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Optimization of Formulation and Processing Conditions for Wet-Spun Alginate Fibers

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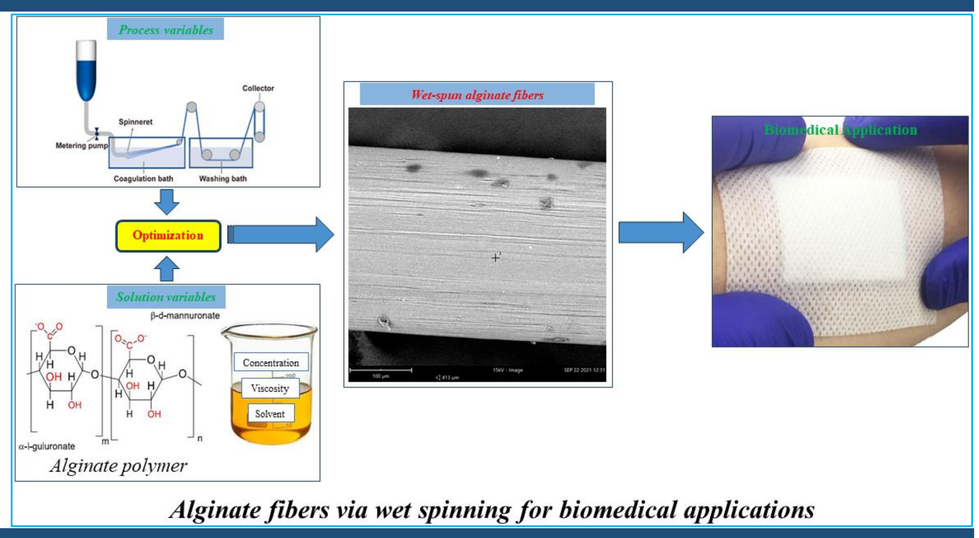
Introduction

Despite the extensive use of alginate fibers in biomedical applications, a clear understanding of how key solution and processing parameters affect the morphology and mechanical performance of the resulting filaments remains limited.

Most reported studies focus either on formulation aspects or on end-use properties, without systematically correlating solution and processing parameters with the final fiber characteristics.

In this context, the present work focuses on the elaboration of alginate filaments and the investigation of how the concentrations of alginate and the coagulation bath influence their morphological and mechanical properties.

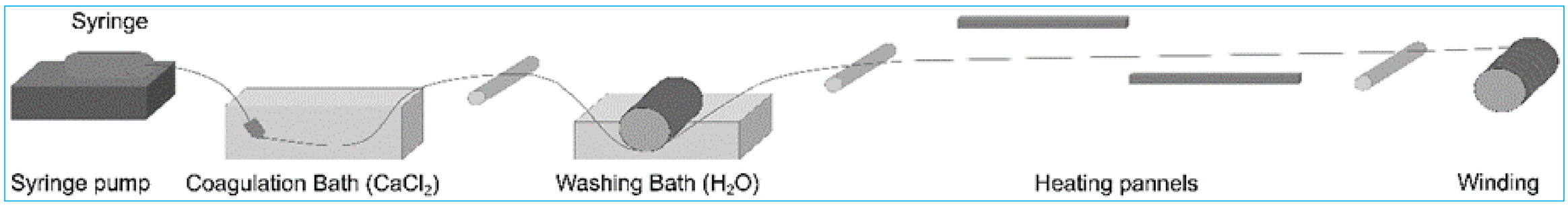
A forthcoming study will further explore their biocompatibility and medical performance, highlighting their potential as a sustainable and versatile platform for medical device innovation.



Alginate fibers via wet spinning for biomedical applications

Wet-spinning apparatus setup

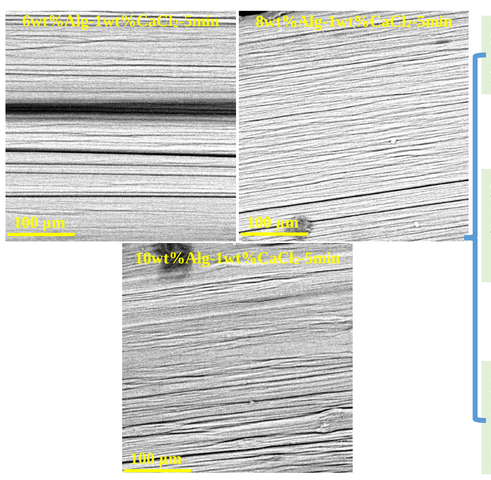
The aim of this work is to develop and optimize a laboratory-scale wet-spinning process for the controlled fabrication of sodium alginate fibers. Unlike prior studies that often report empirical spinning conditions, our approach systematically investigates the influence of alginate concentration, calcium chloride ($CaCl_2$) concentration, and residence time in the ionic coagulation bath, thereby establishing clear structure–process–property relationships.



