Engineering of bioaerogels as key ingredients in the development of functional foods to deliver health through diet

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Engineering of bioaerogels as key ingredients in the development of functional foods to deliver health through diet

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Background

Aerogels are solid nanostructured materials characterized by low density, high porosity and a high internal surface area. When obtained from biopolymers (polysaccharides and/or proteins), they are called bioaerogels. Bioaerogels are typically obtained by a multi-step process, involving the gelation of a biopolymer water solution followed by water-to-ethanol solvent exchange and subsequent ethanol removal by supercritical-CO_2-drying [1].

Bioaerogels have gained increasing research attention as innovative food ingredients, thanks to their biocompatibility and food-grade nature, associated with unique porosity-driven functionalities. In particular, whey protein-based bioaerogel particles have been used to structure liquid oil into semi-solid materials (i.e., oleogels) presenting rheological properties analogous to those of traditional saturated fats, associated with an improved nutritional profile, rich in unsaturated fatty acids [2]. In the current context of the plant protein transition, food industries and consumers are increasingly seeking for plant-based alternatives to animal proteins, in view of the lower environmental impact and health benefits. The development of bioaerogels based on plant proteins rather than animal ones is thus particularly interesting. Moreover, recent studies have demonstrated that oil structuring can alter lipid digestibility, but no knowledge is available on the digestibility of aerogel-templated oleogels.

Aim

In agreement with the PhD thesis project, the first two year activities aimed at:

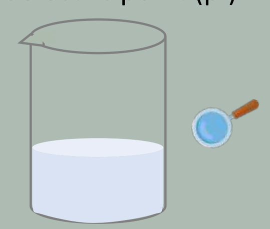
Materials and Methods

Results and discussion

(1) Identification of proteins, including plant-based ones, suitable as bioaerogel precursors

Whey (WPI), soy (SPI) or pea (PPI) protein isolate

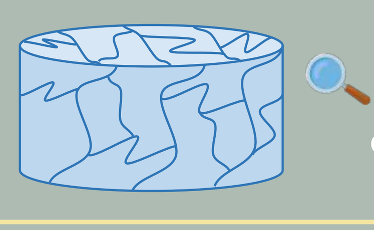
Dispersion in water, adjustment at pH 7 or at isoelectric point (pI)



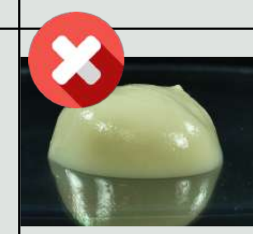
Maximum dispersibility

Gelation (85°C × 20 min)

Hydrogel



Gel characteristics

Protein	WPI		SPI		PPI	
pH	7	4.8	7	4.5	7	4.5
Maximum dispersible concentration (%)	20		14		19	
Gel appearance						
Gel characteristic	Strong gel	Strong gel made by aggregated microgels	No gel	Strong gel made by non-aggregated microgels	No gel	Strong gel made by non-aggregated microgels

Whey, soy and pea proteins are able to form strong gels at proper concentration and pH and can be thus used as precursors for aerogels production [3].

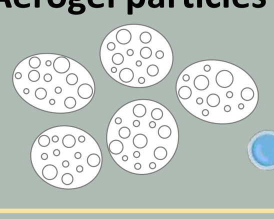
(2) Bioaerogels preparation and characterization

Water-to-ethanol solvent-exchange (immersion in EtOH at increasing concentration up to 98% w/w)

