PHD PROJECT DESCRIPTION

(4000 characters max., including the aims and work plan to be published online)

Project title: Polysaccharide crosslinked sponge and hydrogel dressings incorporating active plant-derived compounds: preparation and characterization

1.1. Project goals

- To design and synthesize innovative hydrogel and sponge matrices utilizing selected polysaccharides;
- To integrate crushed plant components (specifically leaves and seeds) into the polymer network as natural sources of bioactive compounds;
- To comprehensively analyze the biological and physicochemical characteristics of the formulated materials;
- To enhance the inherent antioxidant and antimicrobial capabilities of the resulting dressings;
- To develop highly efficient, fully biodegradable systems tailored for advanced wound management

1.2. Outline

Modern wound dressings based on biodegradable hydrogels and sponges are highly effective in wound healing due to their ability to maintain an optimal moist environment, support natural regeneration, and minimize environmental impact. Hydrogels create a humid microenvironment that accelerates cell migration, reduces necrotic tissue formation, and enables gentle autolytic debridement. Sponge dressings, especially those made from biodegradable polysaccharides such as alginate or chitosan, are highly absorbent, efficiently manage wound exudate, protect the surrounding skin from maceration, and provide cushioning and mechanical protection.

To further enhance their therapeutic potential, the modified dressings will incorporate active plant-derived compounds in the form of fragmented plant components, specifically leaves and seeds. These botanical inclusions will serve a dual purpose: acting as a natural reservoir for the sustained release of bioactive agents (such as antioxidants and antimicrobial phytocompounds) directly to the wound bed, and potentially serving as natural micro-fillers that improve the mechanical integrity and structural stability of the polymer network.

The use of biodegradable materials ensures that, after fulfilling their function, these dressings naturally degrade, significantly reducing medical waste and the ecological footprint of wound care. Clinical studies show that both hydrogel and sponge dressings reduce inflammation and scarring in burns compared to traditional methods. In chronic wounds, such as pressure ulcers, they shorten healing time by stimulating angiogenesis and effectively managing exudate. Both types are well-tolerated by tissues, minimizing pain and trauma during dressing changes. Hydrogels offer cooling and non-adherent properties, which further increase patient comfort, while sponges adapt to various wound shapes and provide additional support. Moreover, both hydrogel and sponge dressings are biocompatible and mimic the extracellular matrix, further supporting the natural healing processes. Their biodegradability, combined with high therapeutic efficacy, makes them an innovative and patient-friendly alternative to traditional dressings, allowing for tailored wound care and contributing to more sustainable medical practices. Summarizing the design of biodegradable hydrogel and sponge dressings is extremely important because it combines clinical benefits with environmental responsibility. Such dressings effectively support the wound healing process by providing optimal moisture conditions, protection against infection, and patient comfort.

1.3. Work plan

The main goal will be achieved through the implementation of working elements as follows:

Task 1: Material selection and crosslinking using agents derived from plant extracts.
Task 2: Introduction of plant particles of selected leaves or seeds
Task 3: Development of a sponge-forming method from solution and freeze-drying processes
Task 4: Physicochemical characterization of prepared materials by different methods, e.g., ATR-FTIR, mechanical testing, contact angle measurement, SEM, swelling/degradation tests, thermal properties, aging tests, antioxidative properties,
Task 5: Conducting biological studies – biocidal properties and cytotoxicity.
Task 6: Selection of the most promising wound dressing material.

1.4. Literature (max. 7 listed as a suggestion for a PhD candidate preliminary study)

Pengcheng Zhang et al., *Rapid hemostasis and removal: Oxidized dextran-coated chitosan-alginate sponges via dynamic calcium crosslinking*, International Journal of Biological Macromolecules, 340, Part 1 (2026) 150230

Xuekun Yang et al., *Rapid Fluid-Induced-Expanding Chitosan-Derived Hemostatic Sponges with Excellent Antimicrobial and Antioxidant Properties for Incompressible Hemorrhage and Wound Healing*. Biomacromolecules *26* (1) (2025) 689-704

Yu Zhang, et al., *Advances in the study of polysaccharide-based hydrogel wound dressings*, International Journal of Biological. Macromolecules 307 (2025) 142134

Xuehao Tian, et. al. *Recent advances in smart hydrogels derived from polysaccharides and their applications for wound dressing and healing*, Biomaterials 318 (2025) 123134

Chao Ma, et al. *A review of polysaccharide hydrogels as materials for skin repair and wound dressing: Construction, functionalization, and challenges.* International Journal of Biological Macromolecules 280 (2024) 135838

Huiqing Xu et al. *Research progress of natural polysaccharide-based and natural protein-based hydrogels for bacteria-infected wound healing*. Chemical Engineering Journal 496 (2024) 153803

Chuan Tang et al. *Preparation and characterization of chitosan/sodium cellulose sulfate/ silver nanoparticles composite films for wound dressing.* Materials Today Communications 33 (2022) 104192

1.5. Required initial knowledge and skills of the PhD candidate

- ❑ Strong analytical reasoning and problem-solving skills
- ❑ High motivation and eagerness to acquire new knowledge
- ❑ Background in polymer science
- ❑ Familiarity with fundamental material testing techniques
- ❑ Basic understanding of polymer chemistry and modification strategies
- ❑ Introductory knowledge of phytochemistry or natural bioactive compounds

1.6. Expected development of the PhD candidate's knowledge and skills

- ❑ Mastery of advanced material characterization methodologies

- ❑ Proficiency in operating sophisticated instrumental analysis equipment
- ❑ Refinement of general laboratory practices and biological testing skills
- ❑ Enhanced critical thinking and experimental design capabilities
- ❑ Comprehensive professional growth and establishing a foundation as an independent researcher