Physicochemical properties of polyvinyl alcohol-based hydrogels for cartilage tissue regeneration

A.S. Oliveira [1,2,3], R. Colaço [2], A.P. Serro [1,3]

[1] CQE, IST, UL, Lisbon, Portugal; [2] idMEC, IST, UL, Lisbon, Portugal; [3] CiiEM, IUEM, Caparica, Portugal.

INTRODUCTION

Clinically, cartilage damage due to congenital abnormalities, disease or trauma is always a significant concern due to the tissue's limited ability for self-repair, which may gradually result in the loss of functionality (Chen and Liu 2016). Amongst the existing materials to repair cartilage, hydrogels have been extensively explored, since they have proved their ability to simulate cartilage tissue better than any other class. In particular, polyvinyl alcohol (PVA) hydrogels, which present an excellent biocompatibility, high water content and permeability, and a rubbery and elastic nature, have been the focus of a large number of studies (Kenawy et al. 2014). These materials are highly advantageous for cartilage repair, providing desirable 3D environments for growth and proliferation of cells and simultaneously being able to withstand loads under motion in the human joints.

OBJECTIVES

The objective of the present study was to investigate the effect of adding a pore forming agent on relevant properties of physically crosslinked PVA hydrogels, namely the swelling capacity, thermotropic behaviour, surface morphology and mechanical performance.

MATERIALS

PVA solution at 15% w/v in DD water

Dissolution: 6 h, 95 ºC

Processing

Nº of cycles: 5

Freeze time: 10h

Thawing time: 2h

No Salt / NaCl

Samples: PVA, PVA+NaCl

METHODS

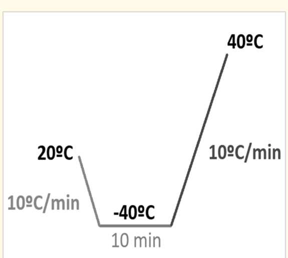
SEM

FEG-SEM (JSM–7001F, JEOL).

Samples lyophilized for 50 h and coated with 20nm of Au/Pd.

DSC

DSC (200 F3 Maia, NETZSCH).



Swelling

Samples dried at 60ºC until reach the equilibrium.

$$\text{Swelling (\%)} = \frac{W_{water}}{W_{dry\ sample}} \times 100$$

$$\text{EWC(\%)} = \frac{W_{water}}{W_{wet\ sample}} \times 100$$

$$\text{FLBW (\%)} = \frac{\Delta H_{sample}}{\Delta H_{pure\ water}} \times 100$$

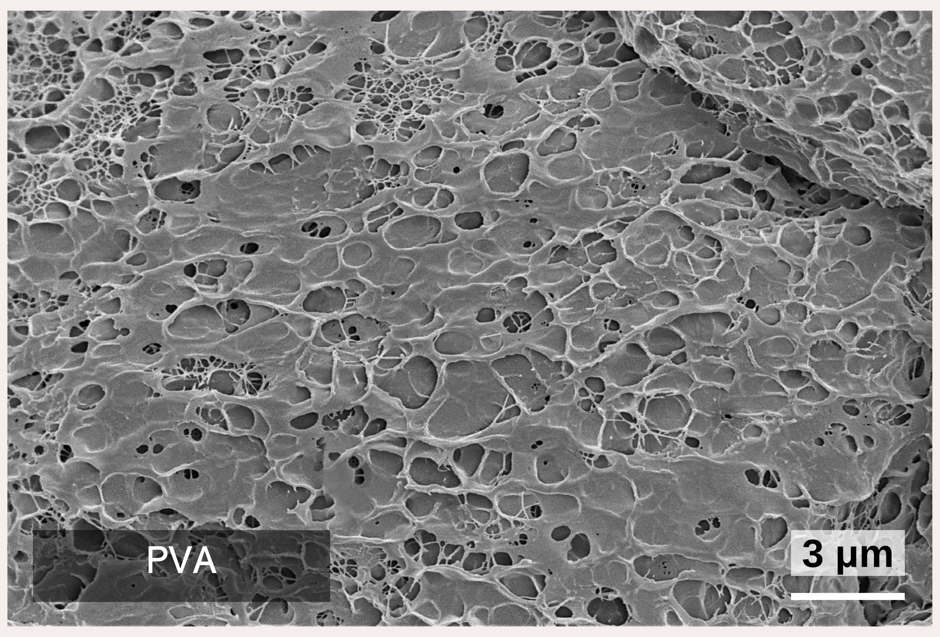
$$\text{TBW(\%)} = \text{EWC (\%)} - \text{FLBW(\%)}$$

