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Synthesis of Cellulose Nanoparticle from Renewable and Natural Sources

Ishita Sil[1], Amlan Bishal[1*], Amir Sohail[1], Mohini Mondal[1], Reechik Bandyopadhyay[1], Richa Dayaramani[2] Biplab Debnath[3*]

[1] Department of Industrial Pharmacy, Bharat Technology, Jadurberia, Uluberia, Howrah 711316, West Bengal, India

[2] Principal and Professor, Silver Oak Institute of Pharmacy and Research, Silver Oak University, Ahmedabad, India

[3] Department of Pharmaceutical Chemistry, Bharat Technology, Jadurberia, Uluberia, Howrah 711316, West Bengal, India

***Corresponding author:**

Amlan Bishal, Bharat Technology, Uluberia, Howrah-711316

Biplab Debnath, Bharat Technology, Uluberia, Howrah- 711316

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KEYWORDS

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Macromolecule polymer

ABSTRACT:

Cellulose is present in plants and bacteria widely. These days, research is mostly focused on the application of bio-based materials. For new generations of enhanced resources to be developed, current technologies must be combined with readily available and renewable resources. The possibility of biomass and waste cellulosic materials as sustainable sources for nano-crystalline cellulose extraction has been studied by academics. In addition to the many treatment methods suitable for a wide range of applications, this review aims to offer thorough information on the extraction methods and applications of cellulose nanocrystals and cellulosic fibers derived from wastes of different sources. The synthesis of macromolecule polymer material is impacted by it. It has some great material properties. For that reason, cellulose nanocrystal has a great prospect in industrial area. Cellulose nano crystal is denoted as CNC and Cellulose nano fiber is also denoted as CNF. As this is a very important renewable future material, I have discussed about the methods of preparation of CNF and CNC.

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Introduction

Lignocellulosic components, including lignin, hemicellulose and cellulose are the primary component of plant biomass. Plant biomass agricultural byproducts can be used as low-cost, renewable, and sustainable raw resources to produce industrial biopolymers (1). The main component of cellulose is glucose, a macromolecular polysaccharide. It is a naturally occurring polysaccharide and crystalline macromolecular substance (2)(3). High strength, low density, high crystallization, biodegradability, biocompatibility, and other qualities are among the many attributes of cellulose nanocrystals. It is mostly utilized in the building, barrier, electronics, food, and pharmacy industries, among others (4)(5)(6). The main methods for preparing CNF include mechanical processes, among many more. Every technique has pros and cons of its own. We will be talking about the creation and uses of cellulose nanocrystals in this paper (7)(8).

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Table 1 Varieties of Nano celluloses, their manufacturing processes, the size of their building blocks, and how strong they are mechanically

Types of Nano cellulose	Main Sources	Production technique	Average size
CNC (Cellulose nanocrystals)	Bamboo, bacterial cellulose, wood, tunicate cotton, and ramie	Acid hydrolysis	3 to 50 nm in diameter Length: 30-300 nm based on cotton and wood, 100 nm to multiple microns (based on bacterial cellulose and tunica) (10)
CNF (Cellulose Nano fibrils)	Hemp, flax, potato, cotton, and wood	Grinding, Cry crushing, Micro fluidization, High pressure homogenization (11)	Diameter of 5–60 nm and length of many microns, irrespective of the source of cellulose (12)

Methods Of CNF Preparation:

Because of its low price and abundance mainly plant fibers are used in preparing the CNF. With a diameter of around 3 nm and lengths are in the micron range, CNFs show crystalline and amorphous portions both. (13) (14). Microfibers made of cellulose can be used to make them. Mechanical fibrillation may comprise homogenization, micro fluidization or grinding of cellulose biomass ultra finely—develops CNF based on the sources of cellulose and pre-treatments. Pretreatments, such as mechanical, chemical, or enzymatic pretreatments, are sometimes used to CNF to accomplish various goals, such as lowering energy input or improving CNF quality (15). Since cellulose is the most common biopolymer and the primary structural component of plant cell walls, it has been effectively exploited because of societal concerns about sustainable, ecologically friendly products.

