Food/saliva ratio

2 robust studies about insalivation rates for different food matrices 

Ratio of 1 : 1 (weight of SSF or saliva added : dry weight of food) is more physiologically relevant

Food bolus particle size

Adapt their oral processing (increased number of chewing cycles) to reach same particles size

Need for a robust, simple, reproducible protocol to grind the food

Duration

Longer only for older adults equipped with a denture

New model

Oral phase

	Young adults 18+	Older adults 65+
SSF composition	See Brodkorb et al., (2019)	Same
Food:SSF dilution	1:1	1:1 (volume or according to DM)
pH	7.0	7.0
Duration	2 min	2 min
Chewing protocol	See Brodkorb et al., (2019)	Meat mincer, then add SSF or saliva
Amylase	75 U ml^{-1} (using the DNS assay)	Same

Manual, 5 cm mincing disk,
0,5 cm mesh size, one pass

Gastric phase

Ionic composition of gastric secretions

No information, research extended to animal models

Different from young adults

Gastric enzymes activities

Marked lack of knowledge in the postprandial state in older adult populations

Pepsin: reduced by 40% (basal & pentagastrin-stimulated pepsin output, n = 22)

Feldman et al. *Effects of ageing and gastritis on gastric acid and pepsin secretion in humans: a prospective study.* Gastroenterology, 110 (4), 1043-1052 (1996)

Gastric lipase: decline with age of activity (gastric mucosal biopsies, n = 22)

Moreau et al. *Human gastric lipase: variations induced by gastrointestinal hormones and by pathology*. Scand. J. Gastroenterol. 23 (9), 1044-1048 (1988)

pH

Gastric pH curve in fasted and fed conditions followed w/ the Heidelberg capsule technique (n=79, ±71 y.), significant increase in gastric pH with age. **Russel et al.** *Upper Gastrointestinal pH in 79 healthy, elderly, north American men and women*. Pharm. Research, 10 (2) (1993)

In static model: consider the pH at gastric emptying half-time ($t_{1/2}$)

Bolus/gastric secretions ratio

No specific data were found, following curve from *Russel et al.:* 50/50 dilution is calculated at $t_{1/2}$

Duration

Still controversial, but several studies have shown that gastric emptying slows down with age: increases by 34 - 46%

New model

Gastric phase

	Young adults 18+	Older adults 65+	
SGF composition	See Brodkorb et al., (2019)	Same	
Bolus:SGF dilution	1:1	1:1	
pH	3.0	3.7	↗
Duration	2 h	3 h	
Pepsin	2000 U ml^{-1}	1200 U ml^{-1}	↘ - 40%
Gastric lipase	60 U ml^{-1}	36 U ml^{-1}	

Intestinal phase

Ionic composition of intestinal secretions

No precise information, but 1 study shows an increase in Ca concentration with age: $[Ca^{2+}] = 0.01 \times age + 0.35$

Laugier et al. *Changes in pancreatic exocrine secretion with age: pancreatic exocrine secretion does decrease in the elderly*, Digestion, 50(3–4), 202–211 (1991)

Pancreatic enzymes activities

Some studies showed no difference, but general trends indicate a decrease in activity/output of enzymes of 13 to 35%

- **Pancreatic amylase**: More data are available compared to the other pancreatic enzymes
- **Trypsin:** Two studies showed opposite results
- **Chymotrypsin:** No dif. or decrease in chymotrypsin output with ageing
- **Pancreatic lipase**: Reported results highly controversial

Bile salts content

Limited data, decrease in bile acid synthesis

Different from young adults

Chyme/intestinal secretions ratio

Extremely difficult to assess, if we consider pancreatic exocrine secretions data are controversial: some saw a reduced volume of secretions, others no significant changes (n = 1615).

Dreiling et al. *The effect of age on human exocrine pancreatic secretion*. The Mount Sinai journal of Medicine, 52(5) (1985)

Duration

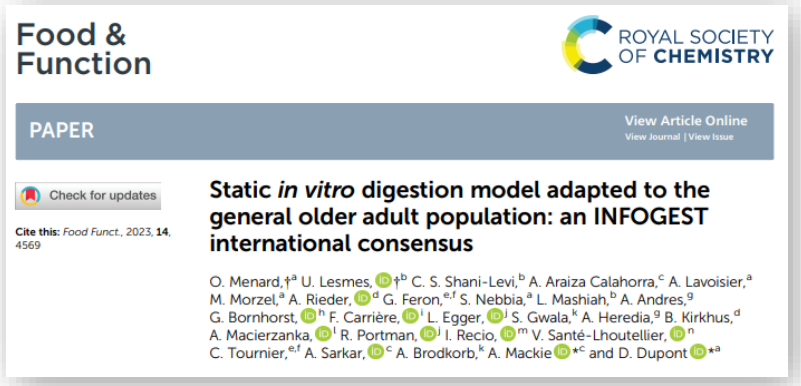
Not often monitored, if we consider whole gut transit time: no significant change in a recent study (n=111).

