ACQUISITION AND UTILIZATION OF NANOFIBERS EXTRACTED FROM BIOMASSES

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ABSTRACT

Biomass nanofibers are ultrafine fibers with diameters in the range of nanometers, normally produced through mechanical, chemical or electrospinning processes. The search for advanced, environmentally friendly materials suitable for a variety of applications in the home, office and industry led material scientists to discover cellulose nanoparticles. The most used techniques for its synthesis are electrospinning, pyrolysis, hydrothermal treatment and ultrasound. There are countless applications for nanofibers, which can be used as plastic reinforcement, manufacture of composites, films, flexible and translucent, of aerogels and biogels, dressings, polystyrene (plastic) and polymethyl methacrylate (acrylic), carbon fibers and reinforcement for biodegradable films. This study shows several varieties and capabilities of these nanofibers, but it is still a subject that should receive more attention and further studies in order to alleviate a worldwide problem that is the amount of waste generated by the industrial sector, with this study it is possible to see the viability of the use of nanofibers in value-added materials, with this process it is expected to improve the issue of the environment and economy simultaneously.

Keywords: Biomass. Nanofibers. Sustainability. Cellulose.

1 INTRODUCTION

Nanofiber from biomass is an emerging sustainable material garnering increasing interest for applications addressing environmental challenges[1]. One such material that has gained significant attention is cellulose nanofiber, derived from renewable biomass sources with unique properties and the potential to revolutionize the industry[2]. Biomass nanofibers are ultrafine fibers typically produced through mechanical, chemical, or electrospinning processes[1].

Fibers can be obtained from various biomass sources such as wood, plants, and agricultural residues[1]. The use of biomass is attractive for nanofiber production due to its abundance, renewability, and potential for reducing carbon emissions[3].

The production of biomass nanofibers encompasses various techniques, each presenting distinct advantages and limitations. Mechanical processing methods, including grinding and refining, are utilized to fragment biomass into finer fibers[4]. Chemical methodologies, such as acid hydrolysis or enzymatic treatment, offer the capacity to selectively eliminate undesirable constituents, thereby augmenting the purity and quality of the nanofibers[1]. Moreover, electrospinning, a sophisticated process reliant on an electric field to fabricate nanofibers from polymeric solutions, has emerged as a viable approach for generating biomass nanofibers endowed with tailored morphology and structure[5].

Carbon nanofibers derived from biomass offer a potential alternative to petroleum-based limited resources, along with desirable physical and chemical properties[6]. Agricultural waste-derived activated carbons can synthesize carbon nanofibers, as the iron content present in the activated carbon ash serves as a catalyst[7].

Several polymers employed in the production of biomass nanofibers encompass PAN (polyacrylonitrile), poly (vinyl alcohol), vanillin polymer, and polyvinylpyrrolidone. Among these, cellulose and lignin stand out as the predominant biopolymer sources for these nanofibers. Cellulose exhibits notable flexibility, while lignin is distinguished by its elevated carbon content, substantial aromatic ring structure, and thermal resilience[6 8].

The use of natural materials and biopolymers can represent an alternative for environmentally friendly applications in biomass nanofiber production. With the growing utilization of biomass across various industries and enterprises, there has been a substantial increase in biomass waste production. This trend has led to environmental issues and the improper utilization of renewable resources. However, the utilization of biomass nanofibers offers a promising solution to this issue[8].

2 MATERIAL & METHODS

In this review work, extensive bibliographic research was conducted, which involved a survey of published works on nanofibers synthesized through cellulose and their primary uses. The publications selected for the research were sourced from platforms such as Google Scholar, Scielo – Brazil, Web of Science, Science Direct, scientific journals, as well as books published within the field. Through this research, it was possible to map the current production processes of biomass-derived nanofibers, as well as to identify bottlenecks and challenges in the utilization of these residues, which serve as potential raw materials for the production of various value-added products.

3 RESULTS & DISCUSSION

According to Zhao et al., 2021, the carbonization of cellulose nanofibrils increases their surface area and capacitance. Hydrothermal methods also enable the extraction of polysaccharide nanofibers, resulting in structures with higher order and capacitance. The extracted nanofibers can be converted into porous carbon nanofibers through potassium hydroxide activation. This process serves as an alternative to previous methods, offering potential for increased efficiency in the production of porous carbon with high capacitance[5].

A relevant application for cellulose nanofibers, according to Moulafera et al., 2021, is their utilization as reinforcement material for biopolymers to enhance their mechanical properties, owing to their high aspect ratio and strength. Biopolymers, synthesized by various microorganisms and organisms, are common in nature, encompassing a variety of biomass substances such as lignin, cellulose, hemicellulose, starch, chitosan, chitin, and oil-based materials[9]. Nanofibers, primarily derived from wood plants and, more recently, bamboo species, are often utilized without lignin for various applications[6].

