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RESEARCH ARTICLE

NANOCELLULOSE FROM SUGARCANE BAGASSE: SYNTHESIS AND CHARACTERIZATION

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ABSTRACT

This work explores the synthesis and characterization of nanocellulose extracted from sugarcane bagasse. Sugarcane bagasse is an abundant agricultural waste material that is typically discarded. However, it contains a high amount of cellulose, making it a promising source for the production of nanocellulose. The work describes the process of extracting and purifying the cellulose from sugarcane bagasse using a combination of mechanical and chemical treatments.Following that, the produced nanocellulose is examined using a variety of analytical methods, including X-ray diffraction, scanning electron microscopy, and Fourier-transform infrared spectroscopy.. The results show that the nanocellulose obtained from sugarcane bagasse has high crystallinity and a uniform fiber size distribution. These findings suggest that sugarcane bagasse could be a cost-effective and sustainable source of nanocellulose for various applications in industries such as packaging, textiles, and biomedical engineering.

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INTRODUCTION

Cellulose is the fundamental structural element of plant cell walls; it makes up around 33% of all vegetable matter (wood and cotton are both 50% cellulose by weight), and it is the most prevalent organic substance in nature[1]. While cellulose is indigestible to humans, it provides a food source for herbivorous animals because they have digestive tract microorganisms that can quickly break it down. The outer cell wall of biomass is where the lignin is found in terms of physical structure. In general, cellulose is found inside the lignin shell. Additionally, hemicelluloses are distributed randomly and have an amorphous structure both inside and between the cellulose and lignin[1,2]. The homopolysaccharide cellulose is composed of D-glucose monomers that are bonded glycosidically in the structure. Cellobiose, a polymer that has partially aggregated into a crystalline structure, is the repeating unit. In contrast to cellulose, hemicelluloses are hetero-polysaccharides that are frequently branched and made of glucose, depending on the plant species and their various pentoses, including xylose, mannose, and arabinose[3,4].Recently, cellulose nanofibers (CNFs) and their applications have received a lot of attention due to the appealing and unique combination of their characteristics, which include excellent mechanical properties, surface chemistry, biocompatibility, and, most importantly, their abundance from sustainable and renewable resources.[5].

Nano-cellulose may be produced using several techniques, including enzymatic hydrolysis, the ultrasonic process, and acid hydrolysis. The approach that uses acid hydrolysis is the most popular. This method makes it quick and easy to produce nanocellulose with improved properties. Studies claim that compared to other procedures, acid hydrolysis produced nanocellulose with a higher crystallinity index.[6,7]. The size of the nanocellulose produced by acid hydrolysis is also smaller. These are the justifications behind the choice to produce nanocellulose through acid hydrolysis. Typically, powerful acids like H_2SO_4 and HCl are used to dissolve the glycoside bonds in cellulose. There are several processes in acid hydrolysis: (1) strong acid hydrolysis of the cellulose under carefully controlled conditions, such as acid concentration, time, temperature, and the ratio of acid to cellulose; (2) dispersion with some water to stop the hydrolysis process and repeated washing with successive centrifugation; (3) dialysis, which aims to completely remove free acid molecules; (4) sonication to create a stable suspension of nano-cellulose; and (5) drying of the suspension to produce solid nano-cellulose[5,7–9]. One of the main sources of sugar in India is sugarcane (SC), which is highly sought for its therapeutic benefits and capacity to provide a variety of by-products, including cellulosic ethanol, molasses, and other substances. According to climatic characteristics, Uttar Pradesh, Maharashtra, Karnataka, and Bihar are the leading states in India for sugar cane growing, with a combined cultivated area of 52.28 lakhs hectares[10].

The waste product collected in large quantities from the sugar and alcohol industries is known as sugar cane bagasse. In the current work, SCB (Sugar Cane Bagasse) is used to create nanocellulose by the Acid Hydrolysis method and high-intensity ultrasonication. FTIR, XRD, and SEM characterizations are used to analyze the nanocellulose's structural integrity[5,11].

EXPERIMENTAL

MATERIALS AND METHODS

Acetic acid (CH_3COOH), sulphuric acid (H_2SO_4), sodium chlorite ($NaClO_2$), and sodium hydroxide (NaOH) were purchased from SD Fine Chemicals. Sugar Cane Bagasse was obtained from the sugarcane juice centre Mumbai in the vicinity of our institute. All chemicals used were 98.0% pure and did not undergo any additional purification.

Alkaline Pretreatment: Grinded form of 20gm sugarcane bagasse was added in 400ml of 5%w/v sodium hydroxide constantly stirring it for 60 minutes at 90°C in a heating mantle. After washing the material with distilled water until the pH got neutral and squeezed, then dried for 24 hours[12].

Bleaching: Approximately 10 g of pretreatment material were added to a buffer solution of 250 ml of peracetic acid solution (peracetic acid- 50% acetic acid+ 38% hydrogen peroxide + 12% distilled water) at 60 °C, where they were vigorously agitated for 24 hours to complete the bleaching process[13,14].