Nandhra et al. *Normative values for region-specific colonic and gastrointestinal transit times [..]* Neurogastroenterology & Motility, 32(2) (2020)

New model

Intestinal phase

	Young adults 18+	Older adults 65+
SIF composition	See Brodkorb et al., (2019)	Same, except for [Ca2+] = 1 mM ↗
Chyme:SIF dilution	1:1	1:1
pH	7.0	7.0
Duration	2 h	2 h
Pancreatin	100 U ml^{-1} trypsin	80 U ml^{-1} trypsin ↘ - 20%
Bile salts	10 mM	6,7 mM ↘ - 33%



Food & Function

ROYAL SOCIETY OF CHEMISTRY

PAPER

View Article Online
View Journal | View Issue

Check for updates

Cite this: *Food Funct.*, 2023, **14**, 4569

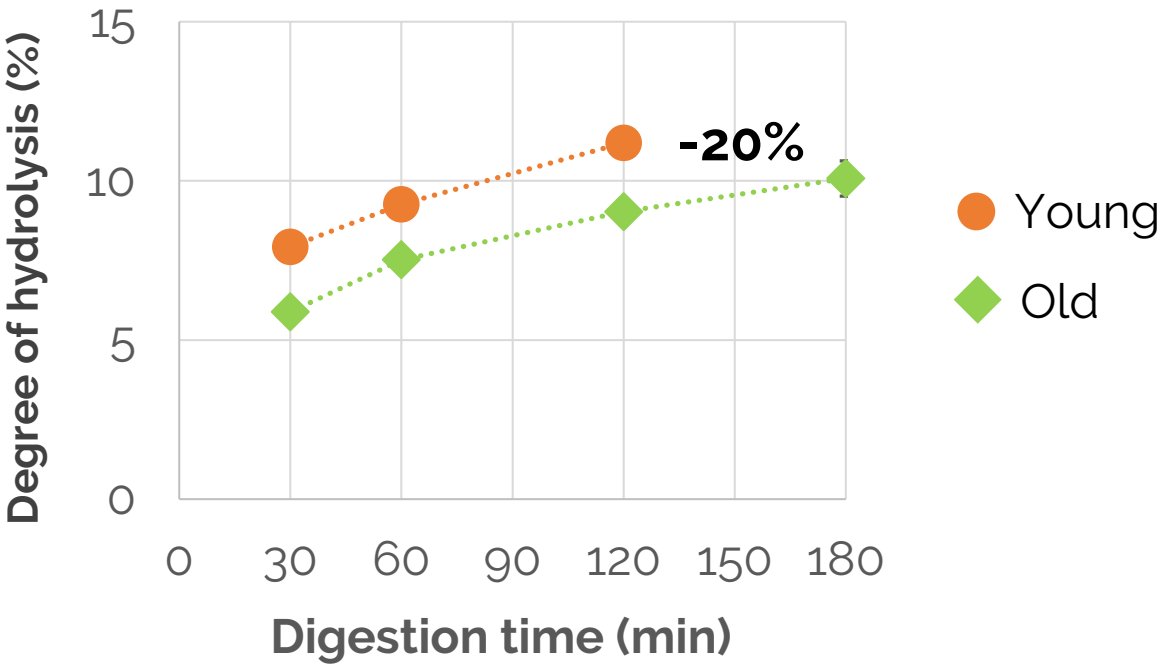
Static *in vitro* digestion model adapted to the general older adult population: an INFOGEST international consensus

O. Menard,†[a] U. Lesmes,[b†] C. S. Shani-Levi,[b] A. Araiza Calahorra,[c] A. Lavoisier,[a] M. Morzel,[a] A. Rieder,[d] G. Feron,[e,f] S. Nebbia,[a] L. Mashiah,[b] A. Andres,[g] G. Bornhorst,[h] F. Carrière,[i] L. Egger,[j] S. Gwala,[k] A. Heredia,[g] B. Kirkhus,[d] A. Macierzanka,[l] R. Portman,[j] I. Recio,[m] V. Santé-Lhoutellier,[n] C. Tournier,[e,f] A. Sarkar,[c] A. Brodkorb,[k] A. Mackie[*c] and D. Dupont[+a]

