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Spatial-temporal mapping of the intra-gastric pH, pepsin concentration and proteolysis in pigs fed egg white gels

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7th International Conference on Food Digestion

➤ Spatial-temporal mapping of the intra-gastric pH, pepsin concentration and proteolysis in pigs fed egg white gels

F. Nau, S. Le Feunteun, Y. Le Gouar, G. Henry, M. Pasco, C. Guérin-Dubiard, K. Nyemb-Diop, D. Dupont

STLO, INRAE, Institut Agro, 35042 Rennes, France

> Context



PROTEIN DIGESTION



How **food characteristics** can modulate the digestion process and **nutrient utilization** by the human body?



FOOD MATRIX
STRUCTURE

A KEY ROLE OF THE GASTRIC PHASE ?

➤ Previous *in vitro* results on Egg white gels



The extent of ovalbumin *in vitro* digestion and the nature of generated peptides are modulated by the morphology of protein aggregates

Kéra Nyemb^{a,b}, Catherine Guérin-Dubiard^{a,b}, Didier Dupont^{a,b}, Julien Jardin^{a,b}, Shane M. Rutherford^c, Françoise Nau^{a,b,*}



The structure and proteolysis extent of EGG WHITE GELS drive the proteolysis extent and the pattern of peptide fractions generated during *in vitro* digestion

Kéra Nyemb-Diop^{a,b}, David Causeur^c, Julien Jardin^{a,b}, Valérie Briard-Bion^{a,b}, Catherine Guérin-Dubiard^{a,b}, Shane M. Rutherford^d, Didier Dupont^{a,b}, Françoise Nau^{a,b,*}



Investigating the impact of ovalbumin aggregate morphology on *in vitro* ovalbumin digestion using label-free quantitative peptidomics and multivariate data analysis

Kéra Nyemb^{a,b}, Julien Jardin^{a,b}, David Causeur^c, Catherine Guérin-Dubiard^{a,b}, Didier Dupont^{a,b}, Shane M. Rutherford^d, Françoise Nau^{a,b,*}



Investigating the impact of egg white gel structure on peptide kinetics profile during *in vitro* digestion

Kéra Nyemb-Diop^{a,b}, David Causeur^c, Julien Jardin^{a,b}, Valérie Briard-Bion^{a,b}, Catherine Guérin-Dubiard^{a,b}, Shane M. Rutherford^d, Didier Dupont^{a,b}, Françoise Nau^{a,b,*}



➤ Previous *in vivo* results on Egg white gels (EWG)



Spatial-temporal changes in pH, structure and rheology of the gastric chyme in pigs as influenced by egg white gel properties



Françoise Nau^{a,b,*}, Kéra Nyemb-Diop^{a,b}, Valérie Lechevalier^{a,b}, Juliane Floury^{a,b}, Chloé Serrière^c, Natascha Stroebinger^c, Thiébaud Boucher^{a,b}, Catherine Guérin-Dubiard^{a,b}, Maria J. Ferrua^c, Didier Dupont^{a,b}, Shane M. Rutherford^c

^aAgrocampus Ouest, UMR1253 Science et technologie du lait et de l'œuf, 65 rue de Saint-Brieuc, 35042 Rennes, France

^bINRA, UMR1253 Science et technologie du lait et de l'œuf, 65 rue de Saint-Brieuc, 35042 Rennes, France

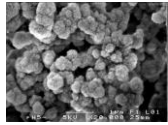
^cRiddet Institute, Massey University, University Avenue, Palmerston North 4474, New Zealand

3 egg white gels: different structures, same composition

Egg White

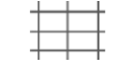
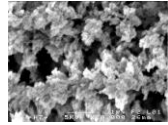
pH 5
IS 0.1M

Heating 90°C – 150 min



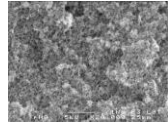
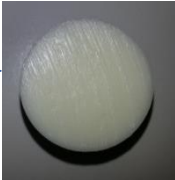
Granular-spongy
gel

pH 7
IS 0.05M



Intermediate
gel

pH 9
IS 0.05M



Smooth-rigid
gel

Test meals: 1 kg



n=99

Euthanization

20 min

60 min

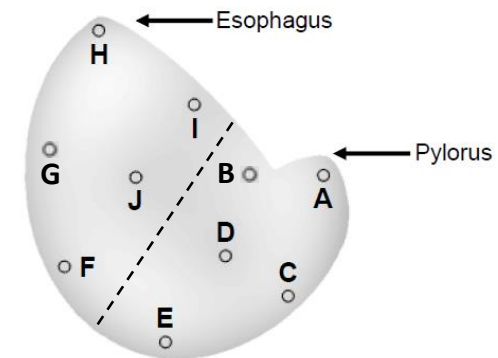
120 min

240 min

360 min

1 trial = 1 EWG x 1 time
5 to 6 pigs / trial

Gastric sampling
in 10 locations



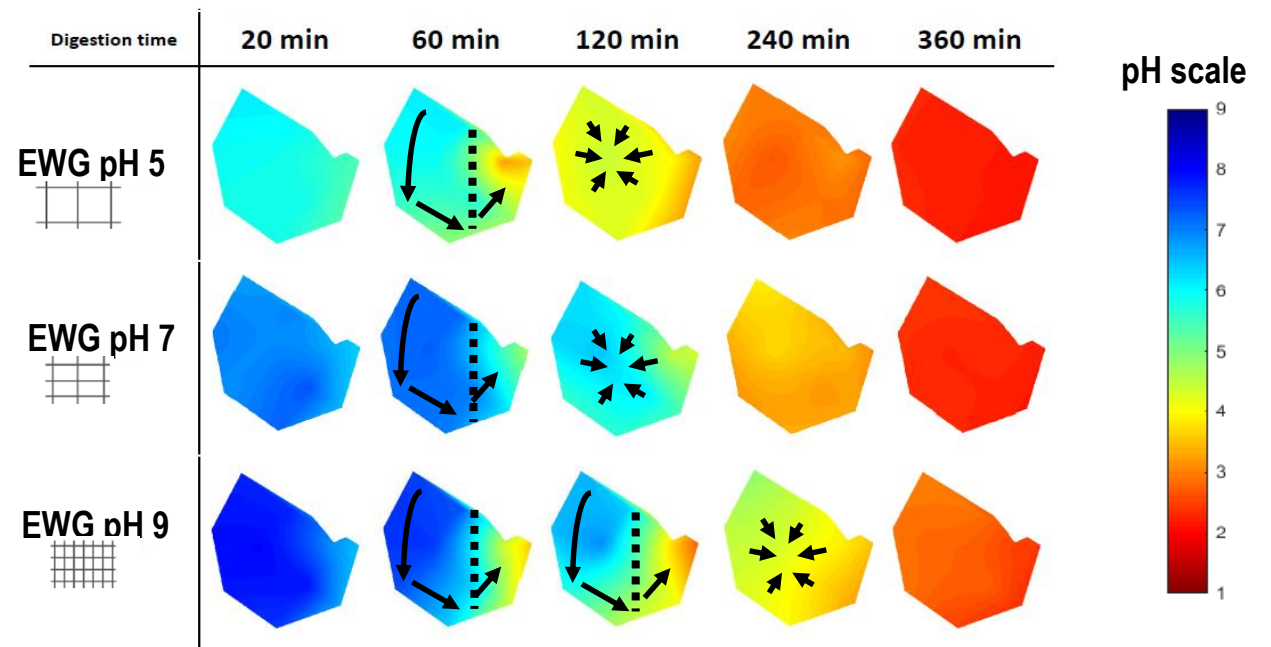
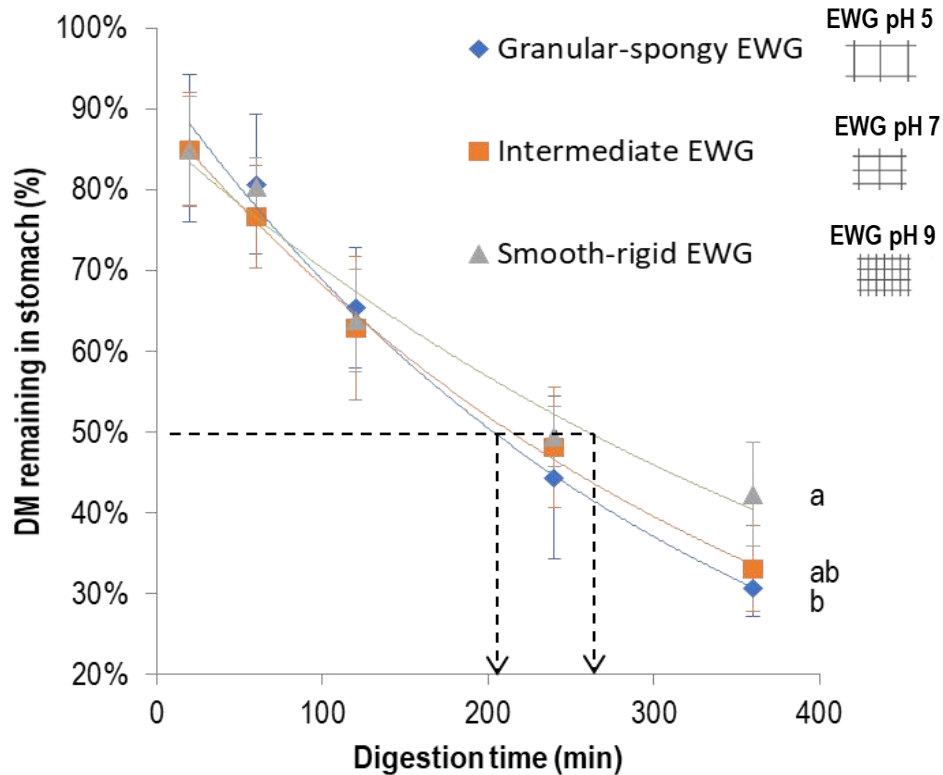
- pH
- Wet and dry masses
- Granulometric distribution
- rheological properties

