"CELLULOSE NANOCRYSTALS IN FOOD INDUSTRY"

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Abstract

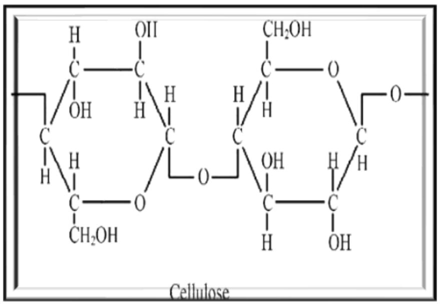
Cellulose, a macromolecule polysaccharide is most **broadly dispensed** in plants, fungi, **micro organism** and marine animals. Nanocellulose is a **time period relating to** nano-**dependent** cellulose. This **can be both** cellulose nanofibers (CNF), cellulose nanocrystals (CNC) or bacterial nanocellulose (BNC). CNC, a **period** of **one hundred** nm, **consists** of nanocelluloses with alternating crystalline **domain names** with rod like structures, **received with the aid of using distinctive** isolation **strategies** like acid, alkali and enzymatic hydrolysis. The cellulose nanocrystals have **incredible bodily** and chemical **houses** and are **taken into consideration** as novel **meals element** and biodegradable packaging **substances** in **meals** industry, used as a thickeners, flavor carriers, suspension stabilizers in a **extensive type of meals merchandise** and in **utility** of **transport** system. Based on its small size, **huge floor** area and **excessive** crystallinity, cellulose nanocrystals **famous incredible** mechanical **houses**, **excessive** thermal stability, **energetic** chemical **response houses**, and the rheological **houses**.

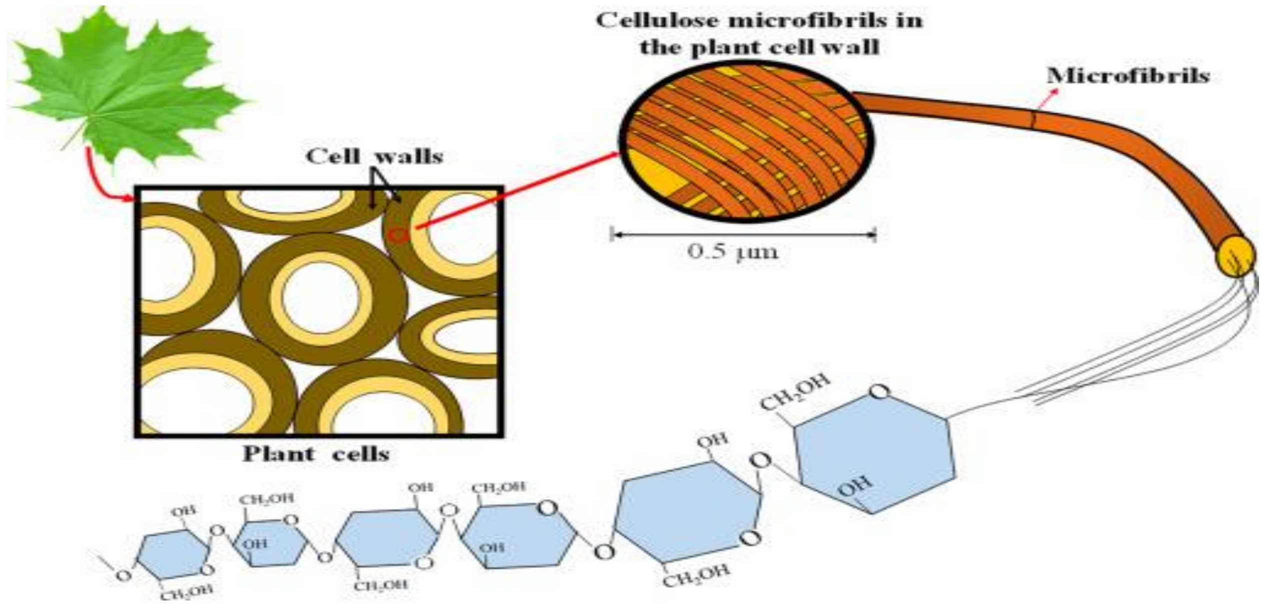
Key words : Cellulose, Nanocrystals, Food industry