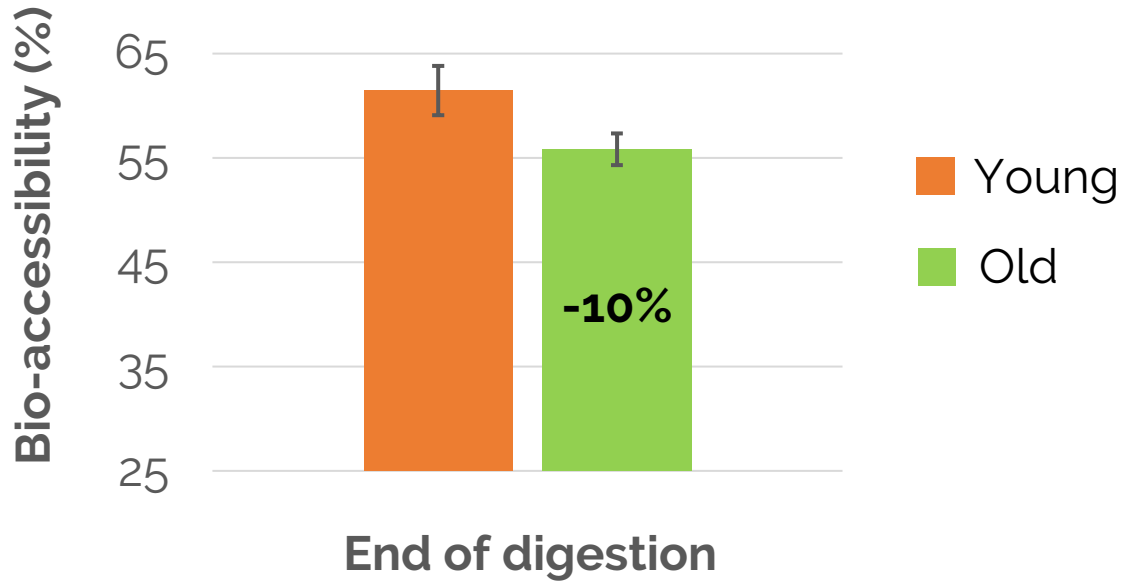
High-protein dairy products digestion

Skyr = commercial fermented dairy product containing mainly caseins (10% w/w)

Protein hydrolysis, gastric phase



Leucine release, intestinal phase



No difference in DH at the end of the digestion: **75-85%** in both conditions

Does age have an impact on food digestion?