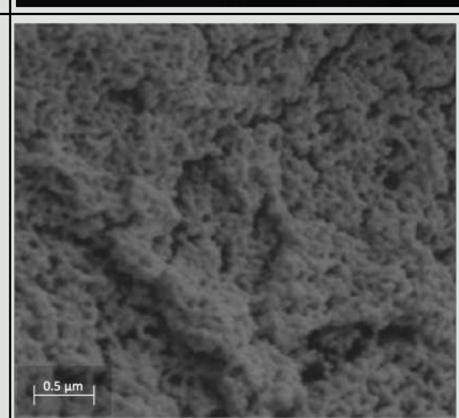
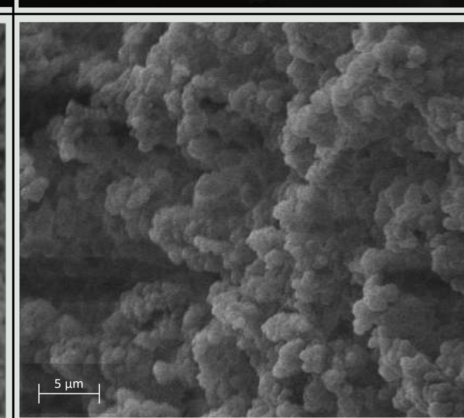
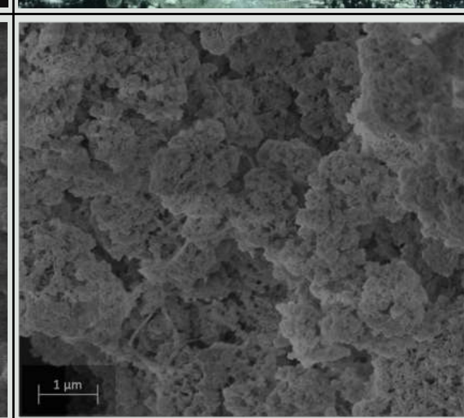
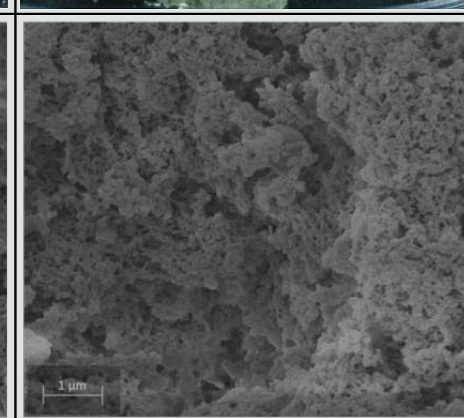
Alcogel

Supercritical-CO_2 drying (12 MPa, 60 °C, CO_2-flow rate 80-120 g/min) + grinding

Aerogel particles



Appearance, Microstructure, Porosity, Internal surface area, Bulk density.

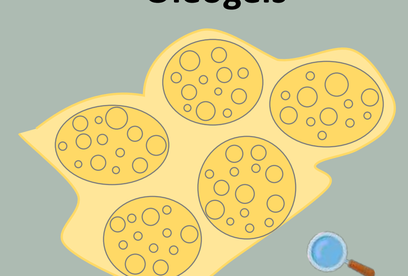
Aerogel appearance				
Aerogel microstructure				
Internal surface area (m^2/g)	370 ± 9	36 ± 2	40 ± 2	46 ± 9
Bulk density (g/cm^3)	0.15 ± 0.03	0.17 ± 0.02	0.43 ± 0.02	0.28 ± 0.01

Whey, soy and pea protein gels can be turned into porous aerogel particles [4—7].

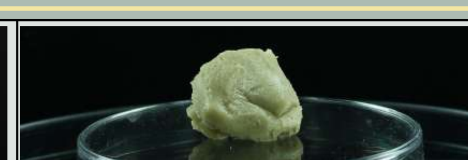
(3) Assessment of the potentialities of bioaerogels as functional ingredients able to structure oil and steer lipid digestibility.