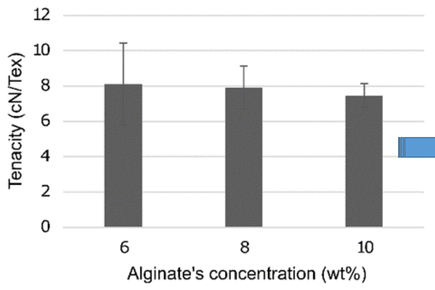
Alginate solutions (6–10 wt%) were extruded through a single-hole spinneret (0.58 mm) at a constant flow rate of 1 mL·min^{-1} into an aqueous $CaCl_2$ coagulation bath (0.5–3 wt%), with immersion times ranging from 1 to 10 minutes.

Results and Discussion

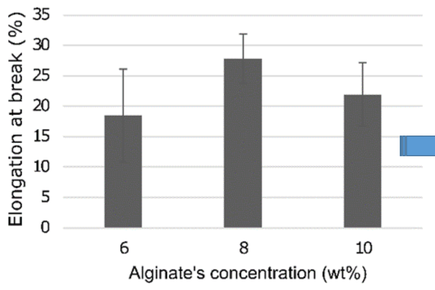
Impact of Alginate concentration on the morphological and mechanical properties of wet-spun alginate fibers



- **6 wt% alginate solution ➔ A fibrillar structure was observed**
- **8 wt% alginate solution ➔ The surface appeared relatively smooth, dense, and homogeneous**
- **10 wt% alginate solution ➔ The reappearance of a fibrillar texture and a rougher surface**

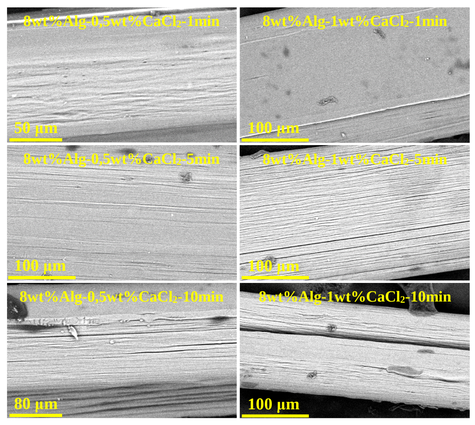


The tenacity values were comparable for all tested concentrations, with a slight decrease observed when the alginate concentration increased from 6 wt% to 8 wt%.

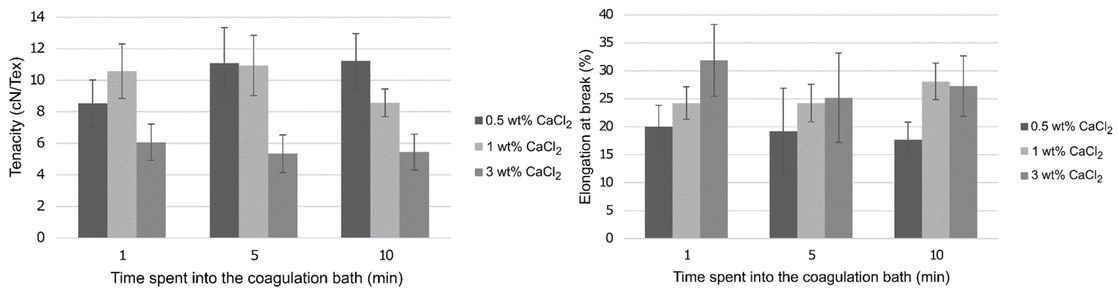


The highest elongation at break was recorded for fibers prepared with 8 wt% alginate

Influence of coagulation bath concentration and residence time on the morphological and mechanical properties of wet-spun alginate fibers



- **1 wt% $CaCl_2$ concentration ➔ Fiber surface appeared smoother than that obtained with 0.5 wt%**
- **Short coagulation times ➔ Fibers exhibited relatively smooth and compact surfaces, especially for samples immersed for 5 minutes.**
- **10 minutes of residence time ➔ Fibrillar and rougher structure emerged.**



0.5 wt% $CaCl_2$
- **Tenacity tended to increase gradually with immersion time**
- **Elongation at break showed the lowest values among all samples**

1 wt% $CaCl_2$
- **Slight improvement in tenacity was observed from 1 to 5 minutes**
- **Elongation remained constant for 1 and 5 minutes**

3 wt% $CaCl_2$
- **Tenacity values were generally low and decreased with time**
- **Elongation decreased from 1 to 5 minutes**

Conclusions and Perspectives

Combining morphological and mechanical analyses, the optimal wet-spinning parameters for alginate fibers were determined to be:

- ✓ **Alginate concentration: 8 wt%**
- ✓ **$CaCl_2$ bath concentration: 1 wt%**
- ✓ **Immersion time: 5 minutes**

The present work will serve as a reference for subsequent studies dedicated to functionalizing and tailoring these fibers for advanced biomedical applications.

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