Food & Function

ROYAL SOCIETY OF CHEMISTRY

PAPER

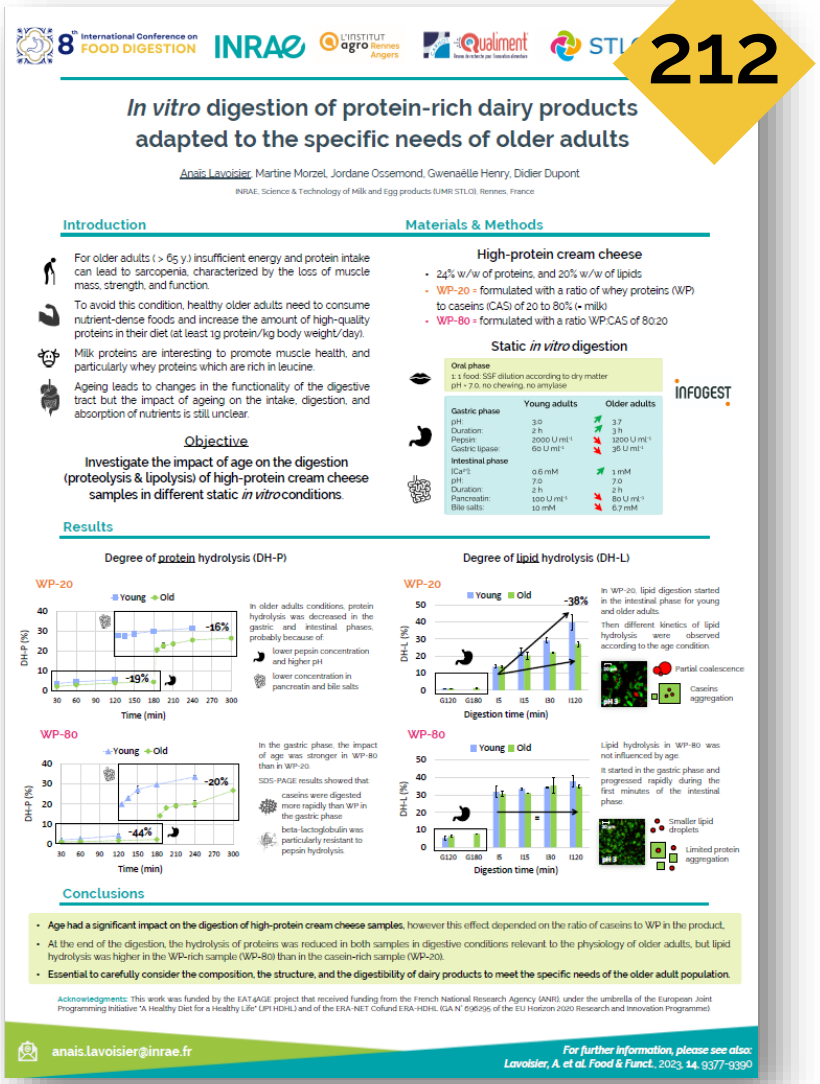
Check for updates

Cite this: *Food Funct.*, 2023, **14**, 9377

In vitro digestion of two protein-rich dairy products in the ageing gastrointestinal tract†

Anaïs Lavoisier, * Martine Morzel, Séverine Chevalier, Gwénaële Henry, Julien Jardin, Marielle Harel-Oger, Gilles Garric and Didier Dupont

212



Yes, but

different scenarios depending on the composition & structure of the dairy products studied

Other applications

Fermented lentils and quinoa, whole and flours

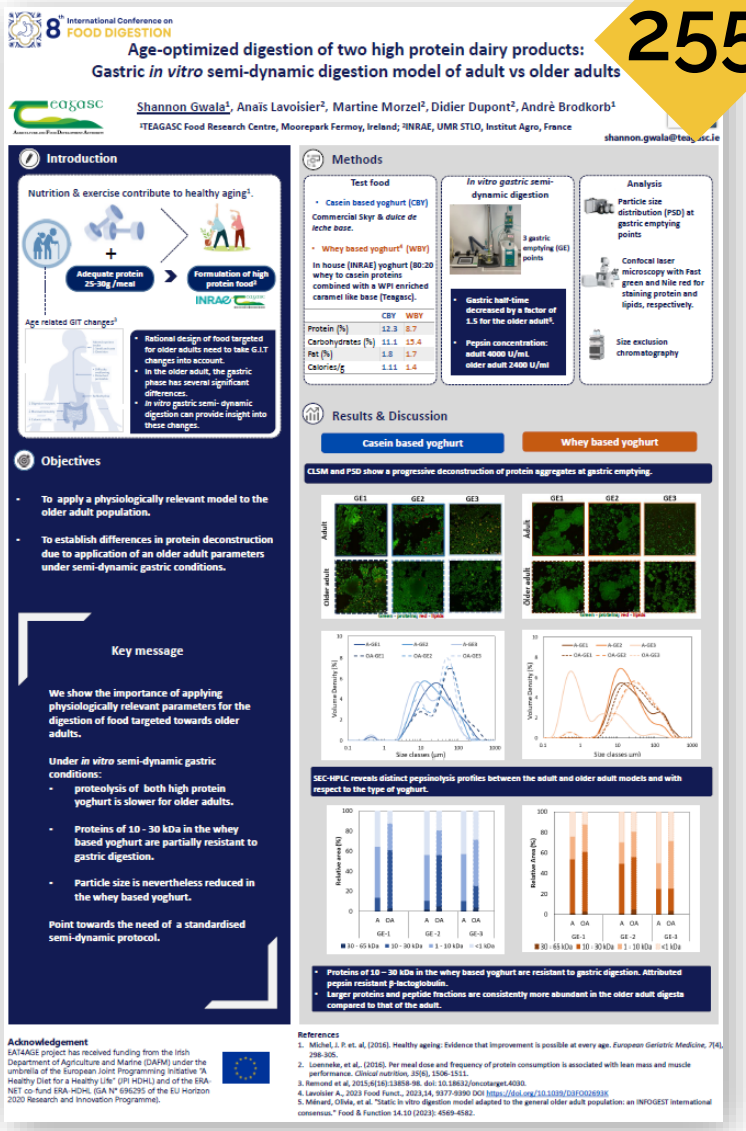
Sánchez-García et al. *Protein digestibility and ACE inhibitory activity of fermented flours in older adults and standard gastrointestinal simulation.* FRI, 180, 114080 (2024)

Sánchez-García et al. *In vitro digestion assessment (standard vs. Older adult model) on antioxidant properties and mineral bioaccessibility of fermented dried lentils and quinoa.* Molecules, 28(21), 7298 (2023)

Cooked lentils

Duijsens et al. *From static to semi-dynamic in vitro digestion conditions relevant for the older population: starch and protein digestion of cooked lentils.* Food Funct.,15, 591-607 (2024)

255



Semi-dynamic & dynamic models

Thank you

EAT4age
Palatable, nutritious and digestible foods for prevention of undernutrition in active aging

This project has received funding from the European Union's H2020 Research and Innovation Programme under grant agreement n.696300

Bioactivity and Nutrition (BN) team