Cellulose based aerogel microfibers for biomedical applications

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Impact paragraph

The prevalence of different kind of wounds especially chronic ones has grown considerably over the past decades. This is mainly due to the rising number of surgeries, escalating worldwide geriatric population, soaring traumatic wounds, and the epidemic of obesity and diabetes as risk factors for the development of chronic wounds [1,2]. Due to the limitations of the existing wound dressing products, a novel biobased wound dressing was developed attempting to address those limitations. As a result, the produced wound dressing from renewable, biocompatible, and biodegradable materials in this work can be applied to and is tunable for a wide range of wound types in order to accelerate and promote the wound healing process.

Aerogels originating from natural polymers, such as cellulose, provide low density, high porosity, large specific surface area, biocompatibility, biodegradability, and the ability to load and locally release bioactive agents [3]. The aforementioned characteristics make bioaerogels promising candidates for biomedical applications such as wound dressing products. Nevertheless, aerogel applications have been widely restricted due to the lack of flexibility, extensibility, and fragile network structures, which are mainly due to the possible configurations of the aerogels such as monoliths, cylinders, and beads [4]. Moreover, commercialization of the aerogels are limited due to the time consuming, expensive, and batchwise processing techniques.

In the current study, however, by producing aerogels in the geometry of microfibers, their mechanical performance, flexibility, and extensibility were improved remarkably. Moreover, benefiting from versatile fiber and textile engineering techniques, bioaerogels can be transformed into micro/nanofibers with different structures including woven, nonwoven, knitted, and braided through shorter and more reproducible processes.

In this study, cellulose-based aerogel microfibers as an emerging class of aerogel materials were explored particularly for biomedical applications of drug delivery and wound dressing. Drug-loaded and non-loaded aerogel microfibers were produced through fiber spinning methods including wet spinning and solution blowing spinning accompanied by supercritical CO_2 drying as a solvent free and green process. Different cellulose-based aerogel microfibers in the form of knitted and nonwoven structures were created for the optimal wound healing and the absorbance of wound exudate. The feasibility of loading various model and actual drugs, such as anti-inflammatory or anti-microbial agents, into the porous structure of the fibers to accelerate wound healing was also positively evaluated.

It should be borne in mind that all the research conducted during this PhD project on cellulose based aerogel microfibers is not providing a “ready-made solution” for biomedical application of drug delivery and wound dressing since this topic is quite “juvenile”. The obtained results present useful instruction and guidelines for future studies.

The result of this study has significant contribution to the scientific and social community. Regarding the scientific aspect, to best to our knowledge, the first indication of aerogel fibers’ existence can be traced back to 2012; however, their potential for wound dressing applications was not investigated prior to the current study. This study can pave the way for other new biomedical applications, such as tissue engineering, where the existence of a highly porous scaffold network in producing human size tissues is essential. Intensive *in vitro* and *in vivo* analysis are required in order to have an in-depth understanding of the cellulose-based aerogel microfibers performance when interacting with living organisms. For example, in the case of wound dressing application, a critical investigation on the advantages of bio-based aerogels for each wound healing stage as well as the exudate control need to be performed.

The current research is also highly beneficial for the social community regarding two main aspects. First, this study is addressing the expanding demand and growing global market of advanced wound dressing products. There is a wide variety of wound dressings commercially available for wound treatment; however, many still lack the ideal characteristics of a wound dressing product. Cellulose-based aerogels microfibers have shown closer behavior to an ideal wound dressing, and this study can be utilized as a road map to enhance a patient’s quality of life. Second, there is an increasing awareness by the public that the impacts of synthetic plastic waste on the environment and our health are global and can be drastic. The development of new, versatile, and multi-functional polymeric materials from renewable resources, such as cellulose, has become a key research focus to meet tomorrow’s engineering applications. Therefore, the integration of environmental sustainability in the fabrication of bio-based materials produced by “greener” processes such as supercritical CO_2 ones is vital in modern technologies to reduce environmental footprints and harmonize polymeric products with our living environment for a better future.

The outcome of the current thesis are relevant and interesting not only for biomedical researchers, clinicians, and patients but also for biomedical corporations. Cellulose-based aerogel fibers can be highly intriguing for biomedical companies that target to expand their biomaterials portfolio for new nanostructured biomaterials. Such companies can aim for early investment and further investigation in the current research in order to integrate bioaerogel fibers in their health care business. In general, hospitals, clinics, home care facilities, and patients are potential customers of a wound dressing product.

Moreover, the results can be fascinating for not only the researchers in the biomedical field but also those focusing on various technical applications of aerogels such as thermal insulation. Aerogel fibers can be extensively used in technical sectors where the load-bearing and different structure formation in conjunction with the superior thermal insulation performance is vital.

The results of this thesis were published in open access peer reviewed articles making them accessible for researchers and public audience. Through participating in different international conferences, the results were presented to the academic and non-academic attendees. Moreover, promotional contents, such as a video and blog, were created and published on the FibreNet project website. The cellulose-based solution blown aerogel microfibers as fully illustrated in the last section of this thesis was introduced into the public and industrial partners by the doctoral candidate under the name of WoundAeroFiber, which was awarded the Maastricht University Challenge Award.

The current scientific journey that began with the fundamental understanding of the fabrication process of a wound dressing product has been long-lasting and complex. It started with material selection, design, processing as well as multiple improvement actions for better and optimized performance, and ended with a prototype. The cellulose-based aerogel microfibers might face many other challenges before possibly reaching society at the commercial level. However, the contributions made to this field of science through this study are highly self-standing and valuable even if the final goal of advancing society with a new wound dressing product remains elusive.

References

1. Sen, C.K. Human Wounds and Its Burden: An Updated Compendium of Estimates. *Adv Wound Care (New Rochelle)* **2019**, *8*, 39-48, doi:10.1089/wound.2019.0946.

2. Boateng, J.S.; Matthews, K.H.; Stevens, H.N.; Eccleston, G.M. Wound healing dressings and drug delivery systems: a review. *Journal of pharmaceutical sciences* **2008**, *97*, 2892-2923, doi:https://doi.org/10.1002/jps.21210.

3. Maleki, H.; Durães, L.; García-González, C.A.; del Gaudio, P.; Portugal, A.; Mahmoudi, M. Synthesis and biomedical applications of aerogels: Possibilities and challenges. *Advances in Colloid and Interface Science* **2016**, *236*, 1-27, doi:https://doi.org/10.1016/j.cis.2016.05.011.

4. Budtova, T. Cellulose II aerogels: a review. *Cellulose* **2019**, *26*, 81-121, doi:10.1007/s10570-018-2189-