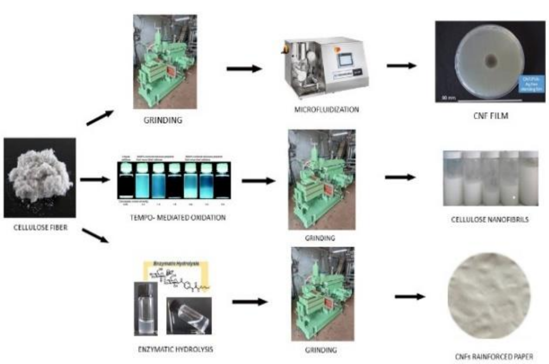

Figure 1 Manufacturing of Cellulose Nano Fibrils (CNF) using various methods

- **Nano Cellulose from Wood:**

Hardwood and softwood are the two main categories of wood. From both sources, Nano cellulose was successfully synthesized. A mechanical homogenizer was used to send a diluted fiber concentration (less than 1-2 weight percent) in order to homogenize the cellulose fibers from pine and eucalyptus pulp into nano-sized fibrils. To expedite the procedure and minimize the quantity of passes, the fibers were initially oxidized in a neutral environment (16) (17). When CNFs were separated from Eucalyptus and Pine, their morphology was examined utilizing a scanning electron microscope for field emission (FESEM). The diameter of the CNFs ranged from 5 to 20 nm. CNF isolation from wood employing a one-time grinding procedure was made possible in an undried state following the removal of matrix materials of 12 - 20 nm diameter (18). In addition to the homogenization process, other methods, such as acid hydrolysis, refining, and sonication—three of the most researched CNF extraction techniques—can be used to separate CNFs from Eucalyptus Kraft pulp (19). CNFs with a diameter of 10–60 nm were produced from sulfonated celluloses by employing a high-pressure homogenizer with chemically bleached birch wood pulp as the starting ingredient (20). CNFs with a diameter ranging from 5 to 20 nm were individually isolated from poplar wood with a strong ultra sonication and chemical preparation (21). Hemicellulose and lignin were extensively removed from the CNFs, providing around 69% crystallinity, according to the findings of the investigation using Fourier-transform infrared spectroscopy (FTIR) and x-ray powder diffraction

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(XRD). To biologically treat softwood kraft pulp, researchers extracted a genetically engineered fungus from Dutch elm tree fungus (22). They found that increasing the CNFs% yield in the region of less than 50 nm diameter was possible by natural fibers that is pre-refined prior to the biological treatment method.

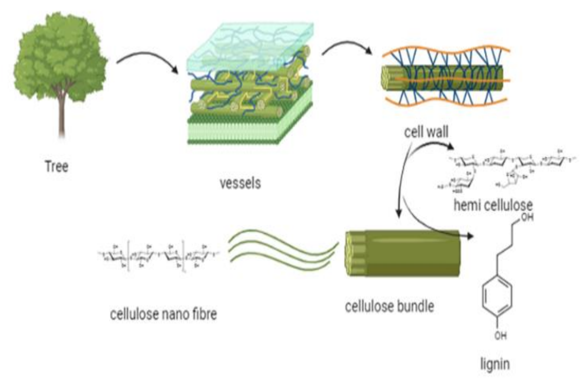

Figure 2 Extraction of Cellulose Nano Fibrils from wood

- **Nanocellulose From Nonwoody Crops and Plants:**

Hibiscus sapdariffa fibers were treated with steam explosion procedures to create CNFs with a greater cellulose percentage and a lower lignin percentage (23). An Explosion of steam in an alkaline media causes the hemicelluloses within the fiber to hydrolyze. It is then possible to extract the resultant sugars from the fiber by water, leaving behind lignin and cellulose residue that ultimately breaks the lignin-hemicellulose bonds. As a result of the reaction, lignin becomes more soluble in alkaline solvent and hemicellulose becomes more soluble in water, but the level of polymerization of the solid residue cellulose decreases. It has been demonstrated that microwave liquefaction, chemical treatment, and ultrasonic Nano fibrillation may all successfully remove non-cellulosic chemicals from bamboo. Successful extraction of CNFs with a diameter of 2 - 30 nm was achieved (24). Bamboo parenchymal cells became a desirable source because of their degree of lignification and comparatively loose cell wall structure (25). Acid hydrolysis is used to produce cotton nanofibers with a diameter of 6–18 nm and a length of 82–225 nm from naturally coloured and white cotton fibers (26). For white cotton nanofibers, the yields are higher. Customized CNFs made of hemp fiber that were between 30 and 100 nm wide and several micrometres long underwent high pressure defibrillation and chemical purification (27).

