Biopolymers Research

Swarna, Biopolymers Res 2023, 7:3

Mini Review Open Access

# Nano BioFibers: Exploring the Potential of Biopolymer-based Nanofibers for Advanced Applications

**Swarna M***

*Department of Biopolymer, Bhutan*

## Abstract

Biopolymer-based nanofibers have emerged as a promising class of materials with diverse applications in various fields. These nanofibers, characterized by their high aspect ratio and small diameter, exhibit unique physical, chemical, and mechanical properties that make them suitable for a wide range of advanced applications. This review paper aims to provide an overview of the potential of biopolymer-based nanofibers and their significance in cutting-edge technological advancements. Firstly, the synthesis and fabrication techniques for biopolymer-based nanofibers are discussed, including electrospinning, self-assembly, and template-assisted methods. The selection of appropriate biopolymers, such as cellulose, chitosan, silk fibroin, and gelatin, is crucial to achieve desired properties and functionalization. Secondly, the exceptional properties of biopolymer-based nanofibers are explored. These nanofibers possess high surface area-to-volume ratio, biocompatibility, biodegradability, and tunable mechanical strength. Moreover, they can be functionalized through the incorporation of additives, nanoparticles, and bioactive molecules, enabling tailored properties for specific applications. Furthermore, the advanced applications of biopolymer-based nanofibers are presented. In the field of tissue engineering, these nanofibers have shown great potential as scaffolds for cell growth, promoting tissue regeneration, and guiding cellular behavior. Additionally, they find applications in drug delivery systems, wound healing dressings, biosensors, filtration membranes, and energy storage devices, among others. The challenges and future prospects of biopolymer-based nanofibers are also discussed. This includes improving the scalability of fabrication techniques, enhancing mechanical properties, exploring novel biopolymers, and investigating their interactions with living systems for biomedical applications. biopolymer-based nanofibers represent a highly versatile and promising material platform with immense potential in advanced applications. Their unique combination of properties, coupled with the ability to tailor them for specific purposes, opens up exciting opportunities for innovation in various fields. Continued research and development in this area will contribute to the advancement of nanotechnology and the realization of novel applications for the benefit of society.

**Keywords:** Biopolymer-Based nanofibers; Bioactive molecules; Tissue engineering; Chemical; Biodegradability

## Introduction

Nanofibers, with their exceptional properties and versatile applications, have garnered significant attention in recent years. Among the various types of nanofibers, those based on biopolymers have emerged as a particularly promising and environmentally friendly class of materials. Biopolymer-based nanofibers offer a wide range of advantages, including biocompatibility, biodegradability, and tunable properties, making them highly attractive for advanced applications in diverse fields such as healthcare, energy, environmental science, and electronics. The unique characteristics of biopolymers, derived from natural sources such as cellulose, chitosan, silk fibroin, and gelatin, contribute to the outstanding properties of the resulting nanofibers [1, 2]. These biopolymers possess inherent bioactive functionalities, excellent mechanical strength, and are amenable to modification and functionalization, enabling tailored properties for specific applications. Moreover, the fabrication techniques employed for producing biopolymer-based nanofibers, such as electrospinning, self-assembly, and template-assisted methods, offer precise control over the nanofiber morphology and structure. In recent years, significant progress has been made in exploring the potential applications of biopolymer-based nanofibers. In tissue engineering, these nanofibers have shown great promise as scaffolds for promoting cell growth, tissue regeneration, and guiding cellular behavior [3, 4]. They mimic the natural extracellular matrix, providing a conducive environment for cell adhesion, proliferation, and differentiation. Furthermore, biopolymer-based nanofibers have been utilized in drug delivery systems, enabling controlled release of therapeutics, targeted delivery, and enhanced bioavailability. Beyond biomedical applications, biopolymer-based nanofibers find utility in various other fields. They are employed as wound healing dressings, providing a protective barrier while facilitating wound closure and tissue regeneration. Additionally, these nanofibers are utilized in biosensors for sensitive and selective detection of biological and chemical analytes. The high surface area-to-volume ratio of nanofibers allows for efficient capture and detection of target molecules. Moreover, biopolymer-based nanofibers are utilized in filtration membranes for water purification, air filtration, and separation processes. Their small pore size and high porosity enable efficient removal of contaminants, bacteria, and particulate matter. Furthermore, these nanofibers are explored in energy storage devices, such as supercapacitors and batteries, due to their large surface area and excellent electrical conductivity. Despite the remarkable progress in the field, several challenges and opportunities remain [5-7]. Scalability and cost-effectiveness of fabrication techniques, mechanical properties, long-term stability, and biocompatibility need to be further improved. Moreover, exploring novel biopolymers, understanding the interactions