➤ Previous *in vivo* results on Egg white gels (EWG)

Spatial-temporal changes in pH, structure and rheology of the gastric chyme in pigs as influenced by egg white gel properties

Françoise Nau^{a,b,*}, Kéra Nyemb-Diop^{a,b}, Valérie Lechevalier^{a,b}, Juliane Flourey^{a,b}, Chloé Serrière^c, Natascha Stroebinger^c, Thiébaud Boucher^{a,b}, Catherine Guérin-Dubiard^{a,b}, Maria J. Ferrua^c, Didier Dupont^{a,b}, Shane M. Rutherford^c

^aAgrocampus Ouest, UMR1253 Science et technologie du lait et de l'œuf, 65 rue de Saint-Brieuc, 35042 Rennes, France
^bINRA, UMR1253 Science et technologie du lait et de l'œuf, 65 rue de Saint-Brieuc, 35042 Rennes, France
^cRidlet Institute, Massey University, University Avenue, Palmerston North 4474, New Zealand



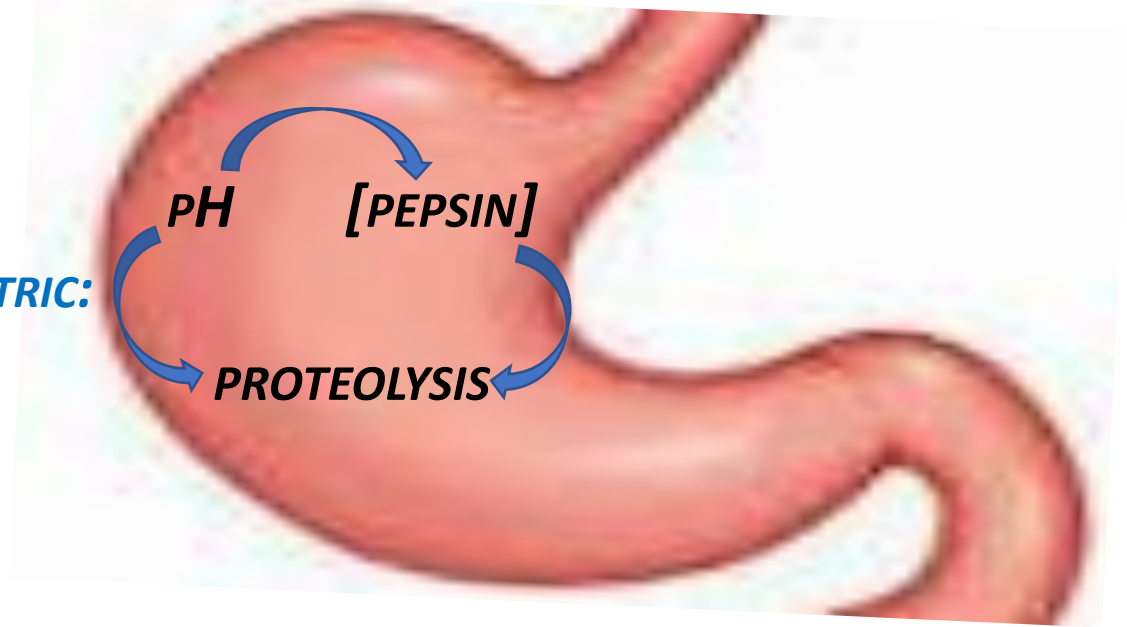
- ✓ Gastric emptying profiles are influenced by EWG characteristics, but not in a great extent ($t_{1/2} \sim 200\text{-}250$ min $\Rightarrow \sim 4$ h)

- ✓ Acidification starts in the pylorus region (HCl streaming along stomach walls)
- ✓ Beyond the initial pH, the gel structure impacts the mixing kinetics
- ✓ Consistent with (Bornhorst et al., *Food Biophysics*, 2014) on almonds and rice

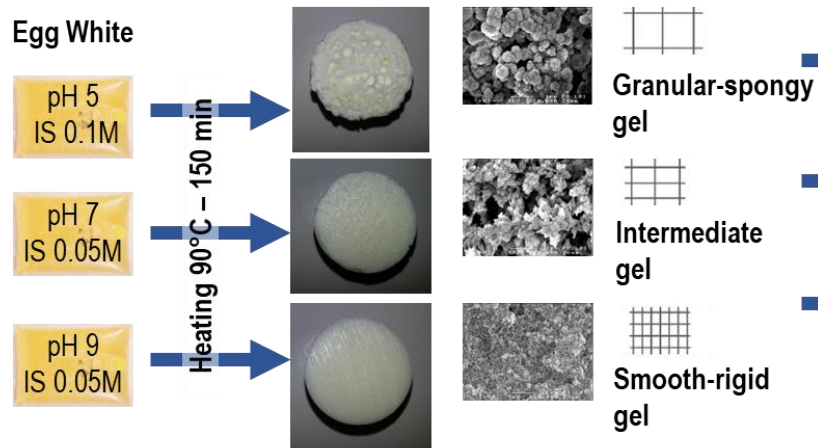
➤ Objectives of the present study

COMPLEMENTARY ANALYSES OF THE SAME SAMPLES TO:

