EXPLORING THE POTENTIALITIES OF CELLULOSE CRYOGELS AND AEROGELS AS FOOD INGREDIENTS

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BACKGROUND

Aerogels and cryogels are unique solid materials characterized by low density and high porosity, prepared, respectively, by subjecting aqueous gels to supercritical-CO_2 drying and freeze-drying [1].

When prepared exploiting the structuring capacity of food biopolymers, such as proteins and carbohydrates, food-grade materials are obtained. Thanks to their characteristics, biopolymeric-based aerogels and cryogels can be proposed as innovative food ingredients [2].

Among biopolymers that could be used for the preparation of food-grade aerogels and cryogels, cellulose is an intriguing candidate. Cellulose is, in fact, a common constituent of food with plant origin and presents health functionalities. Moreover, cellulose can be obtained from agro-industrial vegetable side streams, in a closed loop that avoids the generation of large quantities of waste [3].

AIM

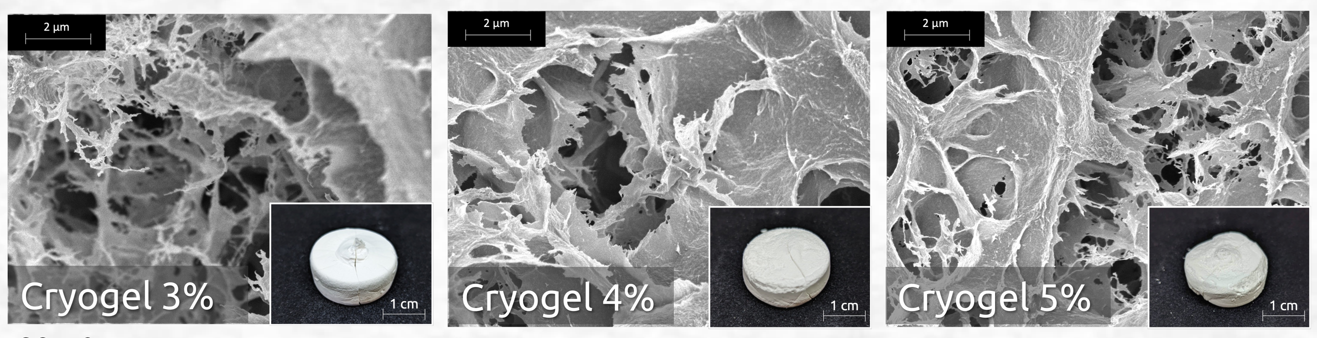
To explore the structural properties of food-grade cellulose aerogels and cryogels and their potentialities as food ingredients.

MATERIALS & METHODS

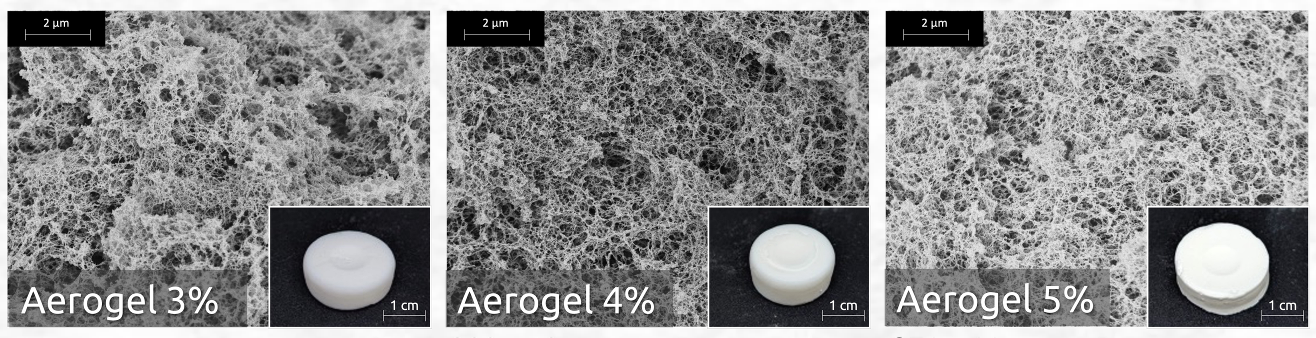
Cellulose hydrogels (3, 4, 5% w/w) were prepared by dissolving cellulose in 8% (w/w) NaOH-solution and coagulating it with water [4].