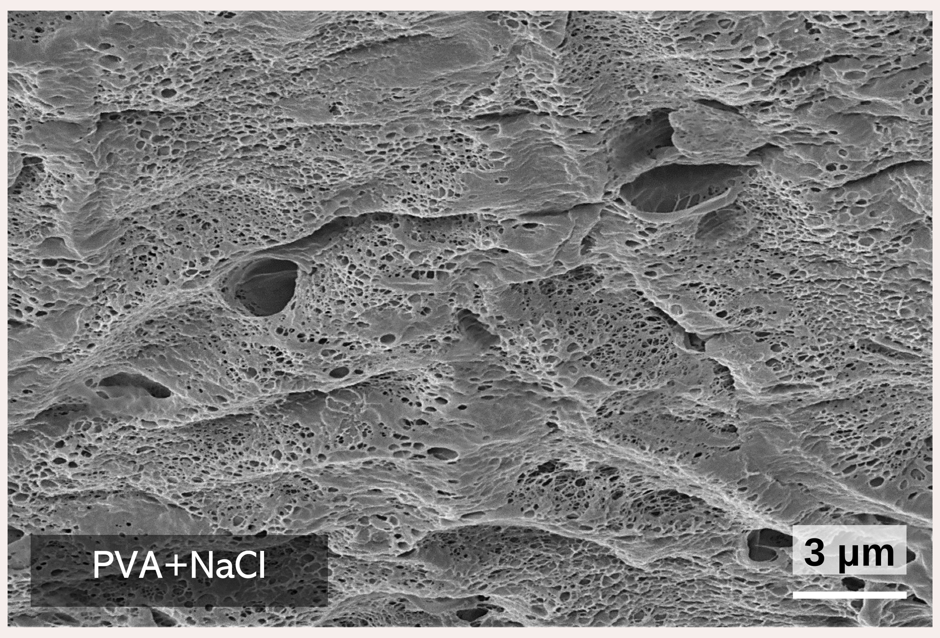
Compression

Texturometer (TA.XT Express Texture Analyser, Stable Micro Systems).

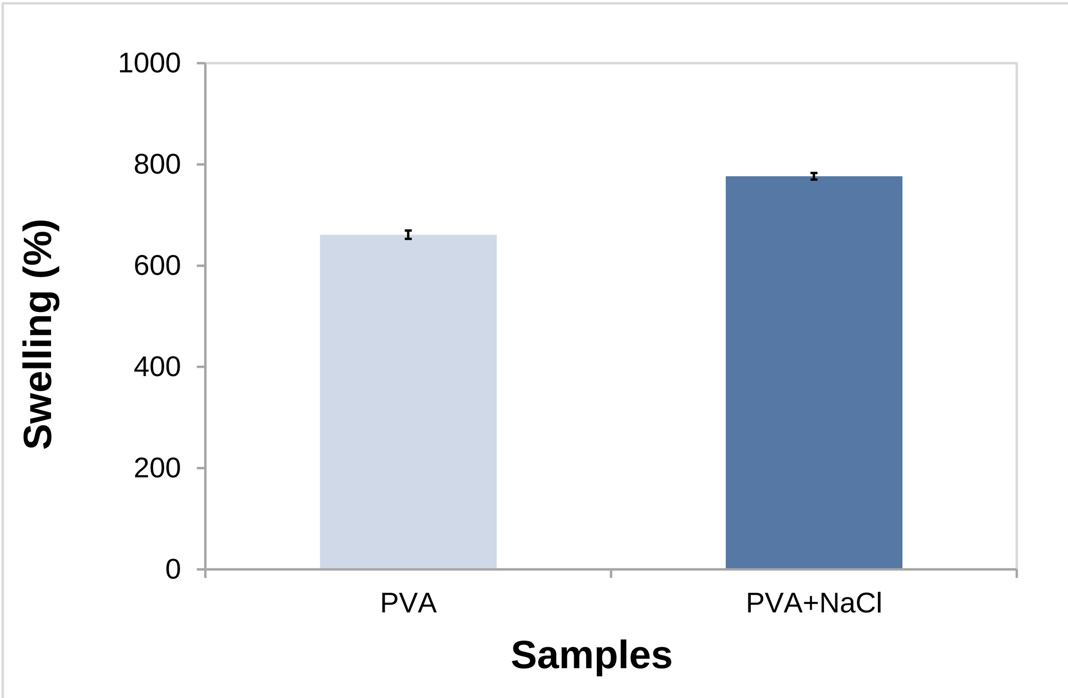
Performed at 37ºC, in unconfined mode. V = 0.1 mm/s. Limit: F = 50N.