- ❑ FURTHER STUDY THE RELATIONSHIPS BETWEEN INTRAGASTRIC:
- ❑ THE CONSEQUENCES ON SUBSEQUENT AMINO-ACID ABSORPTION



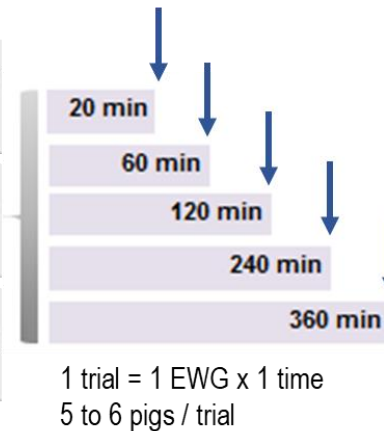
3 egg white gels: different structures, same composition



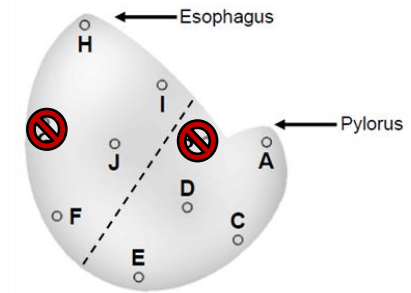
Test meals: 1 kg



Euthanization



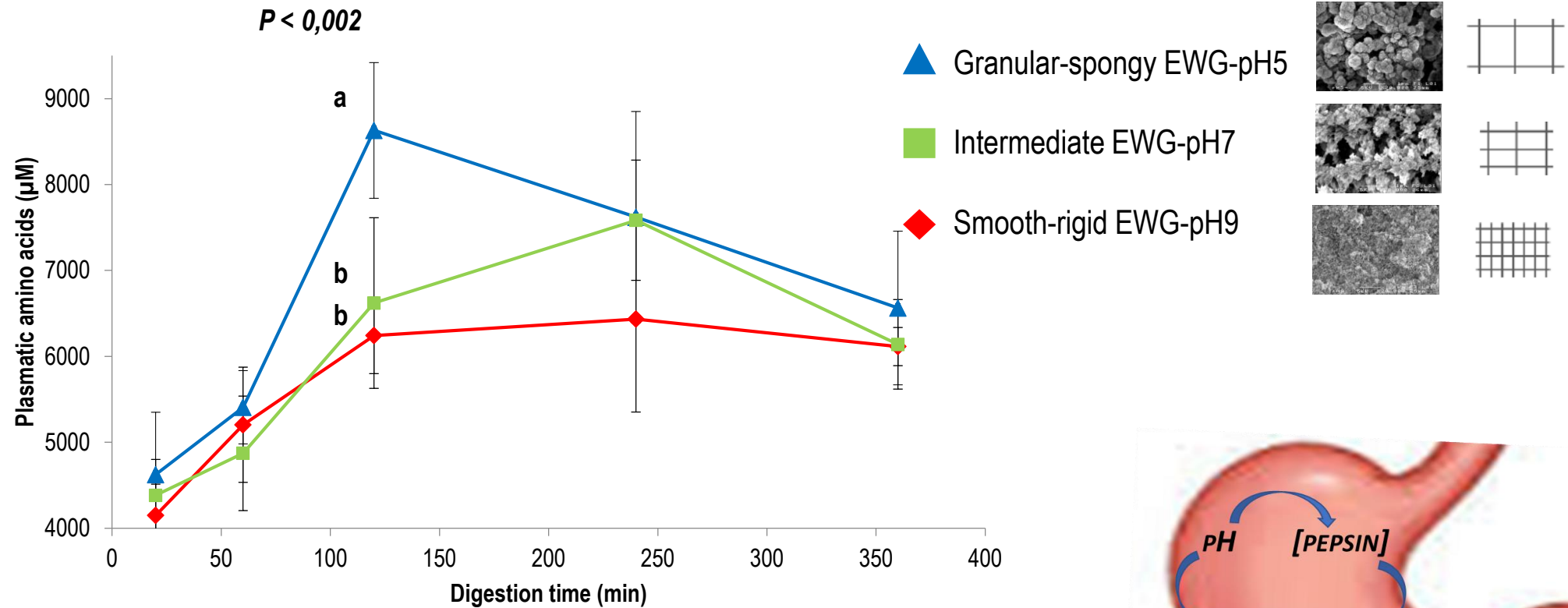
Gastric sampling in 8 locations



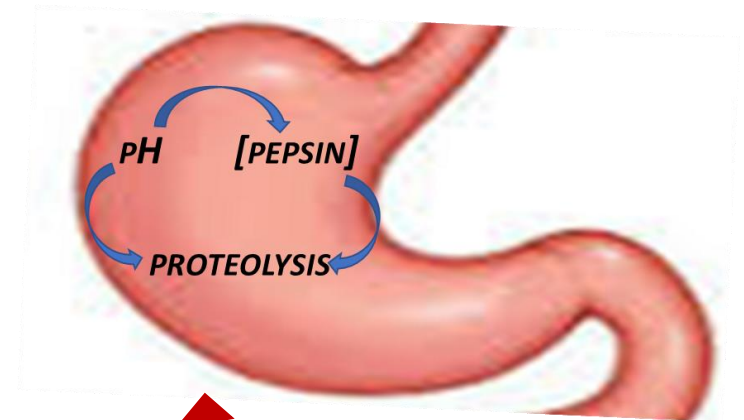
- pH
- Wet and dry masses
- Granulometric distribution
- rheological properties
- Pepsin concentration (ELISA)
- Proteolysis (OPA)

- Free amino acid content (Peripheral blood)

➤ Peripheral blood aminoacidemia

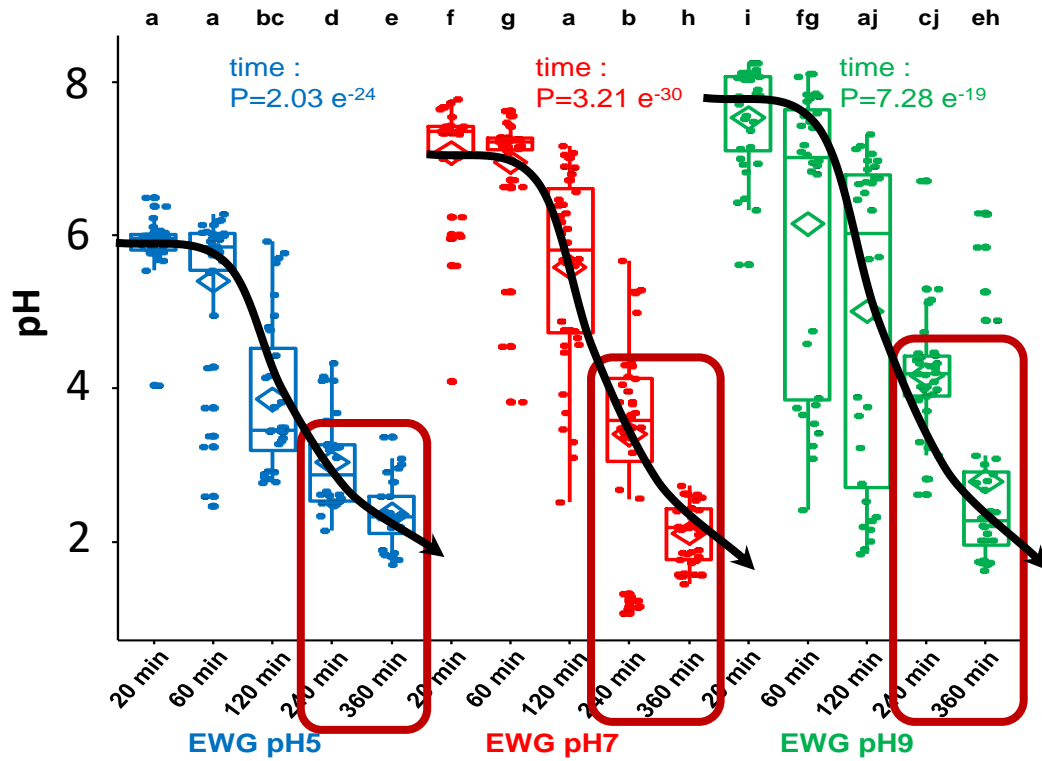


✓ The loosest protein network is the more quickly digested & leads to the highest and earliest plasmatic amino acid peak