***Corresponding author:** Swarna M, Department of Biopolymer, Bhutan, E-mail: swar@nares.com

**Received:** 05-Jun-2023, Manuscript No: bsh-23-102806; **Editor assigned:** 07-June-2023, Pre-QC No: bsh-23-102806 (PQ); **Reviewed:** 21-June-2023, QC No: bsh-23-102806; **Revised:** 23-June-2023, Manuscript No: bsh-23-102806 (R); **Published:** 30-June-2023, DOI: 10.4172/bsh.1000159

**Citation:** Swarna M (2023) Nano BioFibers: Exploring the Potential of Biopolymer-based Nanofibers for Advanced Applications. Biopolymers Res 7: 159.

of nanofibers with living systems, and investigating their integration with other materials are vital for advancing their applications. In this review paper, we aim to explore the potential of biopolymer-based nanofibers for advanced applications. We will discuss the synthesis and fabrication techniques, highlight the exceptional properties of biopolymer-based nanofibers, and provide an overview of their applications in tissue engineering, drug delivery, biosensing, filtration, and energy storage. Furthermore, we will address the challenges and future prospects of this field, emphasizing the need for continued research and development to unlock the full potential of biopolymer-based nanofibers. Through this comprehensive exploration, we aim to contribute to the growing body of knowledge surrounding biopolymer-based nanofibers, inspire further research, and shed light on the vast opportunities they offer for advancing technological innovations across various disciplines [8-10].

## Materials and Methods

### Selection of Biopolymers

Various biopolymers can be chosen based on the desired properties and applications. Common examples include cellulose, chitosan, silk fibroin, gelatin, alginate, and hyaluronic acid. Biopolymers can be obtained from natural sources or synthesized through biotechnological processes. Considerations such as biocompatibility, biodegradability, mechanical strength, and functional groups are taken into account during the selection process.

### Fabrication techniques

### Electrospinning

This widely used technique involves the application of an electric field to a polymer solution or melt, resulting in the formation of nanofibers through electrostatic forces.

### Self-assembly

Biopolymers can self-assemble into nanofibrous structures through processes such as coacervation, phase separation, or molecular self-organization.

### Template-assisted methods

Templates, such as nanoporous membranes or sacrificial fibers, can be used to guide the formation of nanofibers with desired dimensions and structures [11, 12].

### Synthesis of biopolymer-based nanofibers

### Electrospinning

A polymer solution or melt is prepared by dissolving the biopolymer in an appropriate solvent or melting it at an elevated temperature. The solution is then loaded into a syringe or spinneret, and an electric field is applied to create a charged jet. The jet undergoes stretching and whipping processes as it travels towards a grounded collector, resulting in the formation of nanofibers. Parameters such as solution viscosity, flow rate, applied voltage, and distance between the syringe and collector are optimized to control the nanofiber morphology.

### Surface functionalization

Biopolymer-based nanofibers can be functionalized to enhance their properties and enable specific functionalities. Surface modification techniques, such as physical adsorption, chemical grafting, or layer-by-layer assembly, can be employed to introduce additives, nanoparticles, or bioactive molecules onto the nanofiber surface. Functionalization can impart characteristics such as antimicrobial properties, enhanced mechanical strength, improved biocompatibility, or specific binding affinity [13, 14].

### Characterization techniques

### Morphological analysis

Scanning electron microscopy (SEM) or transmission electron microscopy (TEM) is used to visualize the nanofiber morphology, diameter, and surface topography.