Acid Hydrolysis and Ultrasonication: Following the alkaline pre-treatment and the bleaching process. Acid hydrolysis was done by giving treatment to the samples with 63% (w/v) sulphuric acid along with stirring it for 1-2 hours[15,16]. For two hours, samples underwent ultrasonication. also obtained the cellulose nanostructured form by centrifuging at 1000 rpm for 20 minutes, and collecting in sample tubes with labels. The method for creating sugarcane bagasse nanocellulose structure is shown in Figure 1.

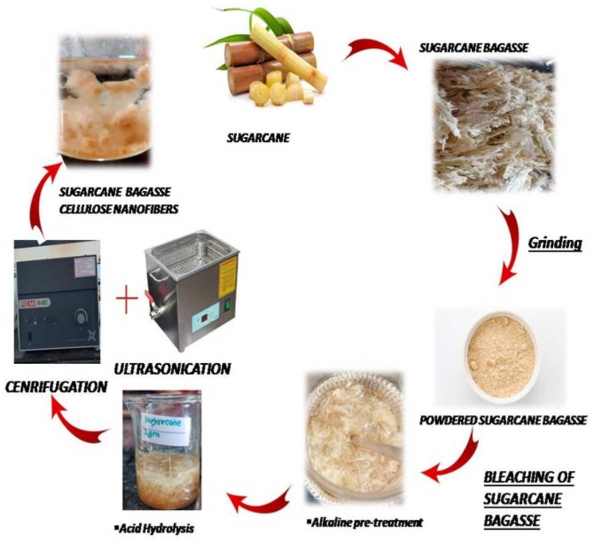

Figure 1. Schematic representation of Synthesis of Nanocellulose from sugarcane bagasse

RESULT AND DISCUSSION

Characterization of Nanocellulose: Fourier Transform Infrared (FTIR) spectroscopy was used to examine the functional groups present in the porous material. The surface morphology of cellulose with nanostructures was examined using scanning electron microscopy (SEM).A desktop X-ray diffractometer (XRD), the MINIFLEX II, was used to investigate the crystallinity of the material following various treatments (RIGAKU) When used at room temperature (RT) with a monochromatic CuK radiation source (= 0.1 539 nm) in the steps can mode, a 2° angle between 10° and 50° with a step of 0.04 and a scanning duration of 5.0 minutes, the angle ranges from the smallest to the largest[10,17,18].

X-ray diffraction analysis (XRD): Figure.2 displays the X-ray diffraction pattern of the sugarcane bagasse nano cellulose fibers following alkaline treatment with ultrasonic assistance. While the later peak at 15.86° reflects the amorphous area of cellulose type, the peak at ϴ = 22° corresponds to the crystallographic field of 200 cellulose lattice. 10° to 50° of diffraction are present. Both the Marcus and crystalline components of the sample's intensity are fully captured in the white ranges. Utilizing XRD analysis, the study determined the crystallinity of nanocellulose[12,14]. According to XRD data, alkali-treated sugarcane bagasse has more amorphous regions. As we go towards bleached material, however, crystallinity rises since lignin and hemicellulose have been removed. After that, an XRD graph with a high intensity shows that the acid-hydrolyzed substance, which is likely nanocellulose, has a high crystallinity[3].

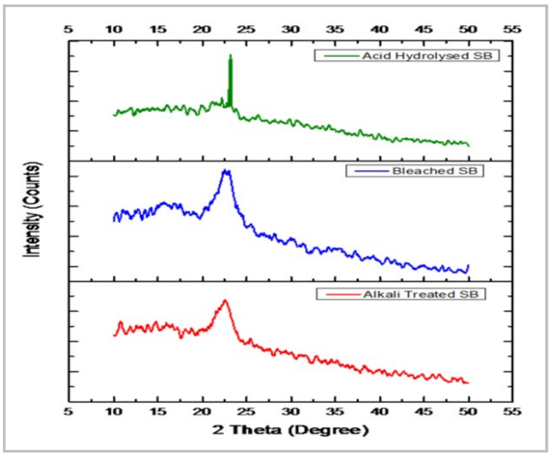

Figure 2. XRD graphs for alkali treated SB, bleached SB and acid hydrolysed SCB

Fourier transforms infrared spectroscopy (FTIR): Since there is no lignin-associated absorbance between 1600 and 1510 cm-1, the bulk of the lignin polymers are eliminated during all extraction procedures. The band at 3328 cm-1 is brought on by stretching of C-H. The O-H bending peak is located at 1314 cm-1, whereas the CH2 bending peak is located at 1425 cm-1 in the spectrum. The peak at 1201 cm-1 denotes the OH in-plane bending of cellulose. The absorption band at 1157 cm-1 is connected to the stretching of the C-O antisymmetric bridge. The C-O-C pyranose ring skeletal vibration occurs between 1076 and 1023 cm-1.[3,18,19]. The IR spectra of sugarcane bagasse nanocellulose are displayed in **Figure 3.**