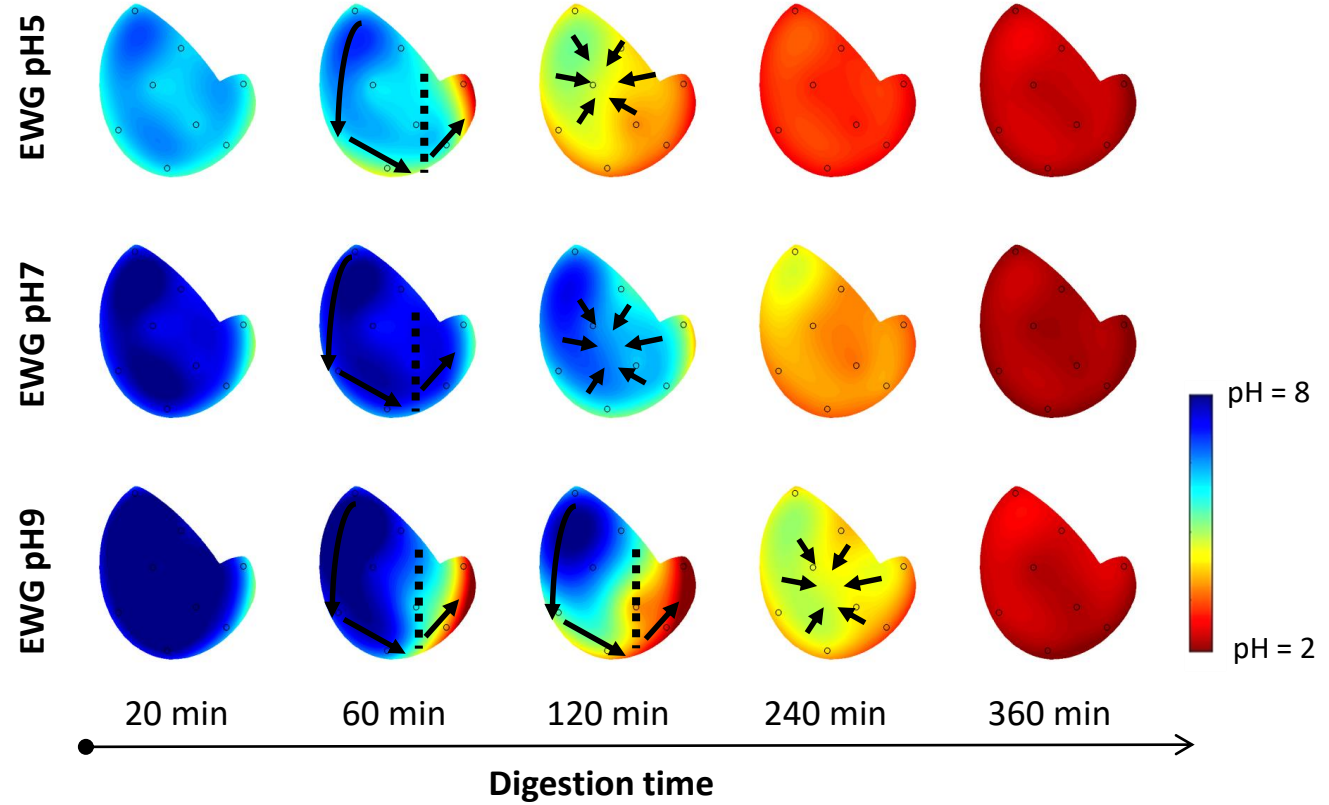


> pH results

All values



Maps

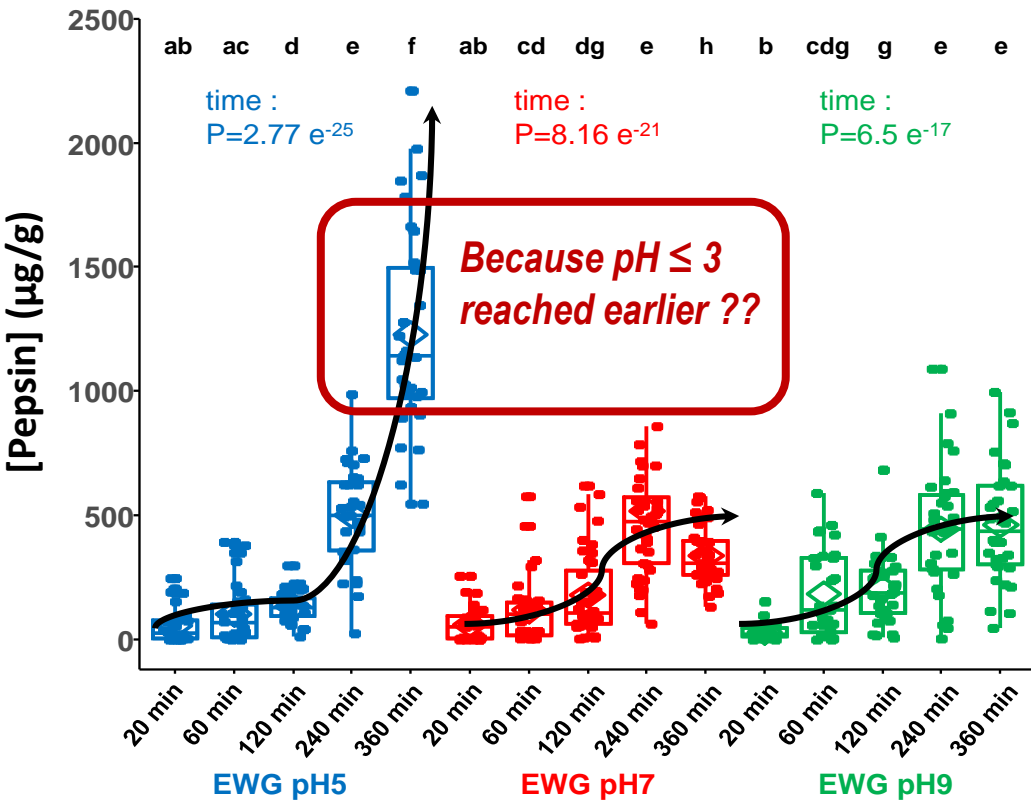


✓ At $t_{1/2}$ (~ 4h), pH range between 3-4

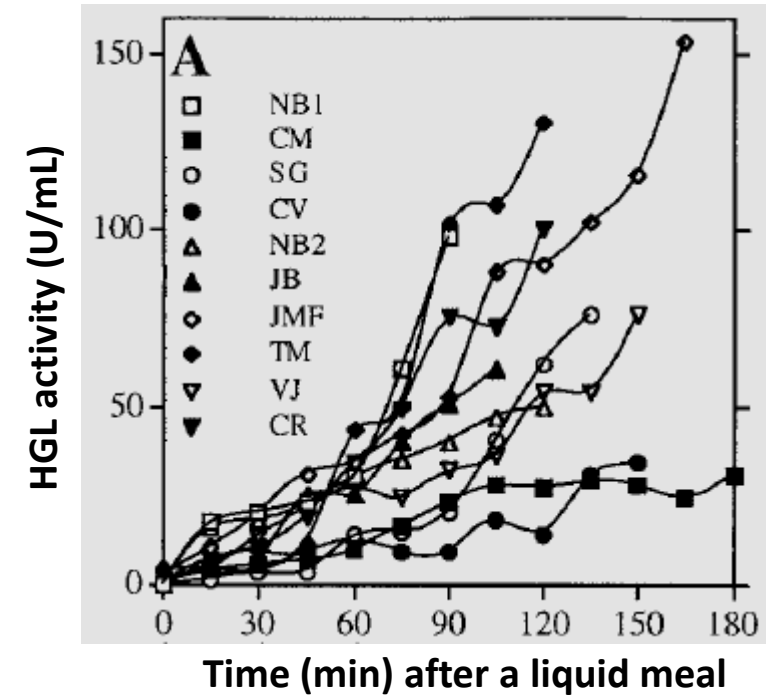
✓ $1.5 \times t_{1/2}$ (6h) to reach pH 2