Mixing with sunflower oil until reaching the maximum oil content

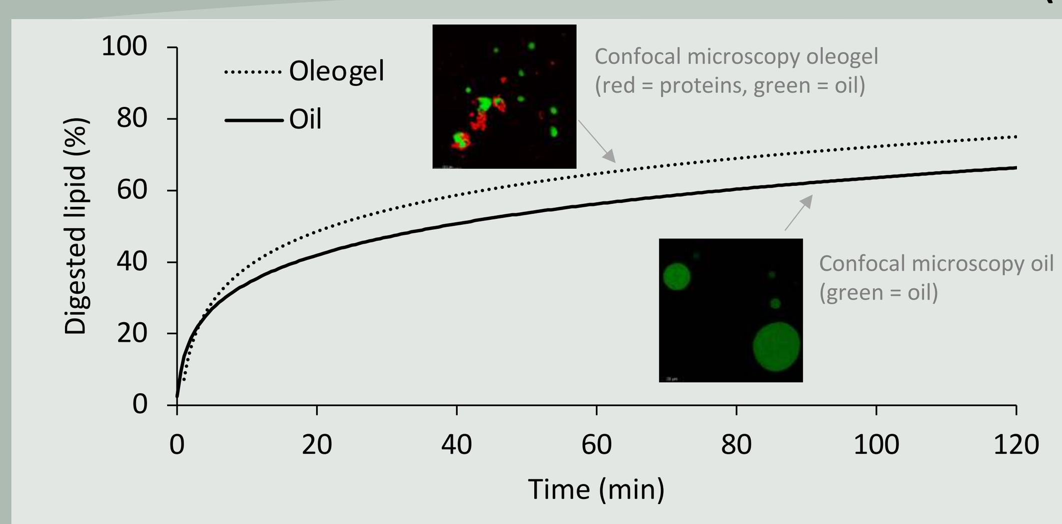
Oleogels

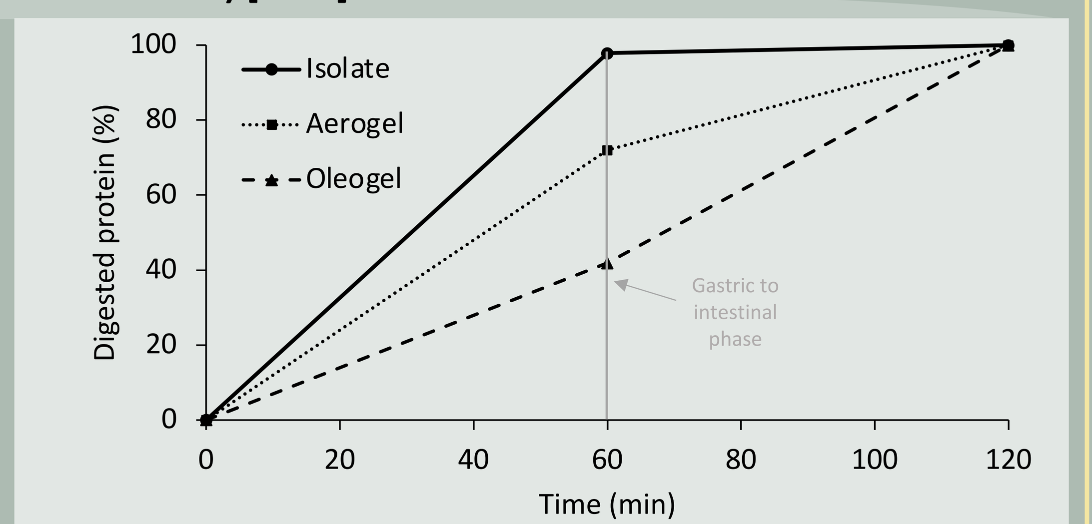


Rheological properties, In vitro digestibility (Confocal microscopy, SDS-page, BCA, DLS)

Oleogel appearance				
Maximum oil content (%)	86 ± 2	85 ± 2	72 ± 1	63 ± 1
Elastic modulus (Pa x 10^5)	2.2 ± 0.1	3.5 ± 0.2	4.6 ± 0.1	8.6 ± 0.2

Porous aerogel particles show high oil-structuring ability leading to oleogels with rheological properties comparable to those of traditional hard fats (8.2–26.7 × 10^5 Pa) [4—6].





Oleogels from aerogel particles presented increased lipid digestibility and higher protein gastric resistance [8].

Conclusions

Protein-based aerogels can be considered interesting ingredients with unique functionalities, able to absorb large amounts of liquid oil obtaining oleogels with tailor-made physical properties. These materials could be used as fat-replacers able not only to provide the required technological performances but also to tune the digestibility of protein and oil they are made of. In fact, this approach could be used to modulate release, stability, and functionality of bioactive peptides from proteins, and for tailored delivery of lipophilic bioactive molecules (e.g., unsaturated fatty acid) in the gut of people with curtailed lipid digestion.

References

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