Aerogels and cryogels were obtained from hydrogels by supercritical-CO_2 drying and freeze-drying, respectively. Aerogel and cryogel physical properties (BET-specific surface area, porosity, bulk density, and firmness) and interaction with common food solvents (water and oil absorption kinetics, water and oil holding capacity, and firmness upon solvent absorption) were studied.

RESULTS & DISCUSSION



SEM image	Cryogel 3%	Cryogel 4%	Cryogel 5%
BET ($m^2\ g^{-1}$)	28 ± 0	31 ± 2	30 ± 1
Porosity (%)	96.2 ± 0.1	95.3 ± 0.1	94.9 ± 0.3
Bulk density ($g\ cm^{-3}$)	0.056 ± 0.002	0.071 ± 0.002	0.077 ± 0.004
Firmness (N)	10.44 ± 1.1	19.9 ± 0.57	25.1 ± 0.48



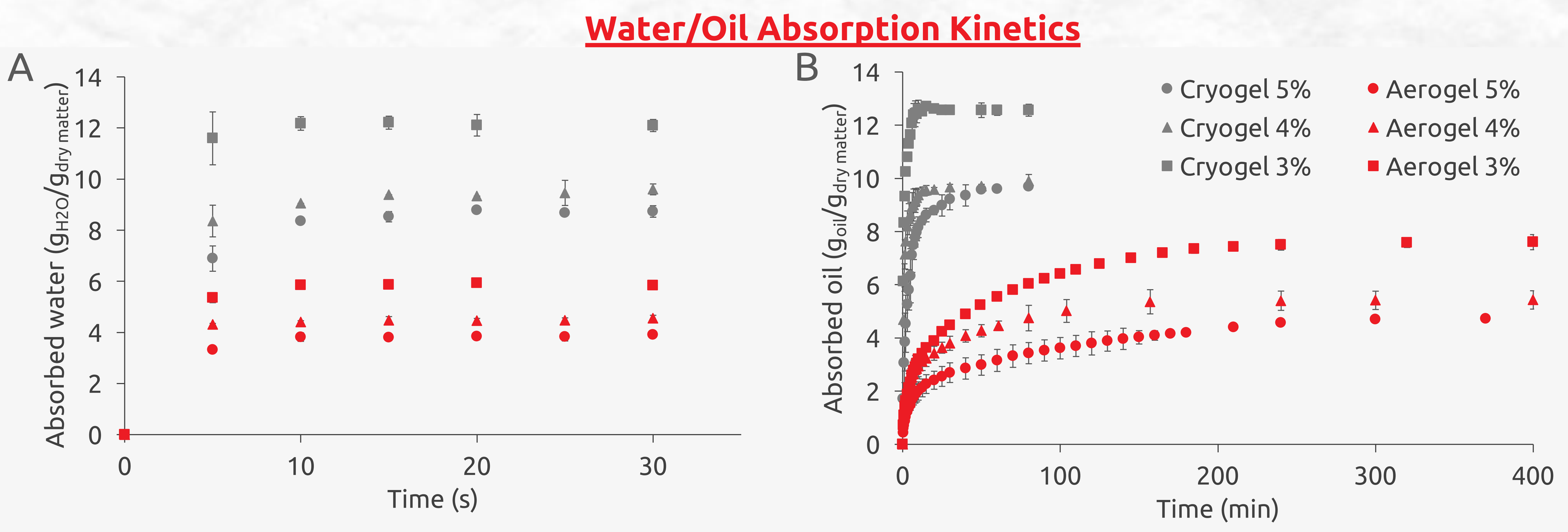
SEM image	Aerogel 3%	Aerogel 4%	Aerogel 5%
BET ($m^2\ g^{-1}$)	384 ± 4	380 ± 10	371 ± 11
Porosity (%)	93.8 ± 0.3	93.5 ± 0.4	92.9 ± 0.2
Bulk density ($g\ cm^{-3}$)	0.077 ± 0.007	0.98 ± 0.005	0.112 ± 0.006
Firmness (N)	21.0 ± 0.36	35.8 ± 1.57	44.1 ± 1.08