Figure 3 Nano cellulose from non –woody sources
Methods

- **Nano cellulose from Agroforestry Residues:**

To create CNFs, non-cellulosic ingredients like lignin, hemicellulose, and pectin compounds were removed using a mix of chemical and mechanical procedures (28). Corn husk, a byproduct of agriculture, was treated alkaline, then homogenized using TEMPO-mediated oxidation to create 8–10 nm width CNFs (29).

Pineapple leaf fibers were successfully removed from CNFs, which ranged in width from 5 to 60 nm, using the steam explosion method (30). High-pressure defibrillation produced an unusual structure of nanofibers that resembled an interlaced web. To extract CNFs, Soy hulls and wheat straw were processed utilizing a combination of mechanical and chemical methods (31). While the width and length of wheat straw nanofibers range from 10 to 80 nm, soy husk nanofibers have a diameter of 20 to 120 nm and a shorter length. Thermal gravimetric analysis, also known as thermo gravimetric analysis (TGA), was used to observe a considerable rise in the nanofibers' temperature characteristics after they underwent mechanical treatment that included cyro crushing, disintegration, and defibrillation. Prior to high pressure homogenization in a homogenous media, ionic liquid was employed as a pre-treatment to separate sugarcane bagasse into nanocellulose, which has 10–20 nm diameter (32). CNFs with lateral diameters of 20–30 nm were made Using crop leftovers from triticale, a high pressurized homogenizer, and a high-speed blender (33). The project's researcher decided that pulps made using

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triticale may be inexpensively and energy-efficiently transformed into CNFs by using a high-speed blender.

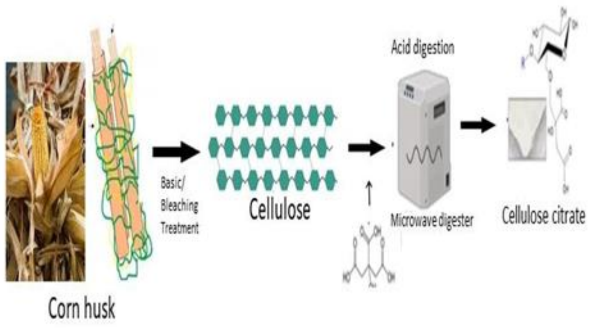

Figure 4 Extraction of nano cellulose from corn husk

- **Nano cellulose from Paper Waste:**

Every year, a massive amount of paper waste was disposed of, which contaminated the environment. Finding new ways to turn this paper from a waste of money into a valuable and difficult task.

A combination of mechanical ultrasonic treatments and acid hydrolysis is employed to extract rod-like CNFs from waste newspaper. Pulping, flotation, and washing are the three different procedures that were employed to investigate the potential of municipal paper waste for CNF manufacture. After that, the trash was subjected to ultrafine grinding (34). It was possible to successfully transform waste corrugated paper pulp into very long cellulose nanofibers with an exceptionally high aspect ratio by combining chemical treatment, grinding, ultra sonication, and centrifugation. The diameter range of the resultant CNFs was 30-100 nm (35).

- **Nano cellulose from Animals:**

Research on animal-derived cellulose was not as developed as that on bacteria, fungus, and plants. But scientists have shown that cellulose can also be taken out of creatures like tunicates, prawns, and crabs.

Atomic force microscopy (AFM) revealed that tunicate was utilized to assemble CNFs with an 8 x 20 nm cross section (36) . The tunicate's mantles were removed and sliced into tiny pieces. Sodium hydroxide and chloride were utilized in accordance with the delignification process to purify the cellulose. Two procedures were utilized to break down pure cellulose into micro fibrils: sulfuric acid hydrolysis and oxidation mediated by TEMPO, then mechanical treatment in water.