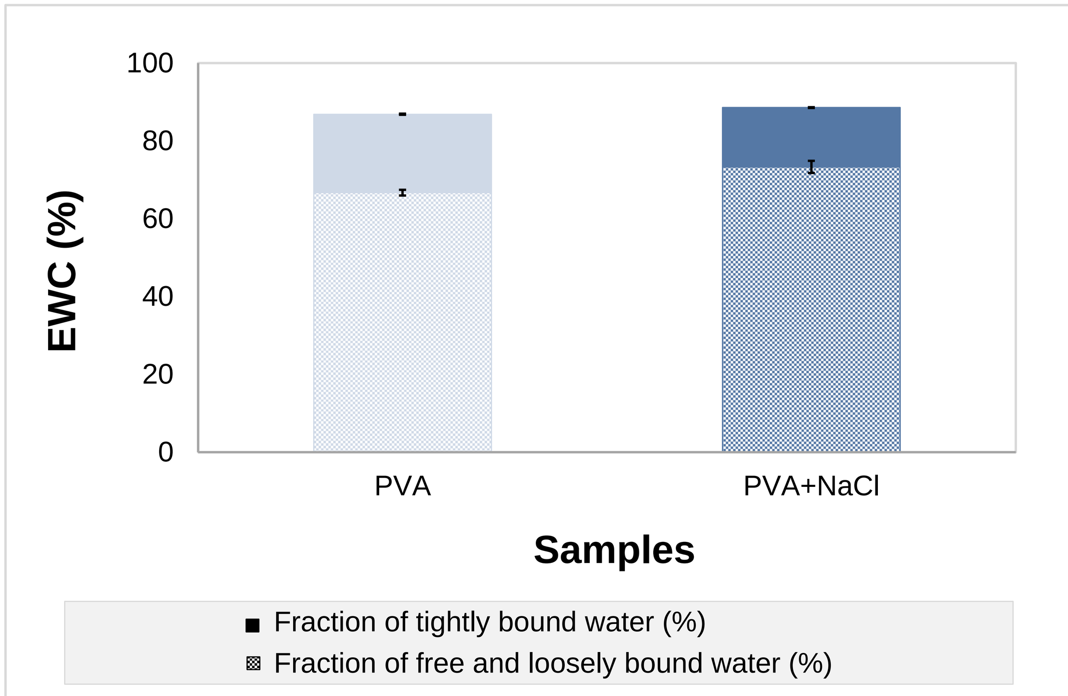
RESULTS AND DISCUSSION



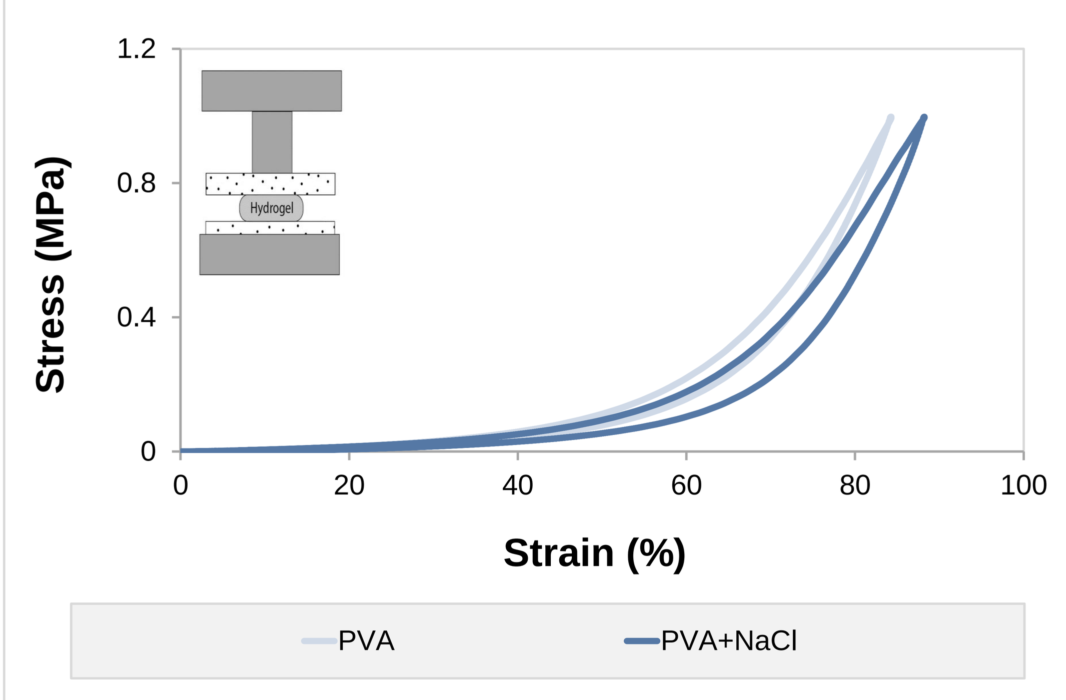


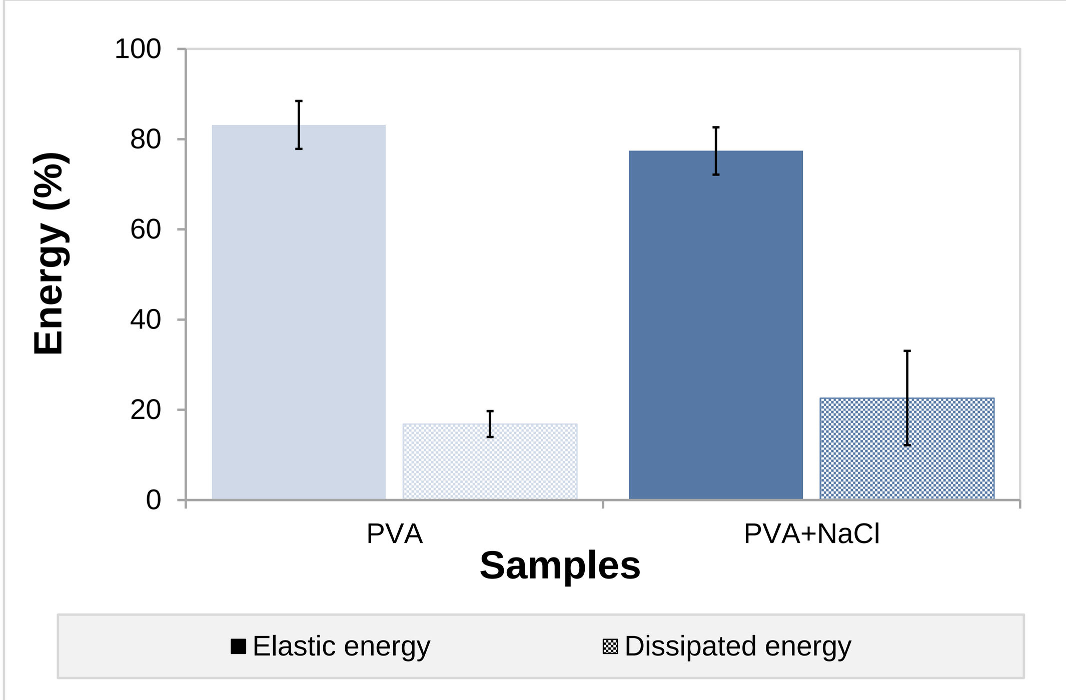
SEM micrographs of the materials' surface showed different porosity patterns. PVA+NaCl samples presented smaller pores, although a small number of large pores was also observed.