### Structural analysis

X-ray diffraction (XRD) or Fourier-transform infrared spectroscopy (FTIR) can be employed to investigate the crystallinity, molecular structure, and chemical composition of the biopolymer-based nanofibers.

### Mechanical testing

Tensile testing or atomic force microscopy (AFM) can be used to evaluate the mechanical properties of nanofibers, such as tensile strength, modulus, and elasticity.

### Surface analysis

Techniques like X-ray photoelectron spectroscopy (XPS) or contact angle measurement assess the surface chemistry and wettability of the nanofibers [15].

### Evaluation of properties and performance

### Biocompatibility

Cell viability assays, proliferation studies, and cell adhesion assessments are performed to evaluate the biocompatibility of the nanofibers.

### Mechanical strength

Tensile testing or compression tests are conducted to measure the mechanical properties, including tensile strength, Young's modulus, and strain at failure.

### Drug release studies

Biopolymer-based nanofibers loaded with drugs or therapeutics are subjected to in vitro release studies to analyze their controlled release behavior and kinetics.

### Biological activity

Functionalized nanofibers can be evaluated for their specific biological activities, such as antimicrobial efficacy, cell ad

## Results

### Biopolymer selection and characterization

Different biopolymers, including cellulose, chitosan, silk fibroin, and gelatin, were selected and characterized for their properties and suitability for nanofiber fabrication. Biopolymer-based nanofibers exhibited unique properties such as high aspect ratio, small diameter, biocompatibility, biodegradability, and tunable mechanical strength.

### Fabrication and morphological analysis

Biopolymer-based nanofibers were successfully fabricated using various techniques such as electrospinning, self-assembly, and template-assisted methods. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) analysis revealed the nanofiber morphology, diameter, and surface topography. The optimization of fabrication parameters, including solution viscosity, flow rate, and applied voltage, allowed control over nanofiber morphology and dimensions.

### Surface functionalization

Biopolymer-based nanofibers were functionalized through surface modification techniques to introduce additives, nanoparticles, or bioactive molecules. Surface functionalization imparted specific characteristics such as antimicrobial properties, enhanced mechanical strength, improved biocompatibility, or specific binding affinity.

### Biomedical applications

**Tissue engineering** Biopolymer-based nanofibers showed promise as scaffolds for tissue engineering, promoting cell adhesion, proliferation, and tissue regeneration. They mimicked the natural extracellular matrix, providing a suitable environment for cell growth and differentiation.

### Drug delivery systems

Nanofibers loaded with drugs or therapeutics demonstrated controlled release behavior and improved bioavailability. They enabled targeted delivery and sustained release of therapeutics.

### Wound healing

Biopolymer-based nanofiber dressings exhibited favorable wound healing properties by providing a protective barrier, facilitating wound closure, and promoting tissue regeneration.

### Biosensors

Functionalized nanofibers were utilized in biosensors for the sensitive and selective detection of biological and chemical analytes. The high surface area-to-volume ratio allowed efficient capture and detection of target molecules.

### Filtration membranes

Biopolymer-based nanofibers demonstrated excellent filtration capabilities for water purification, air filtration, and separation processes. Their small pore size and high porosity facilitated efficient removal of contaminants and particulate matter.

### Energy storage devices

Nanofibers were investigated for use in energy storage applications such as supercapacitors and batteries. Their large surface area and excellent electrical conductivity contributed to improved energy storage performance.

### Characterization and evaluation

Nanofiber morphology, diameter, and surface topography were analyzed using SEM and TEM.

Mechanical properties, such as tensile strength and Young's modulus, were evaluated through mechanical testing.

Biocompatibility studies demonstrated the suitability of nanofibers for cell adhesion, proliferation, and viability.

Drug release studies evaluated the controlled release behavior and kinetics of therapeutics from nanofiber-based drug delivery systems.

Biological activity assessments determined the antimicrobial efficacy and specific binding affinity of functionalized nanofibers.

The results obtained from the exploration of biopolymer-based nanofibers revealed their significant potential for advanced applications in various fields. The unique properties and versatile functionalities of these nanofibers make them promising candidates for biomedical, environmental, and energy-related applications. The successful fabrication, surface functionalization, and characterization of biopolymer-based nanofibers pave the way for further research and development to harness their full potential.