➤ Pepsin results ($\mu\text{g/g}$ of wet chyme)

All values



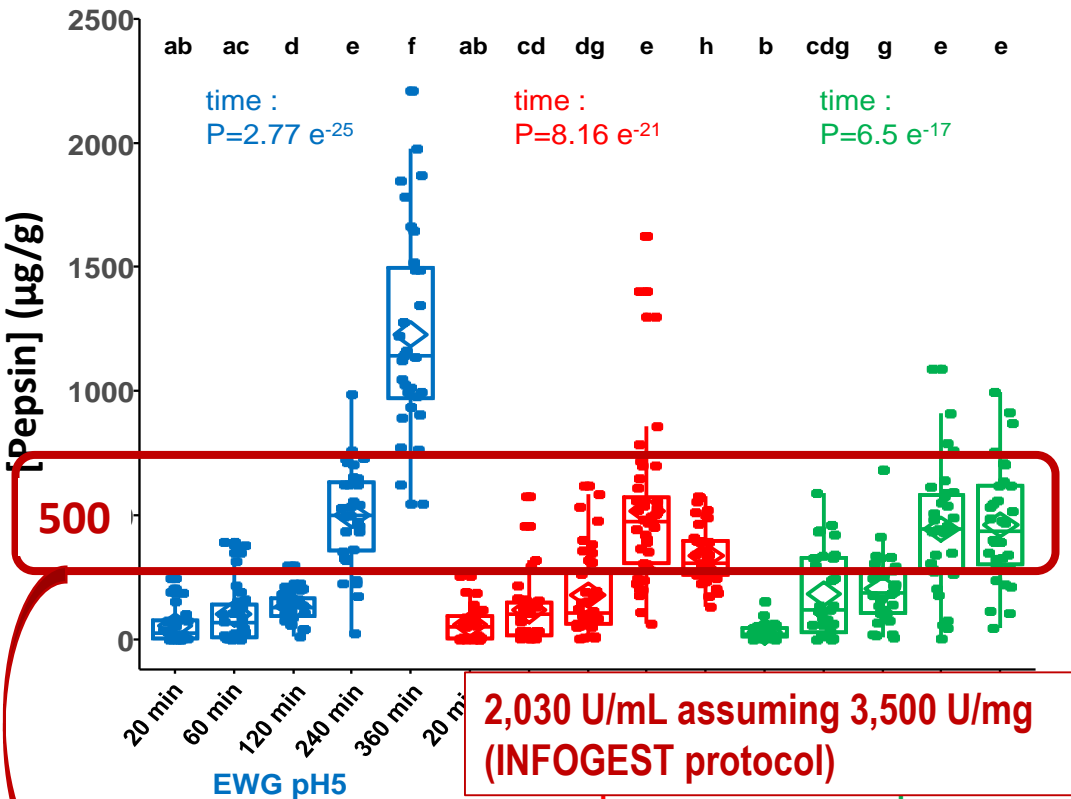
- ✓ Max [Pepsin] reached at $\geq t_{1/2}$ (4-6h, as for $pH \leq 3$)
- ✓ 2 shapes of concentration profiles depending on the gels



- ✓ Consistent with previous reports on Gastric Lipase in Humans (*Carrière et al., Digestion, 2001*)

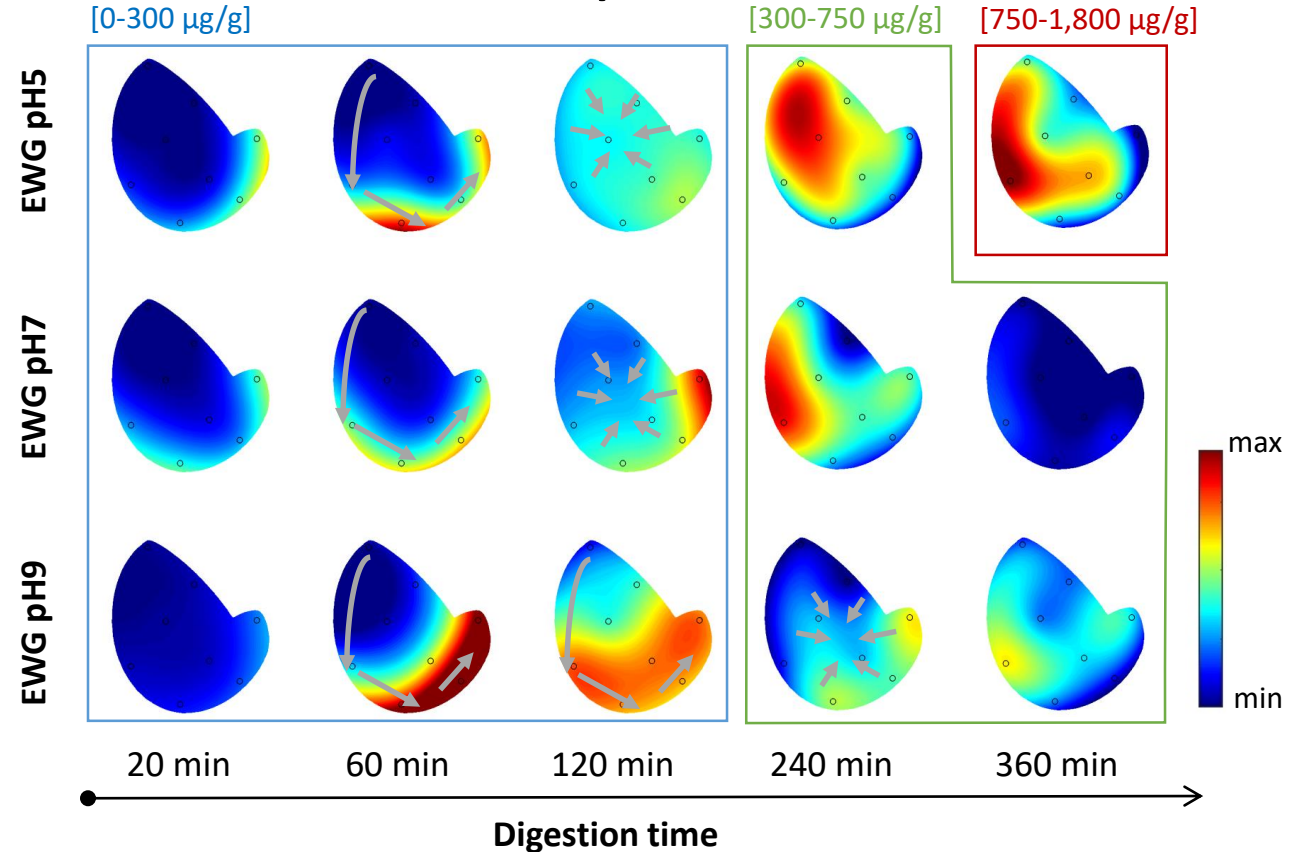
➤ Pepsin results ($\mu\text{g/g}$ of wet chyme)