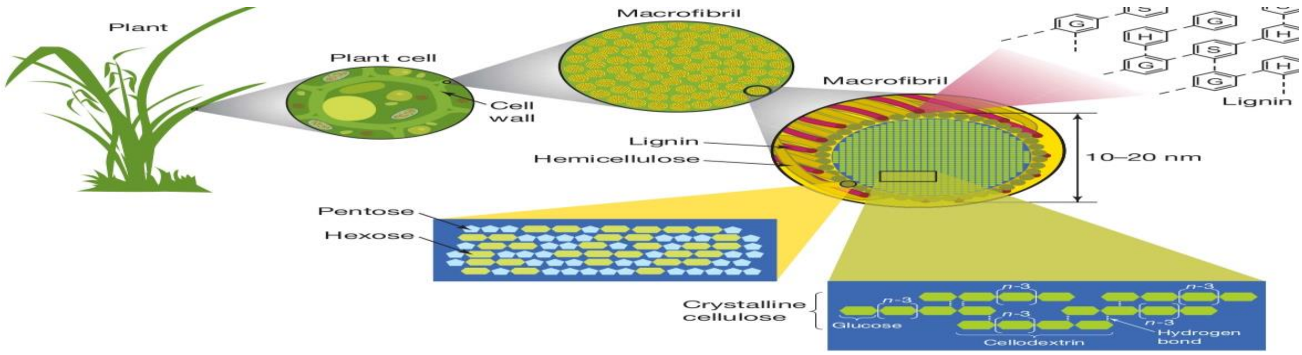
Introduction

Cellulose

- Cellulose was first discovered by Payen.
- Present in plant cell wall at around 30 -50%.
- Two forms of cellulose(crystalline and amorphous).
- It is composed of β 1,4 – linked glucopyranose units.







Cellulose present in the cell wall of plants in the form of cellulose microfibrils. Figure 1 shows the chemical structure of cellulose.

Plant **mobileular partitions** are **complicated systems made out of various** configurations of interlocking polysaccharides. Fig 2. **indicates** the simplified **shape** of the **mobileular** wall and the cellulose **association within side the** plant **mobileular**. Based on its **shape** and composition, the **mobileular** wall **is split** into **3 special** layers: the **center** lamella (ML), the **number one** wall (P), and secondary wall. The ML **carries** a **excessive quantity** of lignin and is **on the whole chargeable for** binding the neighbouring cells. The **number one** wall is **about** 30-**one thousand** nm thick and **carries 3 fundamental** components-cellulose, hemicellulose, and pectin-**in which** cellulose microfibrils (MFs) are **organized** crosswise. The secondary **mobileular** wall is further divided into **3** layers, the outer (S1), **center** (S2), and inner (S3) layers, which **range of their** microfibrils' **attitude** with **admire** to the fibre axis [21]. Among all, the S2 layer is the **maximum precious** and **carries the best quantity** of cellulose.

Types of cellulose

There are **4 one-of-a-kind** polymorphs of cellulose: cellulose I, II, III, and IV. Cellulose I is **local** cellulose, i.e., **determined** in nature, and it **takes place** in allomorphs, Iα and Iβ. Cellulose II is **additionally known as** regenerated cellulose; **it's far** the **maximum solid shape** of crystal, and emerges from aqueous sodium hydroxide **remedy** of cellulose I. The **feature difference among those kinds of** cellulose lies in the **format in their** atoms: the chain in cellulose I is in parallel direction, **while it's far determined** to be antiparallel in cellulose II. Cellulose IIII and IIIII **may be received through** ammonia **remedy** of cellulose I and II, respectively, **while**, cellulose IV is derived from the **change** of cellulose III.

