TUNING THE MECHANICAL PROPERTIES OF ADA-GEL BIOINKS FOR BIOPRINTING APPROACHES BY VARYING THE OXIDATION DEGREE

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Introduction

Extrusion-based 3D bioprinting is one of the most promising and widely used technologies in tissue engineering. However, the development of 3D printable, biocompatible bioinks with tailored mechanical properties remains a major challenge in this field. Advanced alginate-based hydrogels, which include oxidized alginate in combination with proteins [1], are promising materials for bioprinting approaches and tissue engineering applications. The oxidation of alginate by sodium (meta)periodate resulting in alginate dialdehyde (ADA) enables to control and tune the degradation behavior. The combination of ADA with proteins, such as gelatin (GEL), improves the cell adhesion properties. However, to date the influence of the degree of oxidation of ADA on the complex mechanical properties of alginate-based hydrogels remains insufficiently understood.

Methods

We investigate the influence of the degree of oxidation on the mechanical properties of ADA-GEL samples through multi-modal mechanical analyses in compression, tension, and torsional shear under large strains [2]. Furthermore, we study the influence of the fabrication process by mechanically characterizing molded and 3D printed ADA-GEL samples.

Results

Figure 1 (left) shows an increase in stiffness and a more pronounced hysteresis with decreasing degree of oxidation (DO) from 25% to 6%. This observation can be explained by the controlled chemical oxidation of sodium alginate. Samples with a low DO consist of fewer aldehyde groups and more free G-residues available for crosslinking. Figure 1 (right) underlines the influence of the fabrication process on the mechanical properties. Molded ADA-GEL samples are (significantly) stiffer with more pronounced hysteresis compared to 3D printed ones. This can be attributed to the fact that molded ADA-GEL samples show a homogeneous structure and denser arrangement of the molecules.

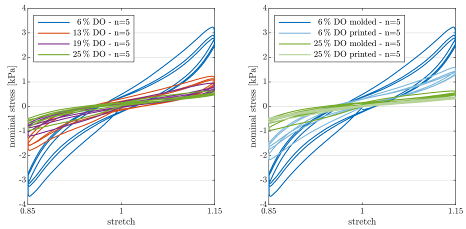

Figure 1: Cyclic loading behavior of molded ADA-GEL samples with a degree of oxidation (DO) of 6%, 13%, 19%, and 25% (left) and comparison of molded and 3D printed ADA-GEL samples with a degree of oxidation of 6%, and 25% (right) ADA-GEL samples during unconfined compression-tension up to a maximum strain of 15%. The curves show the mean values.

Discussion

Our findings highlight that the degree of oxidation is an important parameter to tune alginate-based hydrogels for tissue engineering, e.g., to well match the properties of native tissues. In addition, our findings emphasize the importance of mechanically characterizing 3D bioprinted constructs for biofabricated functional tissue models. Based on the presented data, material model parameters for finite element simulations can be determined by using an inverse identification scheme, where the boundary conditions during testing are well captured. They thus form a valuable basis to further optimize materials and printing parameters in the future.

References

1. Distler et al, J Biomater. Sci, 9:3051-3068, 2021.
2. Faber et al, Curr Protoc, 2(4):e381, 2022.

Acknowledgements

We gratefully acknowledge the support by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) grant BU 3728/1-1 and Projektnummer 326998133 – TRR 225 (subproject B03, B09).