All values



- ✓ 500 $\mu\text{g/g}$ at 240 min \approx 580 $\mu\text{g/g}$ at 210 min in humans (Kalantzi et al., Pharm. Res., 2006)
- ✓ Mean flow rate of 2.1 mg/min \approx 2.5 mg/min in humans (Malagelada et al., Dig. Dis. Sci., 1979)

Maps

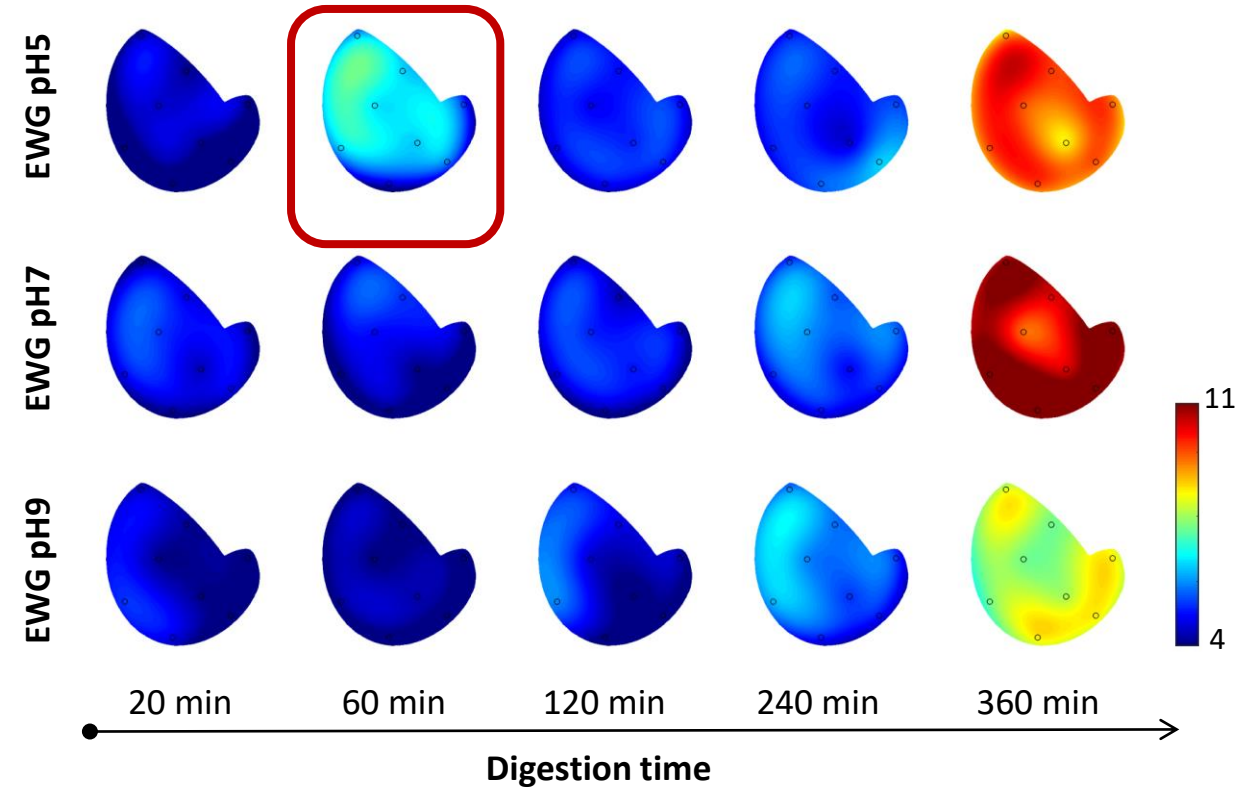
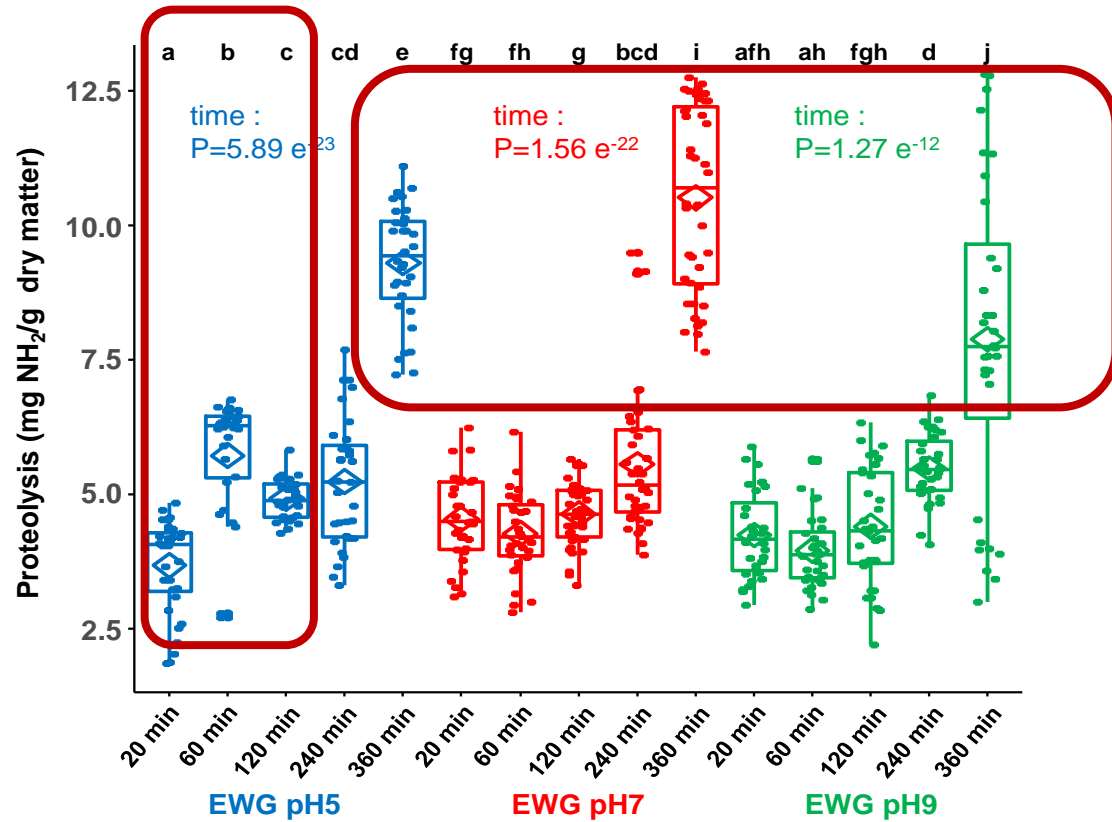


- ✓ Very similar as for the pH (pepsin streaming along the walls)...
- ✓ ... before it turns to accumulate in the proximal region
- ✓ pH and pepsin maps are \neq in the end because:
 - pH is not a concentration (it is a Log)
 - Food buffers

➤ Proteolysis results (mg of free NH₂ / g of dry matter)