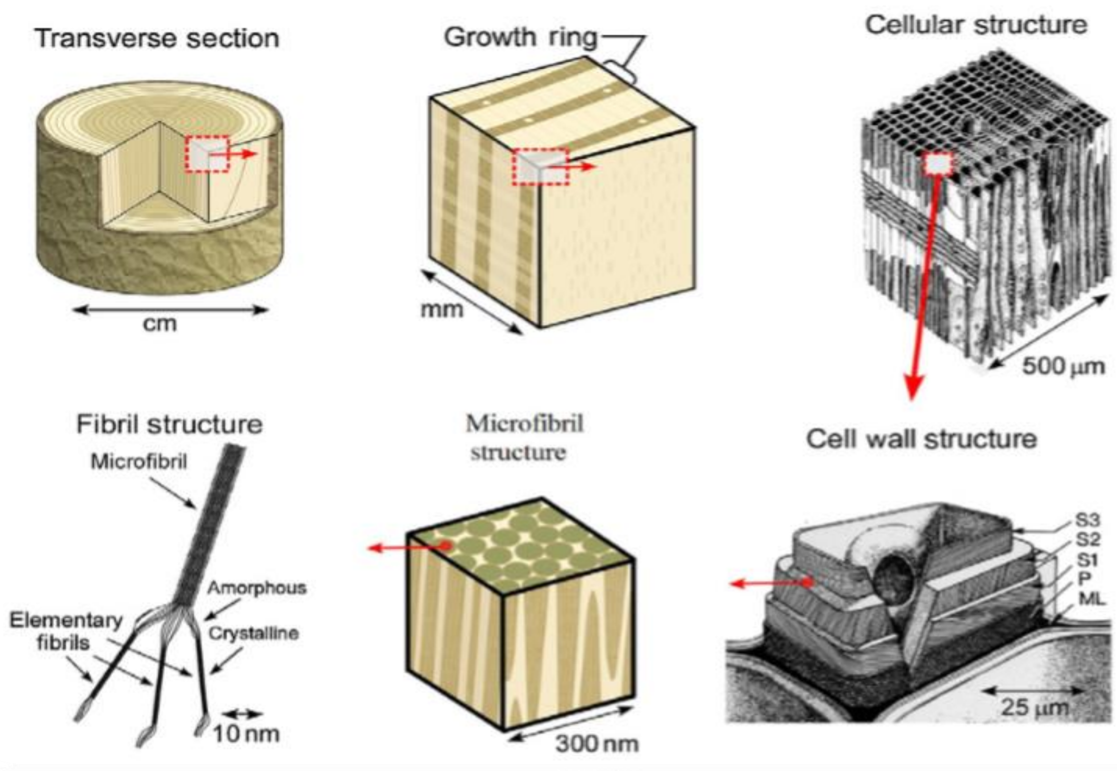
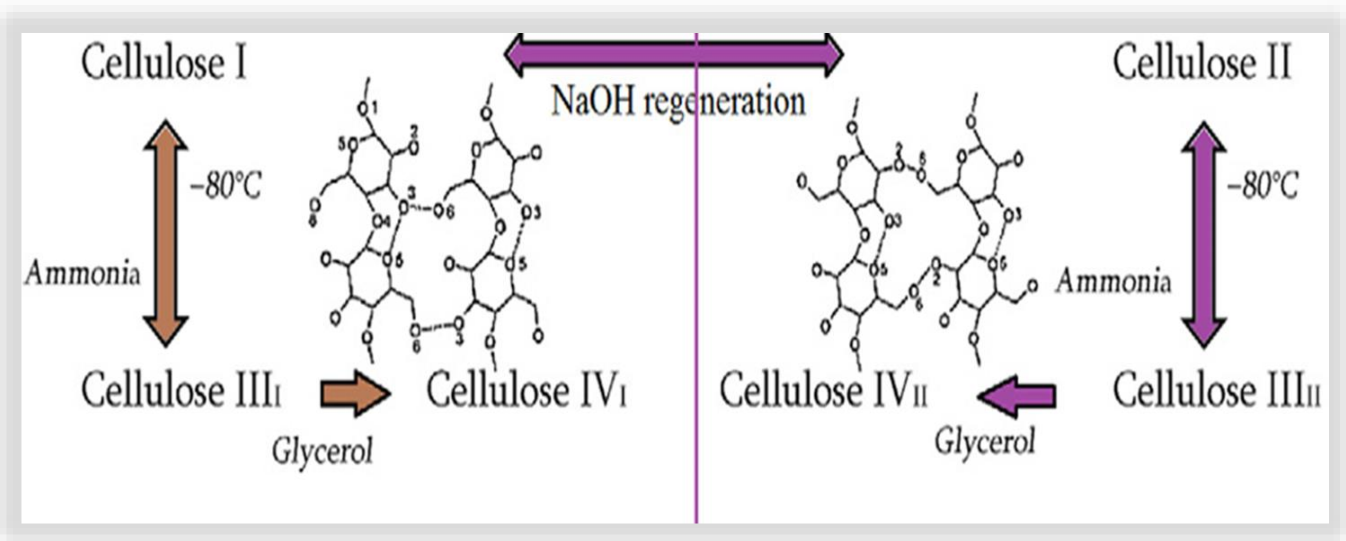


Figure 2: Transection view of cell wall

Nanocellulose



Why nano?

The size reduction enables new opportunities for the development of innovative nano systems and nanostructured materials.

Particle of any shape with dimensions < than 100 nm

Properties of nano particles

Very powerful; wide area; and very reacting, Less Defect, Thermal steadiness, Distinctive optical, electrical, and magnetic characteristics

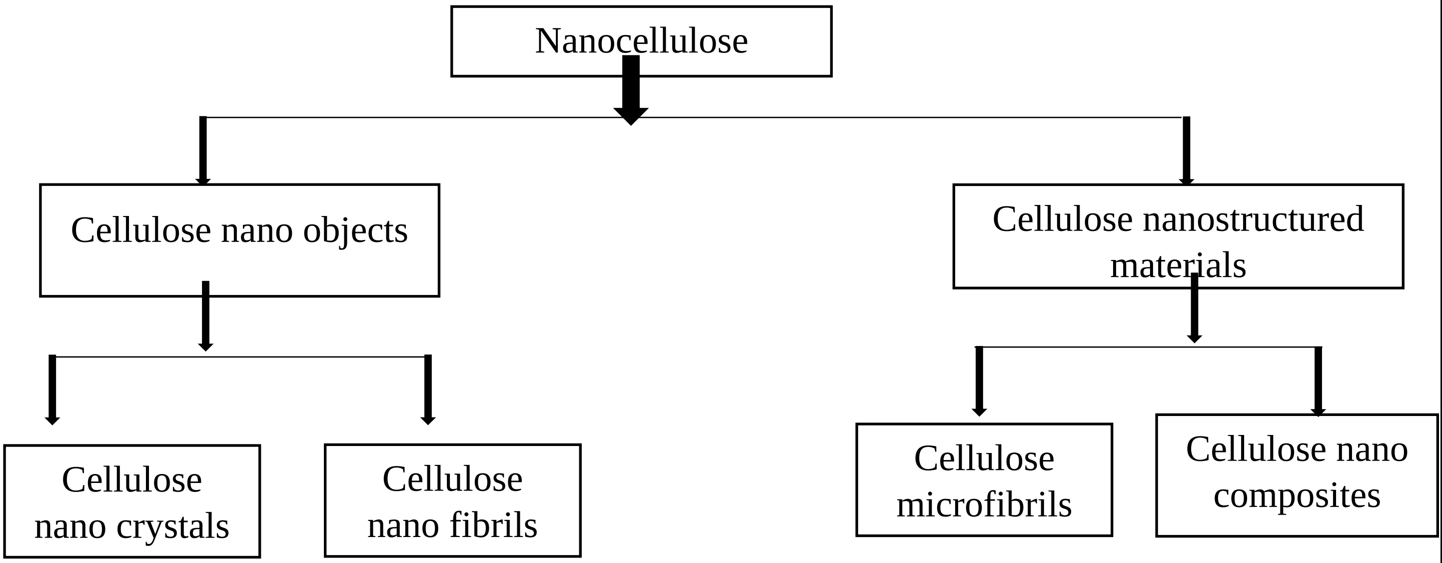
Why cellulose?