Structure

Freeze-drying led to evident cracks on the cryogel surface and resulted in large pores (> 2–5 µm) characterized by flat walls. BET values around 30 cm^2g^{-1} and porosity higher than 93%, were measured.

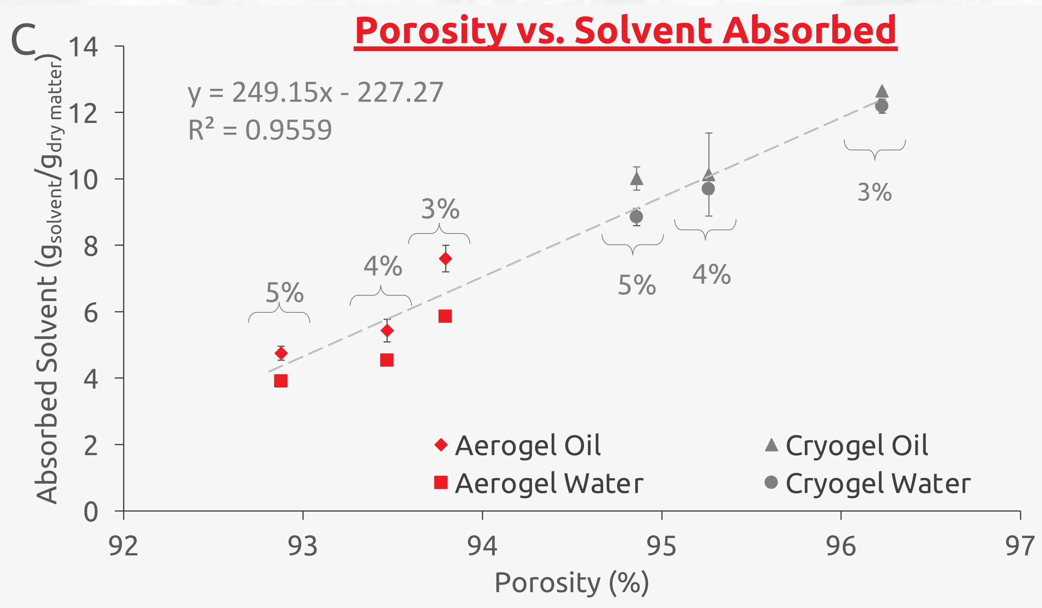
Aerogel microstructure appeared more homogeneous and denser, with higher BET values (> 380 cm^2g^{-1}), bulk density, and firmness compared to cryogels. Accordingly, the aerogel samples showed lower porosity.

For both cryogels and aerogels, the increase in cellulose concentration led to a decrease in porosity and a consequent increase in density and firmness.