All values

Maps



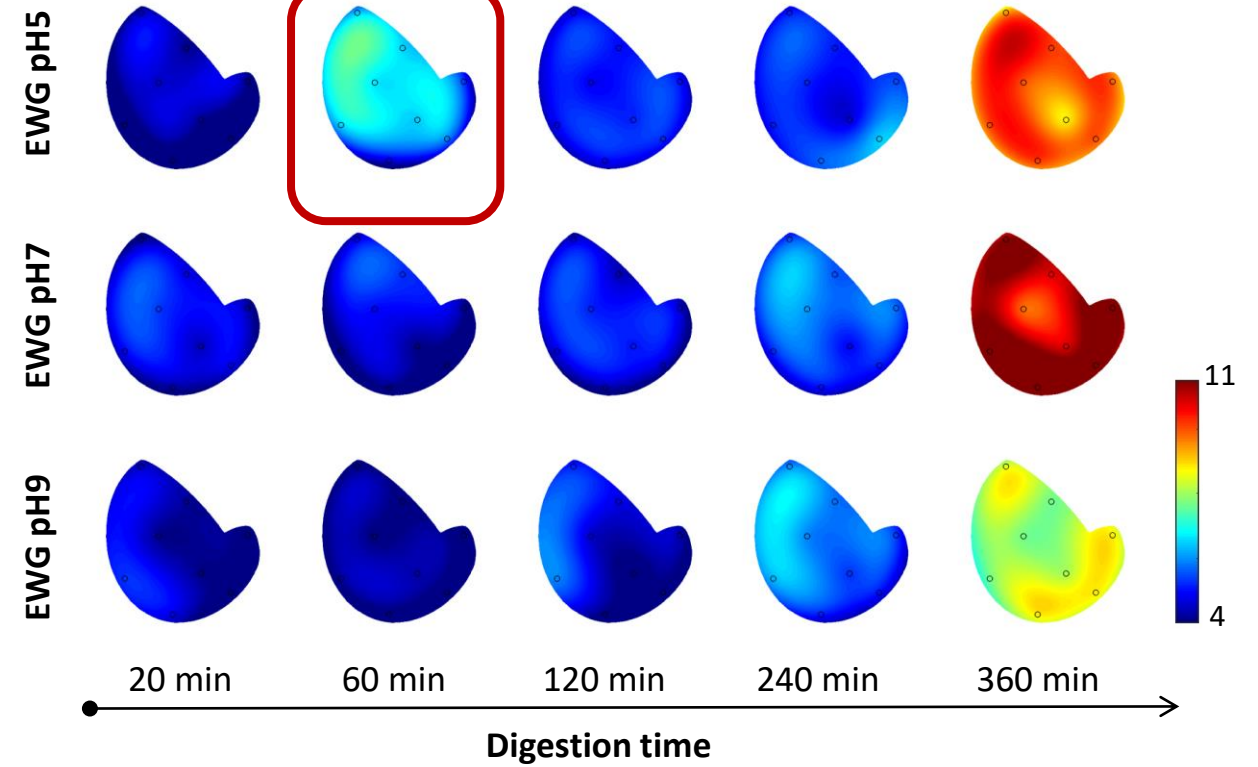
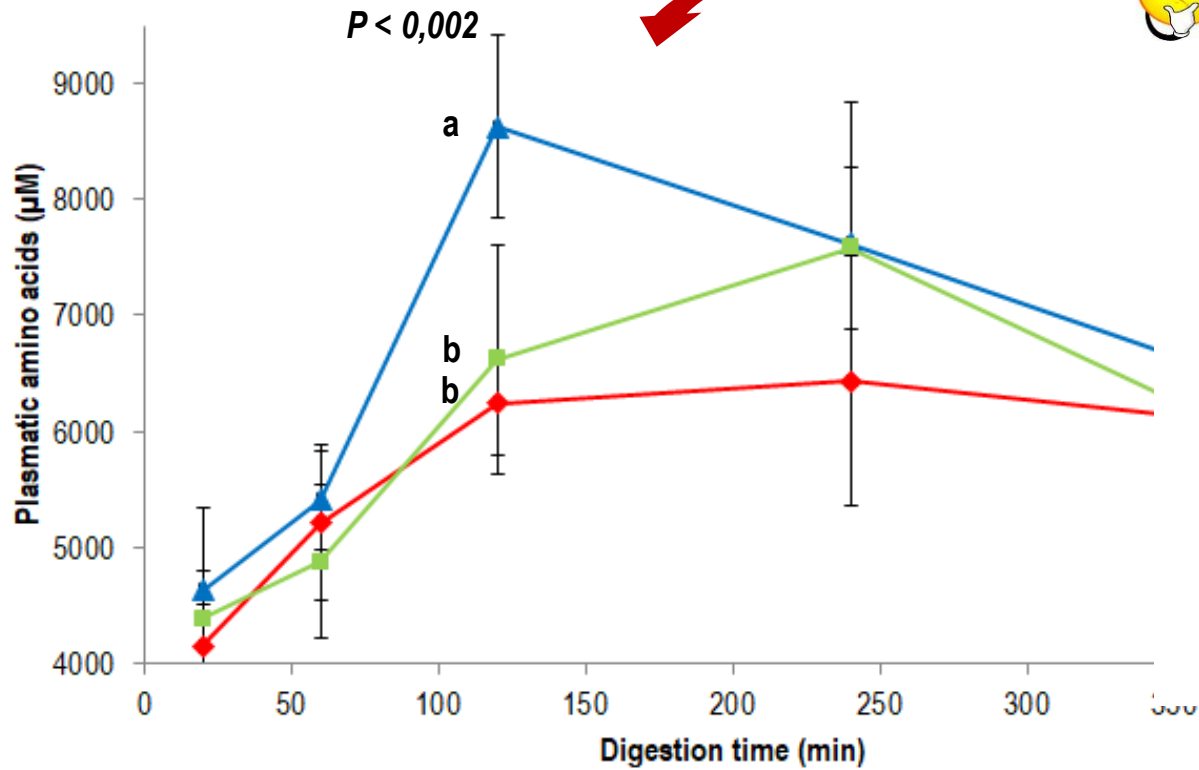
- A clear increase in proteolysis only at 6h (not 4h) !
 A matter of time (kinetics) / of pepsin real activity ?
- Similar extents of proteolysis despite variable pH and [Pepsin] ??

- Nothing special in the pylorus region (0-120 min) & only slightly in the proximal region (from 240 min) ??
- Significant increase at 60 min for EGW-pH5 ??
 (pH ≥ 4 & [Pepsin] range ≤ 300 μg/g)

➤ Proteolysis results (mg of free NH₂ / g of dry matter)