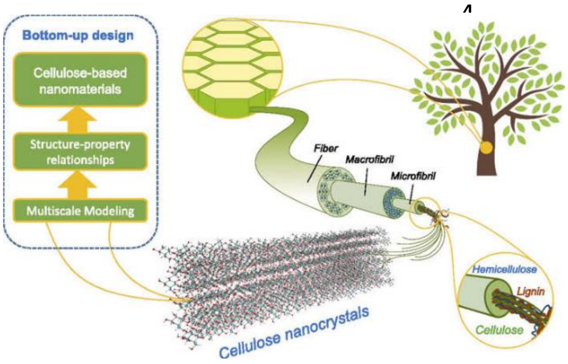
A sustainable material: high availability, natural & renewable, economic, non-toxic, biocompatibility and biodegradability

Properties of nano particles

High strength and modulus, flexibility, and light weight, Charged with electricity, Reactive to chemicals, Dimensional steadiness, Water assimilation, Barrier characteristics, Low aspect ratio, Transparency and opacity

Classification of nanocellulose





Cellulose nanocrystals

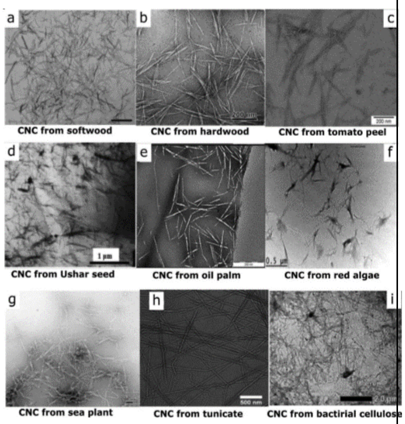
- Cellulose nanocrystals are nanoscale celluloses extracted from **herbal** Nanofibers.
- ·Organized **shape** of strongly ordered crystalline particles.
- ·Rod like crystalline particles.
- ·Crystalline index above 75%.
- ·Rectangular in **pass** section.
- ·These are **fashioned with the aid of using the usage of distinct** isolation methods (acid hydrolysis, mechanical method)

Sources of cellulose nanocrystals

Animal excrement and plants

Industrial wastes like fruit and vegetable peels include 10–30% cellulose, as do agricultural and industrial wastes like rice husks and oat husks, which contain 30–60% cellulose on average. Regarding the extraction of polysaccharide and NC, a variety of plant materials are being researched, including wood, rice husk, sisal, hemp, flax, kenaf, and coconut husk.

Bacteria



There is only cellulose in bacteria. Compared to plant nanocellulose, it has a great capacity to retain water. Because it lacks lignin and hemicellulose, the extraction process is easier than with plant nanocellulose.

Bacterial cellulose (BC) is a byproduct of some bacteria's basic metabolic operations. Gluconacetobacter xylinus is the most frequently seen species of BC-producing bacteria.

Algae :
Among red, green, yellow algae, red algae has more content of cellulose.

Tunicates:
Tunicates are marine invertebrate animals. Tunicate cellulose **consists of just about natural** cellulose of CIβ allomorph **kind** with **excessive** crystallinity.

Hierarchal arrangement of cellulose nanocrystals

Cellulose undergo spinning in hierarchical arrangement in which cellulose present in the form of fibers. Through some of isolation process it convert into cellulose microfibres and again through acid hydrolysis it converts into cellulose nanocrystals.

Bottom up design

Understanding of cellulose nanomaterials through multiscale modelling with the guidance of bottom up design to know the structure property relationships of cellulose based nanocrystals.

Properties of cellulose nanocrystal

• High strength and modules • High surface area and aspect ratios, High thermal stability, Strong water binding ability, Possibilities for modifying chemicals, Ecological disposal or recycling at the end of life, Ecologically sound natural materials