The prawns, crabs, and squids' exoskeleton were processed into chitin nanofibers by a straightforward mechanical procedure and a sequence of purification stages (37). This technique yields thin nanofiber networks with consistent widths of about 10 nm.

CNC Extraction Method:

Previous researchers have devised and employed many ways to extract Nano cellulose from cellulose. primarily the hydrolysis technique, which breaks down the cellulose fibre’s amorphous regions (38). Because acid hydrolysis has a quick reaction time and may extract Nano cellulose, sulfuric acid is the acid of choice for this process. Scholars generally concur that the acid hydrolysis process calls for a relatively high acid concentration (50–70 weight percent), an estimated temperature of 40–50 degrees Celsius, and a retention period of 30–90 minutes (39).

Enzymatic hydrolysis is a hydrolysis technique that is different from acid hydrolysis in that it breaks down cellulose into sugars using enzymes, which are often found in bacteria and fungus (40) (41) research on the production of CNC from wheat straw using cellulose in conjunction with ultra sonication treatment revealed that this method has drawbacks due to its lengthy duration, even though the yield obtained is comparable to that of acid hydrolysis treatment. Bacterial Nano cellulose, a different type of Nano cellulose made by Acetobacter species, has special qualities that make it ideal for treating wounds, including high water absorbance and biocompatibility (42) (43).

Subcritical water (SCW) treatment stands out because, in contrast to enzymatic hydrolysis, it does not require harsh conditions and can be completed reasonably quickly. The disadvantages of acid hydrolysis include severe conditions and what seems to be a lengthy process. Using SCW, cellulose powder was heated to between 120 and 200°C while pressure was maintained to generate CNCs. The CNCs were then suspended while filtration, dialysis, and sonication were completed (44).

Researchers have also actively investigated mechanical processing as a means of producing Nano cellulose.

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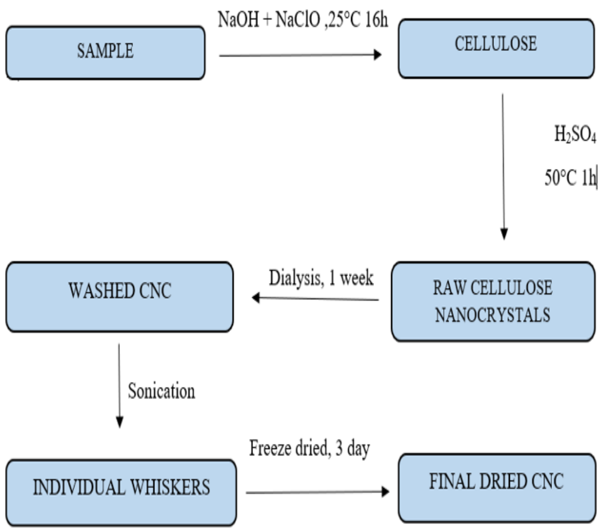
Ultrasonic or pressure homogenization are common methods. The use of hydrolysis and sonication together has also increased interest in improving the aspect ratio of CNC



Flow chart 1: Typical acid hydrolysis process for CNC manufacturing (45)

CONCLUSION:

A growing number of applications are showing interest in nano cellulose because of its special qualities. Even though it's commonly known that cellulose may be found in plant cell walls, Researchers have demonstrated that animal exoskeletons, such those of tunicates, can also yield nano cellulose. When these cellulose sources are treated properly, Nano cellulose can be extracted and exist in the forms of bacterial, CNC, and CNF forms.

Growing interest has been shown in upgrading waste to make it into a product or substance that is valuable, thanks to the abundance of investigation into the extraction of nanocellulose from organic sources. Hydrogel to absorb oil from the ocean and super water absorbent material are just two uses for Nano cellulose, which can be produced by processing waste materials like paper waste. This adds value to the trash rather than just tossing it away. Even though the created Nano cellulose might not have the same qualities as commercial Nano cellulose, waste transformation has evolved into a beautiful endeavour.

Numerous techniques have been investigated to produce Nano cellulose, with hydrolysis emerging as the most popular technique. When it comes to a speedier, safer, and cleaner process than enzymatic hydrolysis and acid hydrolysis, subcritical water hydrolysis is superior, when turning waste into a product or substance with added value, deserves more investigation.

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