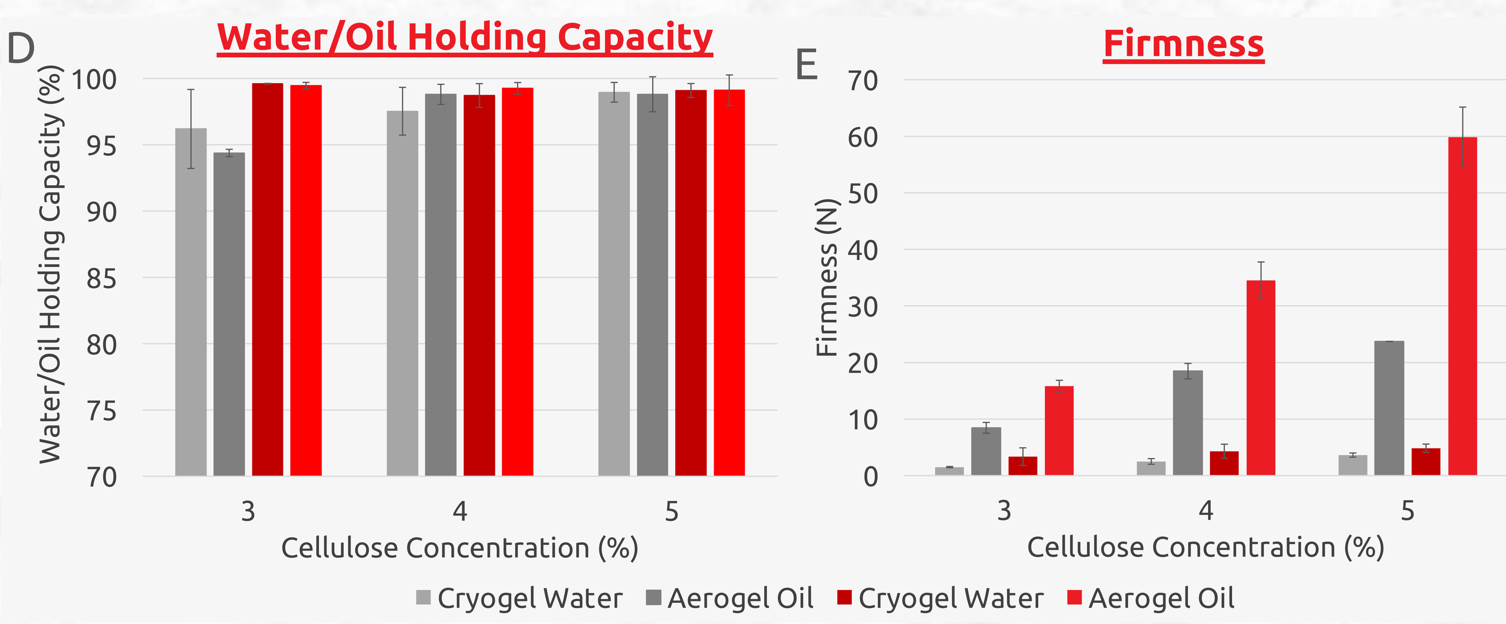
Interaction with Water and Oil

Cryogels and aerogels absorbed water much faster (*plateau* reached in 20 s) than oil (several minutes). Independently on solvent nature, cryogels absorbed a higher amount of solvent than aerogels (Figures A and B).



A linear relation was found between the amount of absorbed solvent and cryogel and aerogel porosity, independently on drying technique and solvent nature (Figure C).

This indicates that porosity rather than chemical affinity drives solvent absorption in cellulose-based aerogels and cryogels.



Aerogels and cryogels impregnated with water and oil showed high physical stability, as indicated by the holding capacity of both water and oil higher than 94% (Figure D).

While oil absorption into aerogels and cryogels had minor effects on their firmness, water strongly decreased this property, possibly due to cellulose swelling (Figure E).

CONCLUSIONS

This work demonstrates the feasibility of converting cellulose hydrogels into aerogels and cryogels presenting a tailored ability to interact with food solvents, depending on their porosity. The latter can be steered by acting on the drying technique and the concentration of cellulose in the hydrogel.

Cellulose aerogels and cryogels can be exploited to strongly embed food solvents of different polarities, thus representing innovative candidates to modulate the rheological properties of foods and possibly deliver both lipophilic and hydrophilic compounds.

This structural approach can be thus regarded as an innovative strategy to turn currently underutilized valuable components from plant-food side streams into innovative ingredients for food applications.

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