Methods of isolation of cellulose nanocrystals

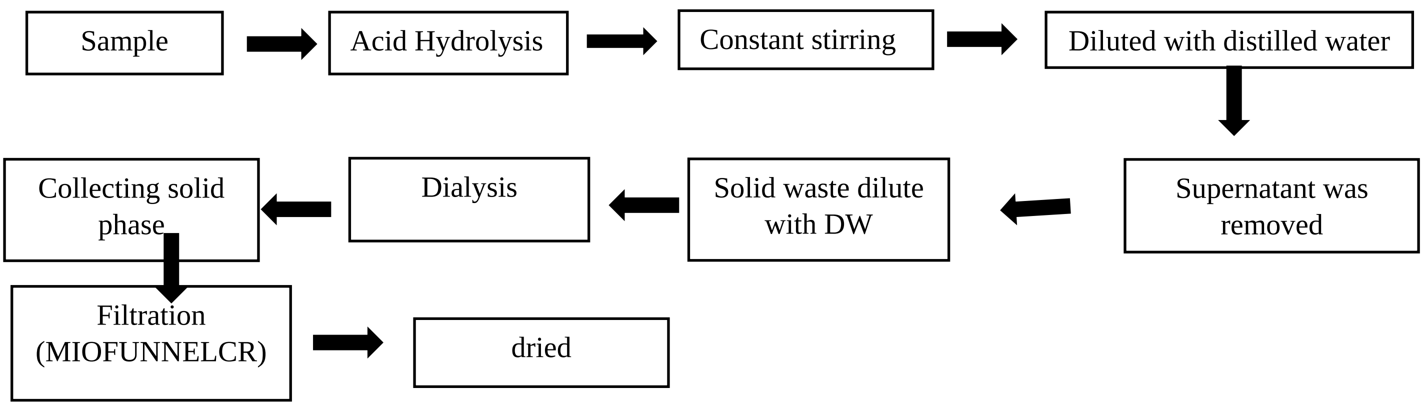
Pre-treatment methods: Enzymatic hydrolysis, Alkali method, Ionic method

Chemical hydrolysis: H_2SO_4 hydrolysis, HCL hydrolysis

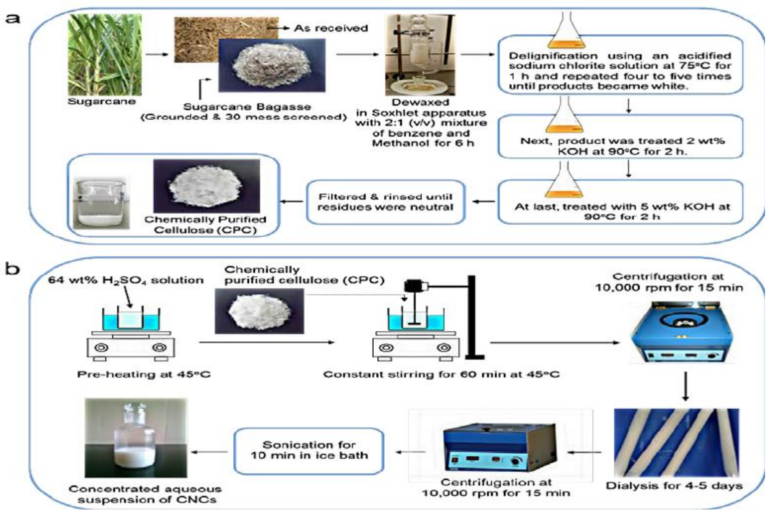
Mechanical method: High pressure, Grinding, Cryocrushing, Ball milling

1. **Acid hydrolysis:**

To **launch** CNCs, acid hydrolysis of purified cellulosic **fabric** is **carried out** using **robust** mineral acids **below managed** temperature, time, agitation, and acid/cellulose ratio conditions. Different mineral acids **may be** used for this purpose, **along with** sulfuric, hydrochloric, phosphoric, maleic, hydrobromic, nitric and formic acids. Sulphuric acid is the **maximum notably** used acid for CNC preparation. During hydrolysis, disordered amorphous **domain names** and **nearby** interfibrillar contacts of cellulose are preferentially hydrolysed, **while** stable crystallites **continue to be** intact and **may be remoted** as rod-like nano crystalline particles. The CNC dispersion in a **robust** acid is diluted with water and washed using successive centrifugations. Neutralization or dialysis with distilled water is performed to **cast off loose** acid from the dispersion. Additional steps **along with** filtration, centrifugation or ultra-centrifugation, **in addition to** mechanical or ultrasound disintegration.

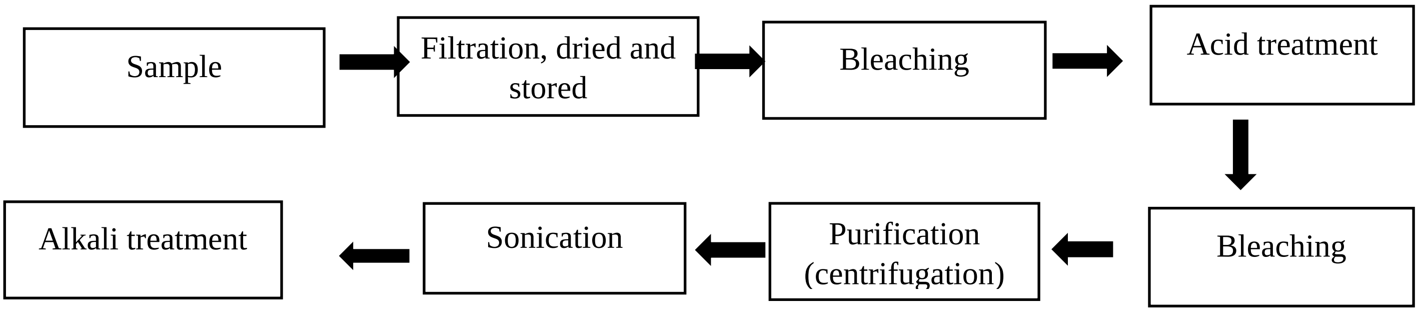


Example :



2. Acid alkali pre-treatment

This pre-treatment **consists of 3** steps
(i)soaking of plant fibers in 12–17.**five** wt% sodium hydroxide for 2h, **so one can growth** the fiber **floor location** and to make the fibers **extra at risk of** hydrolysis
(ii)Treatment of the fibers with 1M HA at 60–80∘C **so one can** hydrolyse the hemicelluloses
(iii)Treating the fibers with 2 wt% NaOH **answer** for 2h at 60–80∘C to disrupt the lignin structure. After such pre-treatment, the cellulose **content material** increases from 43% to 84%.