The current study compiles a range of biomass residues that have been transformed into nanofibers, thereby converting previously discarded materials into high-value products. Table 1 delineates various residues, their respective methodologies, and key characteristics of the resulting nanofibers.

Most methods employ various reagents such as sodium hydroxide, sodium chlorite, acetic acid, hydrochloric acid, sulfuric acid, acetic anhydride, and nitric acid, with the exception of the extraction from fresh carrot residues, which did not involve the use of reagents.

Table 1 Extraction methods.

Biomass	Method	Obtained	Composition	Author
Cassava Bagasse	Chemical Process	-	Rich in cellulose	[10]
Wheat Straw	Chemi-mechanical	Diameters 10–80 nm Crystallinity 35%	Cellulose 84.6%, hemicellulose 6%, lignin 9.4%	[2]
Soy Hul	Chemi-mechanical	Diameter 20–120 nm Crystallinity 16%	Cellulose 94.0%, hemicellulose 3.5%, lignin 2.5%	[2]
Rice Husk	Chemical Process	Diameter of 7nm Crystallinity 59%	Cellulose 96%	[11]
Fresh Carrot Residue	Mechanical Process	Average diameter of 18nm Crystallinity between 43% and 68%	53% glucose and 47% xylose	[12]
Lignocellulosic Residues	Mechanical Process	Diameter ranging from 10 to 15nm Lowest crystallinity index: 79%	Cellulose 96%, Lignin and Hemicelluloses: 4%	[13]
Banana Peel Bran	Chemical Process	Diameter of 10.9 and 7.6 nm Crystallinity 49,2%	Cellulose	[14]
Bamboo	Chemi-mechanical	Diameter 2-30nm Crystallinity 72,5%	Cellulose 83.67%, hemicellulose 13.97%, lignin 0.13%	[15]

The materials derived from nanofibers, generated through the manipulation and assembly of nanofibers, have garnered significant attention owing to their superior strength, high surface-to-volume ratio, and adaptive properties [7]. Besides being renewable and biodegradable, nanofibers exhibit unique characteristics compared to traditional fibers, such as nano-scale dimensions, increased surface area, distinctive morphology, low density, and enhanced mechanical and thermal resilience [4]. Nanofibers have demonstrated potential as viable replacements for conventional fibers, from both environmental and economic perspectives. The production of nanofibers encompasses a broad spectrum of applications, including tissue engineering, wound healing, and filtration [16].

The applications of nanofibers are numerous, including their use as plastic reinforcement, in the production of composites, strong, flexible, and translucent films [12]; aerogels and biogels [13]; wound dressings, polystyrene (plastic) and polymethyl methacrylate (acrylic) [10]; carbon fibers, reinforcement for biodegradable films [7].

4 CONCLUSION

Nanofibers offer significant advantages due to their renewability, biodegradability, and unique properties. Their nano size, larger surface area, distinctive morphology, low density, and mechanical and thermal resistance set them apart from other fibers. Nanofibers have proven to be potential substitutes for conventional fibers, both environmentally and economically. The production of nanofibers has a wide range of applications, including tissue engineering, wound healing, and filtration.

Due to their diminutive scale, they can replicate the extracellular tissue structure within the human body, facilitating the development of synthetic tissues capable of repairing or replacing damaged tissues.

By producing nanofibers from materials that were previously discarded, waste is reduced, thereby decreasing landfill volumes and transforming them into high-value products. Additionally, these nanofibers are produced using low-energy manufacturing processes, contributing to carbon neutrality efforts.

Nanofibers have versatile applications across environmentally beneficial domains, including high-performance air and water filtration systems that enhance environmental quality. They are also instrumental in developing high-efficiency batteries, reducing reliance on non-renewable energy sources. Furthermore, in the medical field, nanofibers are utilized in manufacturing advanced dressings, while also contributing to waste repurposing initiatives.

This study elucidates the diverse range of nanofibers and their capabilities. However, it underscores the need for heightened attention and extensive research to tackle a pressing global concern: the proliferation of industrial waste. Valuable resources sourced from renewable origins are being squandered, and this investigation underscores the potential for utilizing such materials in novel product development. This not only adds value but also enhances waste management strategies. In this vein, both environmental sustainability and economic prosperity stand to gain.

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ACKNOWLEDGEMENTS

The authors express their gratitude to the Federal University of Alfenas (UNIFAL-MG) and Fapemig (grant number APQ-01392-23) for their support and financial assistance.