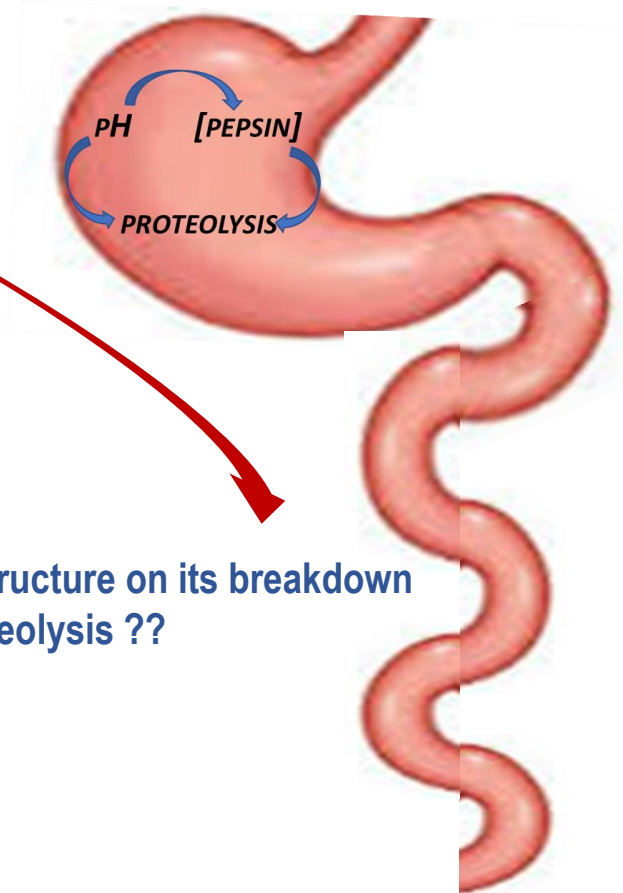
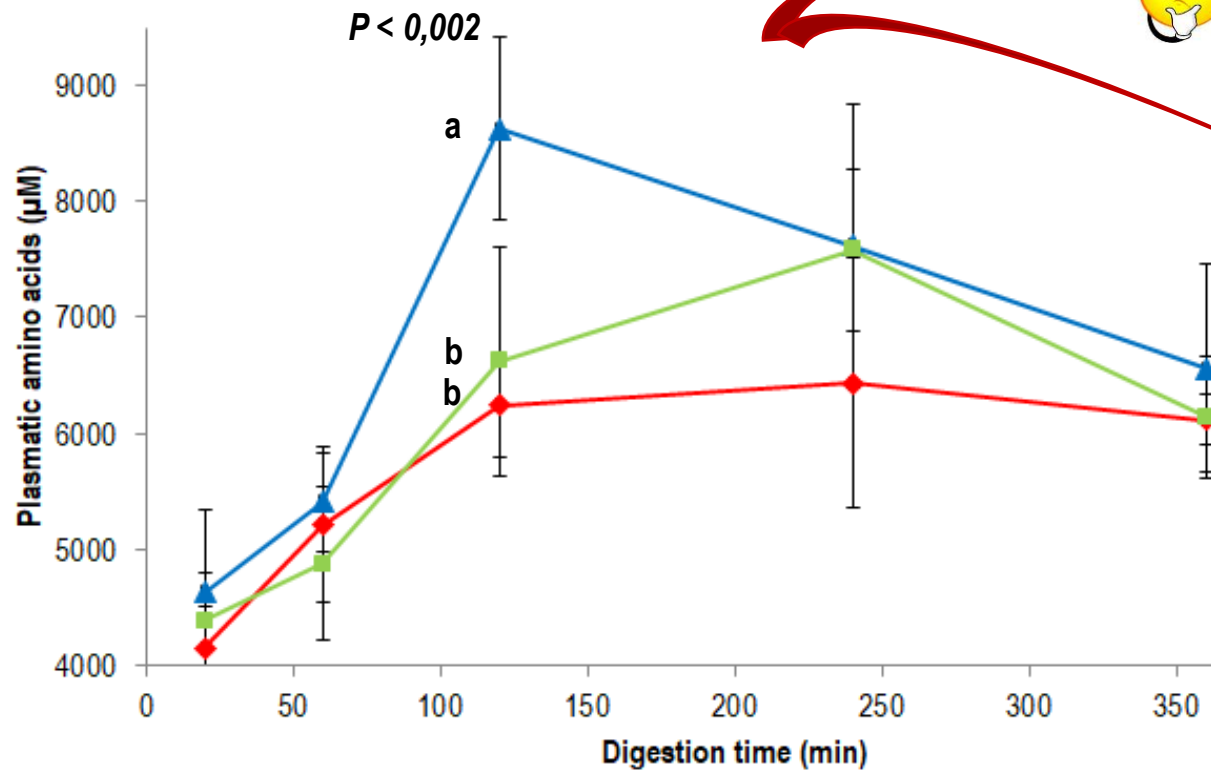
Plasma aminoacidemia

Maps



➤ Proteolysis results (mg of free NH₂ / g of dry matter)

Plasma aminoacidemia



Effect of food structure on its breakdown & intestinal proteolysis ??

➤ Main Conclusions

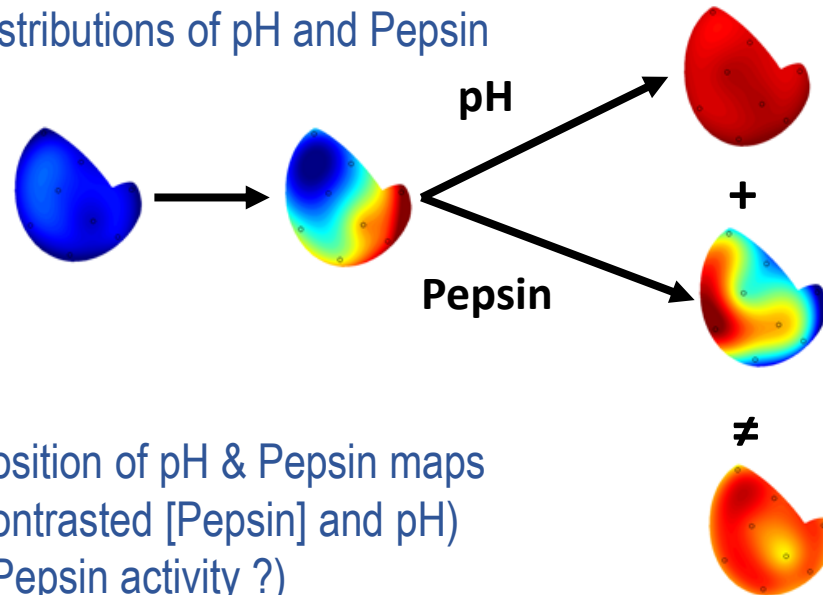
✓ pH and [Pepsin] values are consistent with:

- The available literature
- INFOGEST static and semi-dynamic protocols



✓ Effects of EWG structure were observed on:

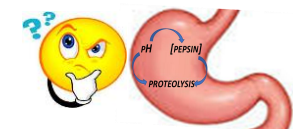
- Gastric emptying
- Gastric mixing ➡ Intra-gastric distributions of pH and Pepsin



✓ Gastric proteolysis was:

- Not simply explained by a superimposition of pH & Pepsin maps
- Robust (similar for all gels despite contrasted [Pepsin] and pH)
- Late (a matter of: time ? [Pepsin] ≠ Pepsin activity ?)

✓ Gastric proteolysis does not seem the one key to understand the effect of EWG structure on plasmatic AA (=> intestinal behaviour ?)



Nau et al., just accepted in



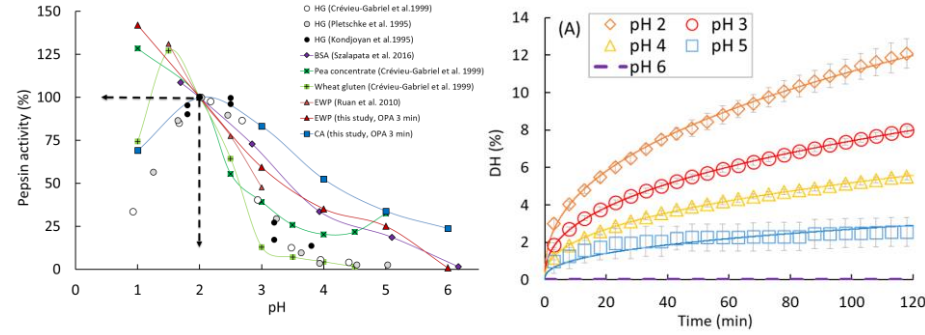
Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem



Pepsin activity as a function of pH, substrates & time:
(Salelles et al., Food Funct., 2021)
Poster 12 (Session 1, Sherrard Suite)



$$DH(\%) = \alpha \times time^\beta$$



Thank you for your attention !