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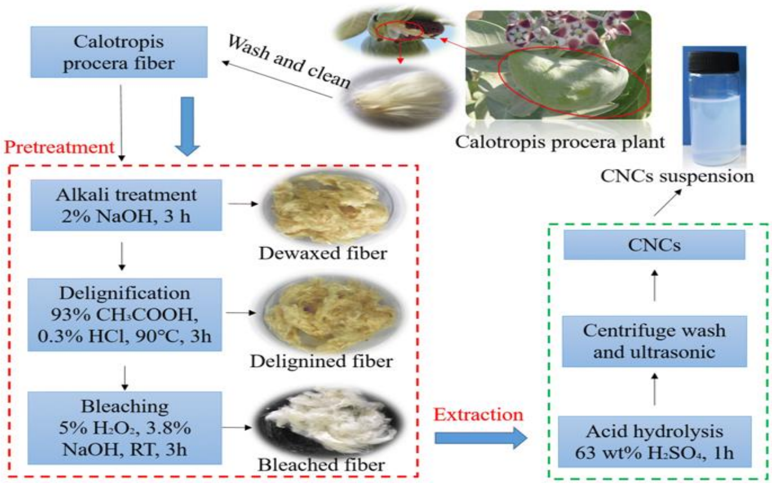
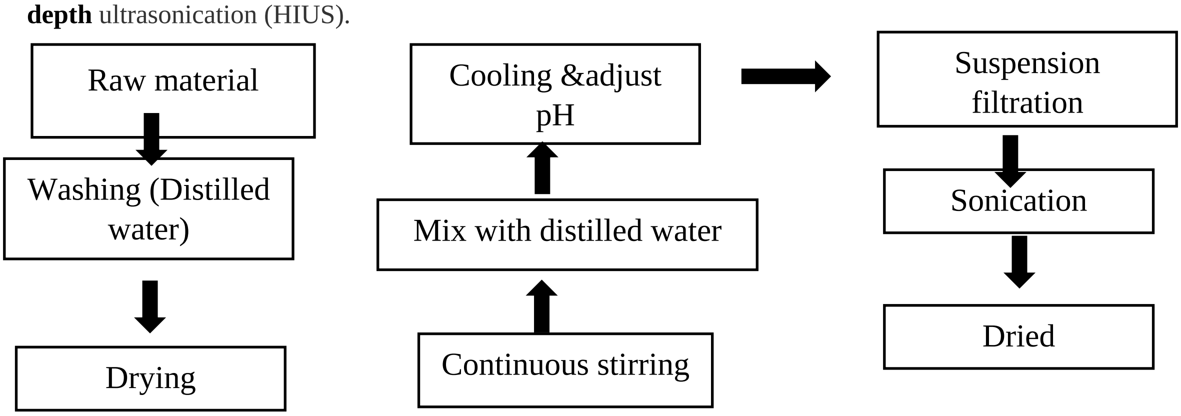


3. Mechanical treatment

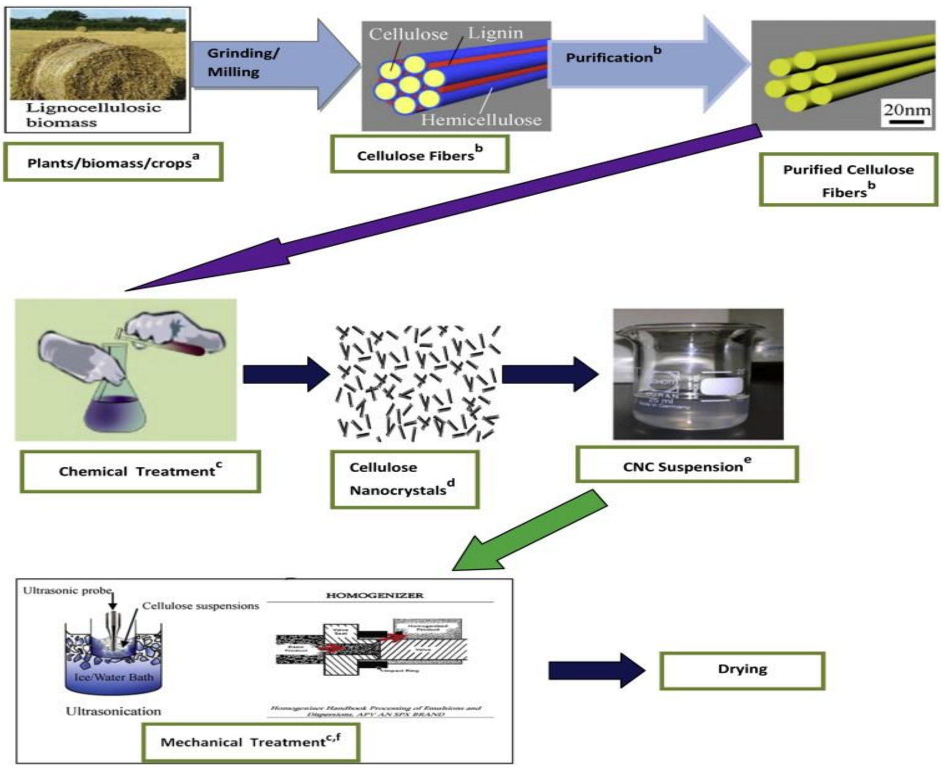
Cellulosic **substances** are required to **undergo** mechanical **remedy** for defibrillation. Pre-**remedy** processing, **both via way of means of chemical compounds** or enzymes, is **finished earlier than** mechanical **traumatic inflammation** to ease the process. Chemical **remedies assist** in widening **the distance among** hydroxyl groups, **growing** the **internal floor**, **changing** crystallinity, and breaking cellulose hydrogen bonds, **as a result improving floor** areas, which **allows improve** the reactivity of the fibres. There are many mechanical **strategies** for converting cellulosic fiber to nanocellulose, **inclusive of** homogenizing, micro-fluidization, grinding, crycrushing, and high-**depth** ultrasonication (HIUS).