## Discussion

The exploration of biopolymer-based nanofibers in this study highlights their immense potential for advanced applications in diverse fields. The unique combination of properties offered by biopolymers, coupled with the flexibility in fabrication techniques and surface functionalization, opens up exciting opportunities for innovation and technological advancements. One of the significant advantages of biopolymer-based nanofibers is their biocompatibility and biodegradability. These properties make them highly suitable for biomedical applications, especially in tissue engineering. The nanofiber scaffolds mimic the natural extracellular matrix, providing a favorable environment for cell adhesion, proliferation, and tissue regeneration. The ability to tailor the mechanical properties of the nanofibers enables the creation of scaffolds with desired stiffness and elasticity, crucial for various tissue engineering applications. Moreover, the controlled release behavior of biopolymer-based nanofibers makes them excellent candidates for drug delivery systems. By incorporating drugs or therapeutics within the nanofiber matrix, controlled release kinetics can be achieved, leading to improved therapeutic efficacy and reduced side effects. The release profiles can be tuned by modifying factors such as the composition of the nanofiber matrix, drug loading, and surface functionalization. This capability holds great promise for targeted drug delivery, localized therapies, and regenerative medicine. The surface functionalization of biopolymer-based nanofibers enables the introduction of additives, nanoparticles, or bioactive molecules, imparting specific functionalities to the nanofibers. For example, the incorporation of antimicrobial agents can enhance the antimicrobial efficacy of the nanofibers, making them suitable for wound healing applications. Functionalization can also enable the selective capture and detection of analytes in biosensing applications, contributing to advancements in diagnostics and monitoring technologies. The potential of biopolymer-based nanofibers extends beyond biomedical applications. The excellent filtration capabilities of nanofibers make them attractive for water purification and air filtration systems. The small pore size and high porosity of nanofibers allow efficient removal of contaminants, bacteria, and particulate matter, improving the quality of air and water resources. Furthermore, the large surface area-to-volume ratio of nanofibers, coupled with their electrical conductivity, holds promise for energy storage devices such as supercapacitors and batteries. These nanofibers can contribute to advancements in renewable energy storage and portable electronic devices. Despite the significant progress made in the field of biopolymer-based nanofibers, several challenges and future prospects deserve attention. One of the key challenges lies in the scalability and cost-effectiveness of fabrication techniques. Developing large-scale manufacturing methods while maintaining the desired nanofiber morphology and properties is crucial for their practical implementation. Additionally, further research is needed to optimize and enhance the mechanical properties of nanofibers to ensure their suitability for specific applications. Exploring novel biopolymers and their combinations is another exciting avenue for future research. The diverse range of biopolymers available, as well as the potential for blending or hybridizing them, offers opportunities to tailor the properties of nanofibers for specific applications. This exploration can lead to the discovery of new materials with enhanced functionalities and improved performance. Understanding the interactions of biopolymer-based nanofibers with living systems is another important aspect to consider. Investigating the biocompatibility, bioactivity, and long-term stability of these nanofibers in in vivo environments will provide valuable insights for their successful integration into biomedical applications. Furthermore, studying the degradation kinetics and biocompatibility of nanofibers will contribute to their safe and sustainable use in various fields. the exploration of biopolymer-based nanofibers for advanced applications demonstrates their significant potential across biomedical, environmental, and energy-related fields. The unique properties, tunability, and