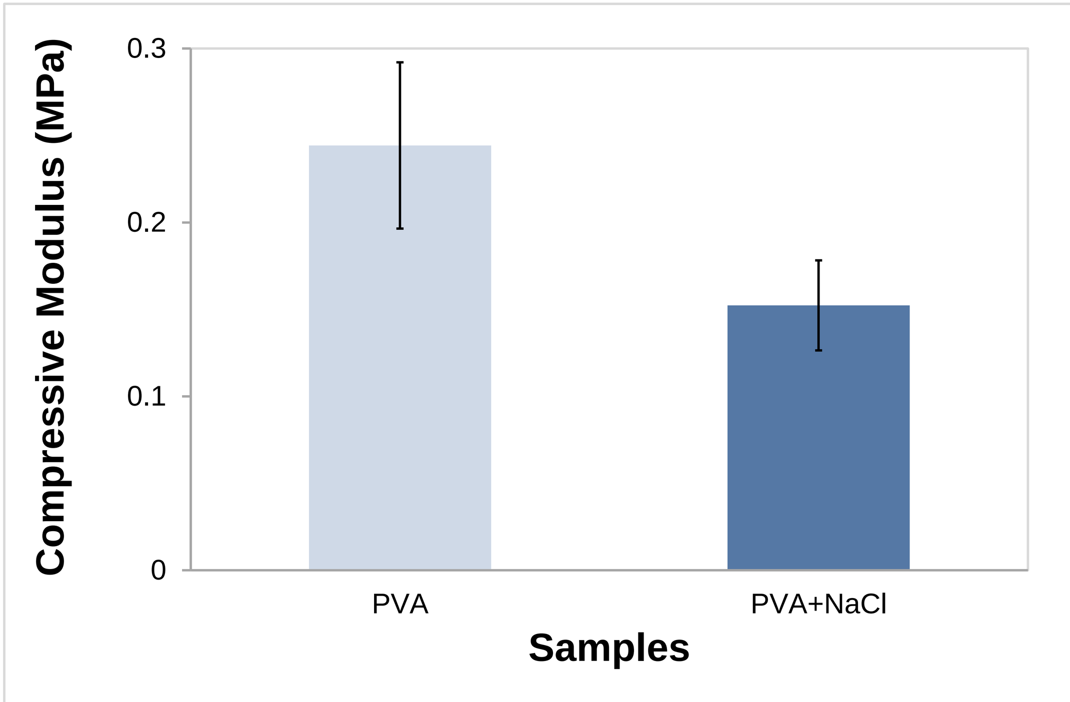




The addition of NaCl as a pore-forming agent led to an increase of the swelling capacity from 661 ± 8% to 776 ± 7%, corresponding to equilibrium water contents of 86.9 ± 0.1% and 88.6 ± 0.1%, respectively, which are similar to that of natural cartilage tissue. This agrees with the resulting fractions of free and loosely bound water, determined from the observed DSC thermograms, which revealed a higher percentage for the PVA+NaCl samples (73 ± 2%) compared to the control (66.7 ± 0.7%).







In compression experiments, PVA+NaCl samples revealed to be slightly less rigid and dissipated more energy than PVA materials. However, both hydrogels demonstrated excellent deformability and a low compressive modulus.

CONCLUSION

In conclusion, the properties of PVA hydrogels are affected by the use of NaCl as a pore-forming agent. The presence of NaCl originated differences in morphology and lowered the elastic modulus. However, both materials presented suitable characteristics and are promising to be used as cartilage repair materials.

REFERENCES

Chen, Fa-Ming, and Xiaohua Liu. 2016. "Advancing Biomaterials of Human Origin for Tissue Engineering." *Progress in Polymer Science* 53 (February): 86–168. https://doi.org/10.1016/j.progpolymsci.2015.02.004.

Kenawy, El-Refaie, Elbadawy A. Kamoun, Mohamed S. Mohy Eldin, and Mahmoud A. El-Meligy. 2014. "Physically Crosslinked Poly(Vinyl Alcohol)-Hydroxyethyl Starch Blend Hydrogel Membranes: Synthesis and Characterization for Biomedical Applications." *Arabian Journal of Chemistry* 7 (3): 372–80. https://doi.org/10.1016/j.arabjc.2013.05.026.

ACKNOWLEDGMENTS

To Kuraray Group for providing the raw materials and Foundation for Science and Technology (FCT) for the Ph.D. grant PD/BD/128140/2016 (A.S. Oliveira) and funding through the research project PTDC/CTM-CTM/29593/2017 and the unit projects UIDB/04585/2020, UIDB/00100/2020 and UIDB/50022/2020 from CiiEM, CQE, and IDMEC/LAETA, respectively.

BIOMAT Research group
https://biomatlabgroup.wixsite.com/biomatresearchgroup/

E-mail: andreia.oliveira@tecnico.ulisboa.pt