Bleaching using sodium hydrochloride → Hydrolysis using sulphuric acid

Convert into powder

Example :

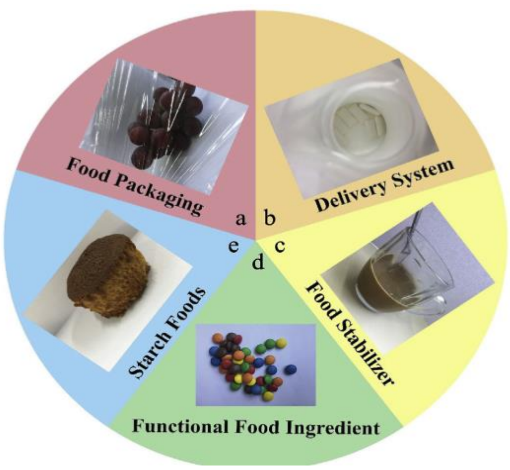


Size of cellulose nanocrystals

Source	Preparation method	Length(nm)	Width(nm)	Aspect ratio(L/D)
Wood	H_2SO_4 hydrolysis	100-300	3-5	20-100
Cotton	HCL hydrolysis	100-150	5-10	10-30
Ramie	H_2SO_4 hydrolysis	70-200	5-15	12
Sisal	H_2SO_4 hydrolysis	100-300	3-5	60
Tunicates	H_2SO_4 hydrolysis	>1000	10-20	100
Bacteria	H_2SO_4 hydrolysis	100-1000	10-50	2-100

The dimensions of cellulose nanocrystals depending on the source and method of preparation

Applications of cellulose nanocrystals

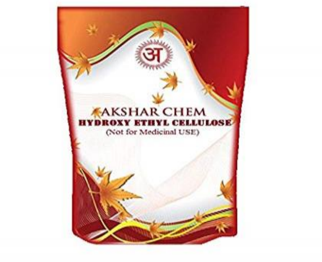


Some derivatives of CNC

Cellulose nanocrystals - ~12% aqueous slurry

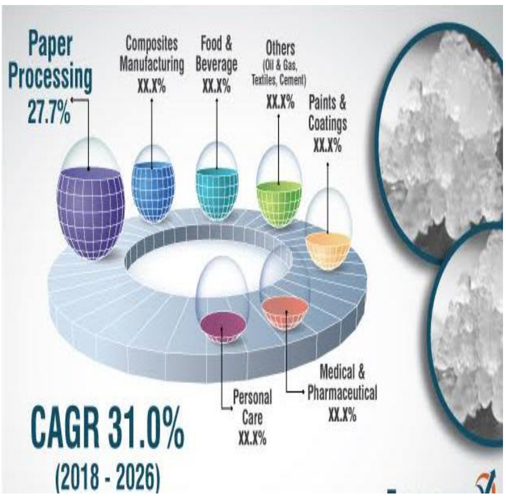
Cellulose nanocrystals - ~98% spray dried

Cellulose nanocrystals - ~98% freeze dried

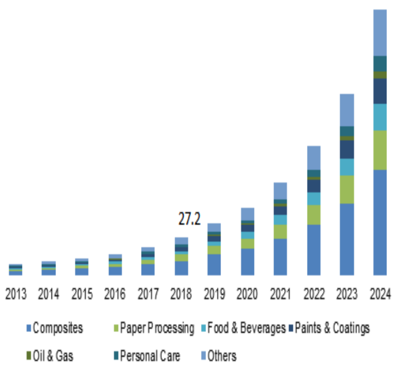


Global Nanocrystalline Cellulose Market Share (%)

By End User (2018)



Compound annual growth rate was expected at 31% at the end of 2026.