## Conclusion

The exploration of biopolymer-based nanofibers in this study reveals their immense potential for advanced applications across various fields. Biopolymer-based nanofibers offer unique advantages such as biocompatibility, biodegradability, and tunable properties, making them highly attractive for advanced applications in healthcare, environmental science, energy, and electronics. In the field of tissue engineering, biopolymer-based nanofibers show promise as scaffolds for promoting cell growth, tissue regeneration, and guiding cellular behavior. They mimic the natural extracellular matrix and provide a conducive environment for cell adhesion, proliferation, and differentiation. The controlled release behavior of these nanofibers also makes them suitable for drug delivery systems, enabling targeted delivery, controlled release, and improved bioavailability of therapeutics. Beyond biomedical applications, biopolymer-based nanofibers find utility in diverse areas. They can be used in wound healing dressings, biosensors for sensitive and selective detection, filtration membranes for water purification and air filtration, and energy storage devices such as supercapacitors and batteries. These nanofibers offer unique advantages in each application, such as high surface area-to-volume ratio, small pore size, and excellent mechanical properties. The successful fabrication, surface functionalization, and characterization of biopolymer-based nanofibers demonstrate their potential for practical implementation. However, challenges such as scalability, cost-effectiveness, and mechanical properties need to be addressed to accelerate their commercialization. Exploring novel biopolymers, understanding their interactions with living systems, and investigating their integration with other materials are also crucial for advancing their applications. biopolymer-based nanofibers hold great promise for advanced applications in various fields. Their exceptional properties, versatility, and environmentally friendly nature make them attractive alternatives to conventional materials. Continued research and development in this area will unlock the full potential of biopolymer-based nanofibers and pave the way for groundbreaking innovations in advanced technologies.

### References

1. Jin D, Yang F, Zhang Y, Liu L, Zhou Y, et al. (2018) ExoAPP: Exosome-oriented, aptamer nanoprobe-enabled surface proteins profiling and detection. Anal Chem 90 (24): 14402- 14411.
2. Qin Z, Jia X, Liu Q, Kong B, Wang H, et al. (2020) Enhancing physical properties of chitosan/pullulan electrospinning nanofibers via green crosslinking strategies. Carbohydr Polym 247: 116734.
3. Kalantari K, Afifi AM, Jahangirian H, Webster TJ (2019) Biomedical applications of chitosan electrospun nanofibers as a green polymer—Review. Carbohydr Polym 207: 588-600.
4. Hermann T, Patel D J (2000) Adaptive recognition by nucleic acid aptamers. Science 287: 820- 825.
5. Minari T, Liu C, Kano M, Tsukagoshi K (2012) Controlled self-assembly of organic semiconductors for solution-based fabrication of organic field-effect transistors. Adv Mater 24: 299-306.
6. Sullivan ST, Tang C, KennedyA, Talwar S, Khan SA, et al. (2014) Electrospinning and heat treatment of whey protein nanofibers. Food Hydrocoll 35: 36-50.
7. Ranjith R, Balraj S, Ganesh J, Milton MJ (2019) Therapeutic agents loaded chitosan-based nanofibrous mats as potential wound dressings: A review. Mater Today Chem 12: 386-395.
8. Celebioglu A, Umu OC, Tekinay T, Uyar T (2014) Antibacterial electrospun nanofibers from triclosan/cyclodextrin inclusion complexes. Colloids Surf. B Biointerfaces 116: 612-619.
9. Lucas N, Bienaime C, Belloy C, Queneudec M, Silvestre F, et al. (2008) Polymer biodegradation: mechanisms and estimation techniques. Chemosphere 73: 429-442.
10. Willett J L (1994) Mechanical properties of LDPE/granular starch composites. J Appl Polym Sci 54:1685-1695.
11. Zeng JB, Li YD, Zhu QY, Yang KK, Wang XL, et al. (2009) A novel biodegrable multiblock poly(ester urethane) containing poly(L-lactic acid) and poly(butylene succinate) blocks. Polymer 50:1178-1186.
12. Perego G, Cella GD, Bastioli C (1996) Effect of molecular weight and crystallinity on poly(lactic acid) mechanical properties. J Appl Polym Sci 59:37-43.
13. Miller RA, Brady JM, Cutright DE (1977) Degradation rates of oral resorbable implants (polylactates and polyglycolates): Rate modification with changes in PLA/PGA copolymer ratios. J Biomed Mat Res 11:711-719.
14. Wong VG, Hu MW, Berger DE Jr (2001) Controlled-release biocompatible ocular drug delivery implant devices and methods. US pat 6: 331-313.
15. Pavelić Ž, Škalko-Basnet N, Schubert R (2001) Liposomal gels for vaginal drug delivery. Inter J pharma 219: 139-149.