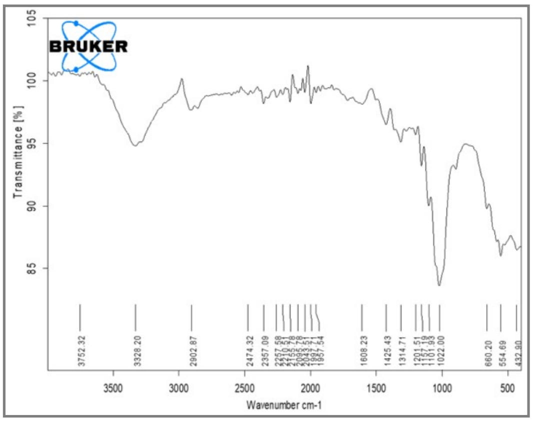

Figure 3. FTIR spectra of nanocellulose extracted from sugarcane bagasse

Scanning electron microscopy (SEM): Figure.4 displays a SEM picture of nanocellulose fibers made from sugarcane bagasse. Similar findings were made by [35], who found that single nano fibrils typically consist of aggregates of cellulose microfibrils rather than smaller single microfibrils. This finding would suggest that a high ratio between the extracted fibers' nanoscale diameter and microscale length was anticipated. The hemicellulose component was rapidly soluble thanks to the use of moderate sulphuric acid hydrolysis, however, the cellulose component is still present in the sugarcane bagasse cellulose nanofibers[8,9,20,21].

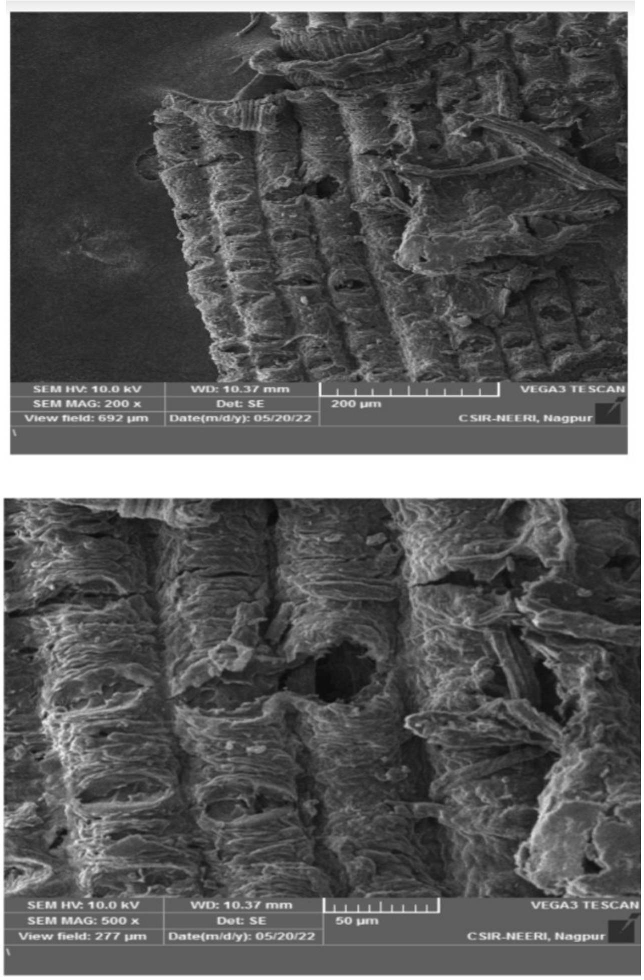

Figure 4. SEM images of nano cellulose extracted from sugarcane bagasse

CONCLUSION

The nanocelluloses (NC) extracted from sugarcane bagasse (SCB) by acid hydrolysis have been the subject of the current research endeavor. There has been research done on a comparison of nanocelluloses made from standard nanocellulose. Applying the synthetic approach allows researchers to examine the characteristics and morphologies of the created nanocellulose. When compared to the other cellulose, which experienced acid-hydrolysis as shown by XRD graphs, the functional portion of nanocellulose exhibits distinctive cellulose peaks in its FTIR spectrum and exhibits better crystallinity. All SEM scans of the materials can reveal the fibrillar and fibrous areas. In terms of a favorable aspect ratio, thermal stability with improved absorption effectiveness, and dispersion stability, nanocellulose outperformed other nanocellulose. Moving forward, several future perspectives could be explored to advance the field of nanocellulose production and utilization. One area for further research could be to optimize the extraction and purification processes to enhance the yield and quality of the synthesized nanocellulose. Additionally, the use of different chemical and mechanical treatments could be investigated to improve the efficiency and sustainability of the production process. Another avenue for future research could be to explore the potential of blending nanocellulose with other materials to create composites with enhanced mechanical and chemical properties. This could lead to the development of innovative materials that have a wide range of potential applications in industries such as aerospace, automotive, and construction. Furthermore, the biocompatibility of nanocellulose makes it a promising candidate for biomedical engineering applications, such as tissue engineering and drug delivery systems.The research presented in this paper highlights the potential of sugarcane bagasse as a sustainable and cost-effective source of nanocellulose. The success of this study underscores the importance of exploring innovative and sustainable alternatives to traditional production methods and opens up new avenues for future research and development in the field of nanocellulose-based materials. The continued advancement and utilization of nanocellulose have the potential to contribute to the development of sustainable and environmentally friendly solutions to a range of industrial and societal challenges.

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