Companies that manufactures CNC

American Process Inc.
Blue Goose
Hokuetsu
NCCTM
Plantrose
Tech Futures
University of Maine
US Forest Service

Review of Literature

Trilokesh and Uppuluri. (2019) conducted a **observe** on isolation and characterization of cellulose nanocrystals from jackfruit peel. Cellulose nanocrystals (CNCs) **had been effectively remoted** from the jackfruit peel **the usage of** sodium chlorite **remedy accompanied via way of means of** sulphuric acid hydrolysis. The **general** produced cellulose **turned into** 20.08 % w/w (dry weight). The **remoted** CNC **had been characterised** for its morphology, functional, crystal and thermal **residences via way of means of** SEM, FTIR, NMR, HPLC and TGA. Results revealed, the presence of α-cellulose **and shortage** of other biomass fractions like hemicellulose and ligninwith **excessive** crystallinityof83.42%. Hencethe **remoted** cellulose and CNCs from jackfruit peel waste **may be hired** for potential applications **withinside the discipline** of food, paper, paints, optics, pharmaceutics, **surroundings** remediation, composite synthesis.

Extraction and characterizations of cellulose nanocrystals from pineapple peel **turned into** evaluated **via way of means of Madureiraet al. (2018)**. Pineapple residues **had been** purified to **cast off** pigments, waxes, hemicellulose and lignin **via way of means of** bleaching for **four** hr (TPP4) **and six** hr (TPP6). The **dealt with** pineapple peel (TPP4 and TPP6) **turned into** taken for extraction of cellulose nanocrystals **via way of means of** acid hydrolysis for 30 and 60 min. These cellulose nanocrystals had small sizes (< 100>)

Extraction of cellulose nanocrystals (CNC) from rice, oat husk and eucalyptus for the **manufacturing** of aerogels for **meals** packaging **utility became** investigated **with the aid of using oliveira et al. (2018)**. Commercial cellulose **became** used as a **manage** sample. CNC **have been acquired** from enzymatic hydrolysis and mechanical treatment. The **common** diameter of the nanocrystals **numerous** from 16.**zero** to 28.**eight** nm. The aerogels **organized** with cellulose nanocrystals **confirmed** a porous and uniform **shape** with a water absorption **potential among** 264.2% and 402.**eight**% at 25°C. The aerogel of oat cellulose nanocrystals **confirmed a bigger** pore **length** and **large** water absorption **potential** of the aerogels than **different** cellulose nanocrystals. These **effects confirmed** that agro-**commercial** residues have promising **packages** in **diverse commercial** fields and **may be** used as aerogel absorbers of water in **meals** packaging.

Varanasi et al. (2018) conducted a **have a look at** onthe **position** of electrostatic forces **withinside the** CNC **capacity** to stabilize oil/water emulsions is explored **the use of** canola oil/water and hexadecane/water as **version structures**. Canola oil/water and Hexadecane/water (20/80, v/v) emulsions **have been** stabilized with the addition of CNCs **the use of** ultrasonication. Emulsion droplet **length is two** µm as measured **with the aid of using** optical microscopy. It **became discovered** that CNC can stabilize oil/water emulsions **no matter** their **rate** density. The **discount** of pH **under** 2 **results in** the aggregation of CNC to **shape** stable emulsion, **shape** a gel-like behaviour. The **effects indicates** that the **structures** are **absolutely** biodegradable and biocompatible **and may shape** gels, **starting** new innovation avenues in **meals** and biomedical **packages**.

Production of biodegradable starch nanocomposites **the use of** cellulose nanocrystals extracted from coconut fibre **became** studied **with the aid of using Cerqueira et al. (2017)**. Cellulose nanocrystals **have been** extracted from coconut fibres and **included** in manioc (cassava) and potato starch **movies** at **exclusive** concentrations. The nanobiocomposite biodegradable **movies evolved** with addition of cellulose nanocrystals exhibited **appropriate** barrier and mechanical **houses consisting of accurate** transparency, manageability, homogeneity, **good enough** solubility, and **excessive** strength. The potato starch **movie** with **the bottom** nanocrystal **attention became discovered** to **showcase** the **first-rate** mechanical **houses**.

GLOSSARY

CNC: Cellulose Nano Crystals
PP : Pineapple Peel
TPP: Treated Pineapple peel
DLS: Dynamic light scattering
SEM: Scanning Electron Emission
NMR: Nuclear Magnetic Resonance
ZP: Zeta Potential
TGA: Thermogravimetric analysis
DSC: Differential scanning calorimetry

CONCLUSION

CNC (Cellulose nanocrystal) is **specific amongst a selection** of **different** nanostructure **substances because of** its renewable, sustainable, nontoxic, and biocompatible nanomaterials in nature and having **greater packages** in **meals** industry. CNC **may be** used as additives, thickeners, flavor carriers, suspension stabilizers, **shipping** system, packaging system. Even **aleven though** it is having **diverse extraordinary residences** and **excessive** availability in nature, the extraction of cellulosic **cloth** is **huge** challenge. There are **nevertheless** no common **policies** for CNC in worldwide, and **unique** human and the environmental **dangers** of CNC is **want** to be **similarly** explored. Further **studies want** to be **targeted** on their technological and **dietary residences**, **protection checks** and **law** for **meals** application.

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