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# Generation of Carrageenan-Based Nanoporous Structures as Green Alternatives for Enhanced Water Uptake

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## INTRODUCTION & AIM

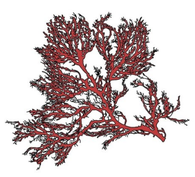
**Superabsorbent polymers (SAPs)** are an interesting class of materials, known for their ability to elastically swell and deswell in the presence of water: they are used in agriculture, as personal hygiene products, etc. However, most of the available commercial SAPs are synthetic, or bio-based and crosslinked with acrylates or other substances suspected of being toxic [1].

In addition, a key aspect in gel swelling mechanism is its **porosity and network interconnection**: therefore, the choice of the drying method can significantly influence how the material responds to water contact [2]. **Supercritical $CO_2$ gel drying** is the way to generate biopolymeric nanostructured materials in a green, solvent-free, and sustainable way [3].

In this work, we aimed at exploiting the properties of a hydrophilic polymer (i.e., k-carrageenan), to generate **sustainable nanoporous materials** – also, exploring the effect of salt addition on gelation – and study their swelling behavior with a view to fabricating SAP-based devices.

## MATERIALS & METHODS

**Hydrogel synthesis**



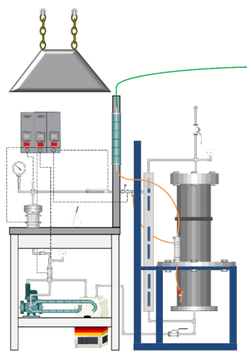
**k-carrageenan**
(2 g/100 mL)

| Sample | $m_{KCl}$, g | $m_{CaCl2}$, g |
|---|---|---|
| 1/0/0 | 0 | 0 |
| 1/0.5/0 | 1 | 0 |
| 1/0.5/1 | 1 | 2 |

**Hydro-to-solvogel transition**

Stepwise solvent exchange, using solutions with increasing percentages of ethanol

**SC-$CO_2$ gel drying**



**Operating conditions:**
**Pressure:** 200 bar
**Temperature**: 40 °C
**$CO_2$ mass flow rate:** 0.8 kg/h

**Analysis**

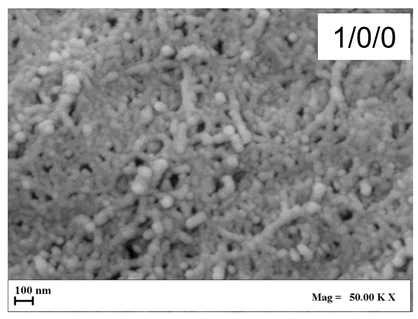
Morphological analysis by FESEM, coupled with image analysis for pore size distribution evaluation

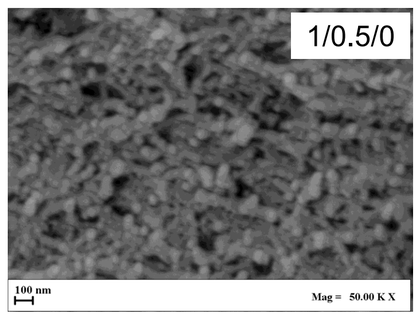
**Water uptake**

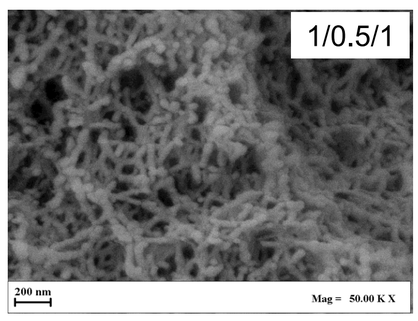
Swelling tests in distilled water for the produced samples

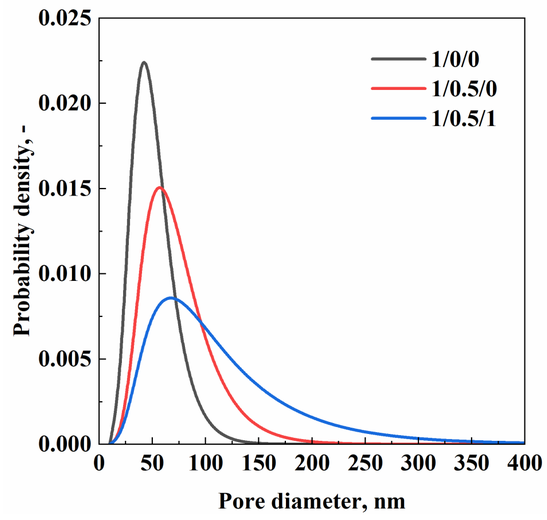
## RESULTS & DISCUSSION

### Morphological analysis



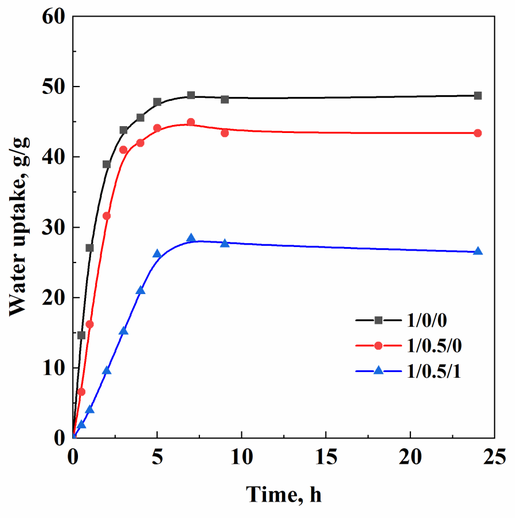




**Salt content** moves aerogels pore size distribution from a narrower shape to a wider one; yet, the wider the pore size distribution, the more interconnected the structure is. Calcium chloride addition defines the transition **from a dense nanoporous domain, to an open and interconnected alginate-like morphology.**

### Swelling tests




Swelling behavior is affected by salt concentration. When salts concentration increases, a maximum water uptake is halvened from about **50 g/g** to 25 g/g, probably due to phenomena of interference between k-carrageenan macromolecules during gelation. Equilibrium conditions and stability in water are defined by a **combination of aerogels pore size distribution and relative chain-chain strength**.

## CONCLUSIONS & PERSPECTIVES

In conclusion, supercritical gel drying reveals to be a tool to generate nanoporous structures to be used in the field of SAPs synthesis, without toxic crosslinkers or additives. Although the maximum water uptake is limited with respect to their synthetic counterparts, this preliminary work represents a starting step to engineer the chemistry of nanoporous aerogels for enhanced water uptake.

**References**

[1] B. Surendran V.S. et al., *Discover Applied Sciences, 2025.*
[2] R. Foudazi et al., *Langmuir, 2023.*
[3] İ. Şahin et al., *Gels,* 2018.