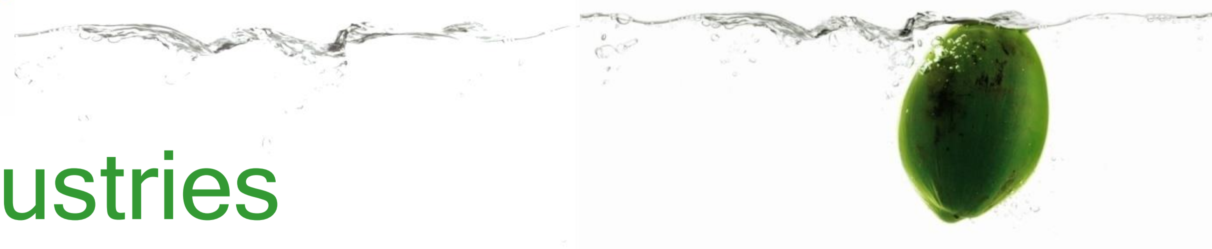
# Green Coco Brasil Project

## Coconut Fiber Nanotechnology and Circular Economy

# Green Coco Europe GmbH

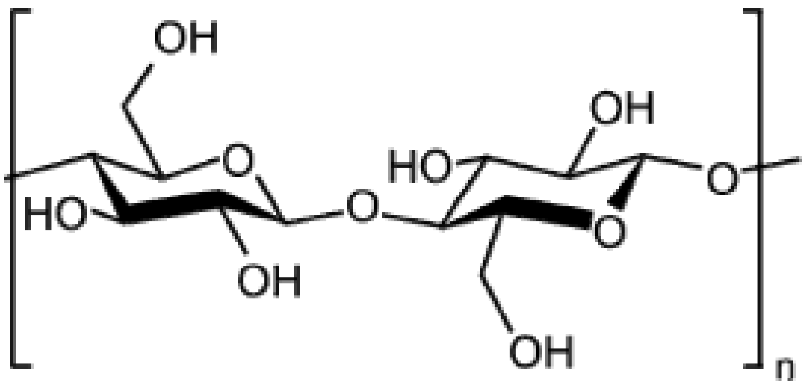

https://dr-martins.com/

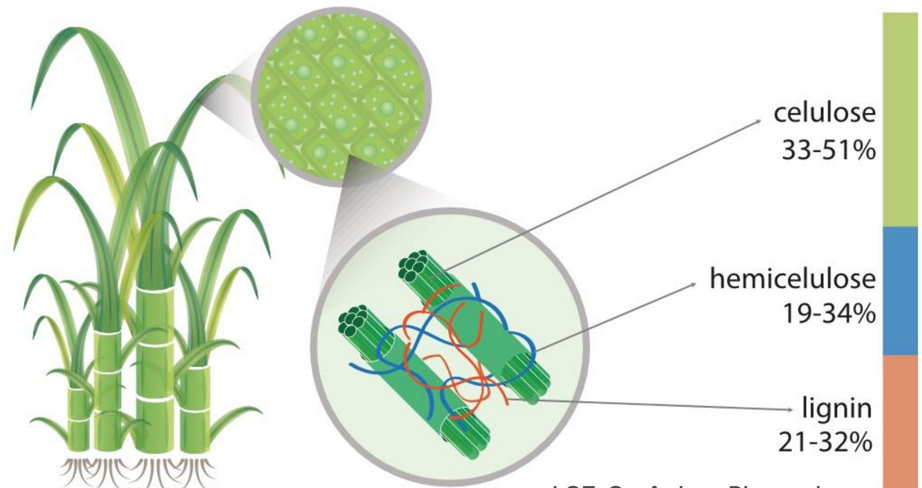

dr. antonio MARTINS



# Green coco Industries
## (Green Coco Brasil Project)

## ❖ Cellulose



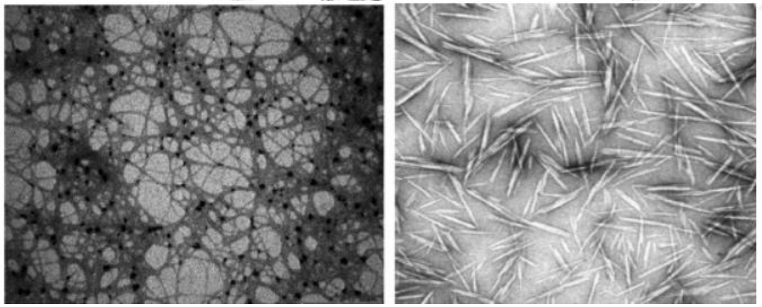




LGE: Genômica e Bioenergia

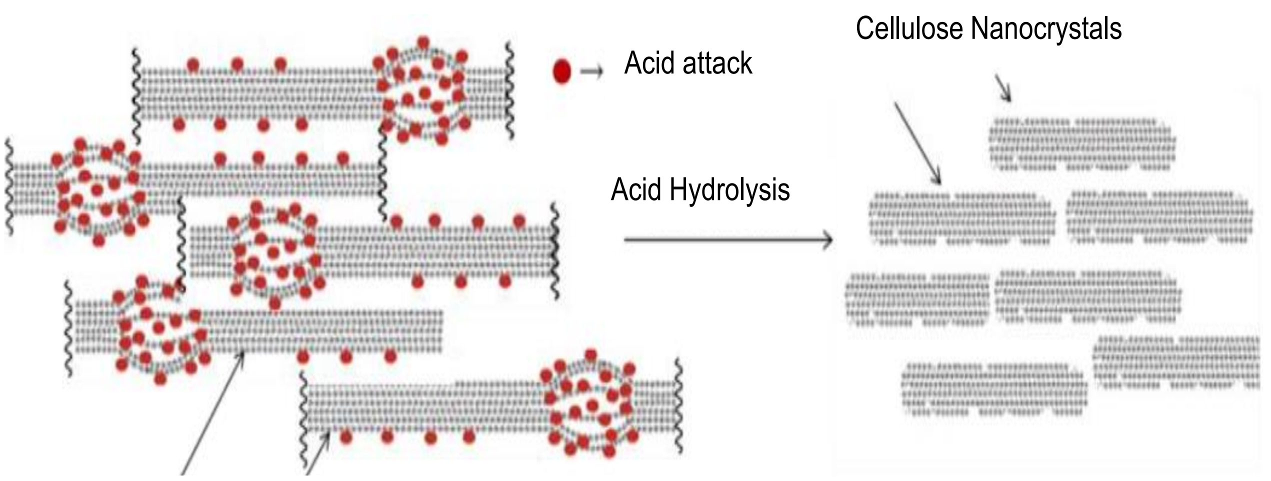
- Abundant natural material obtained from renewable and sustainable sources and with low environmental and health risks (most abundant organic substance on earth);
- Its function is to be the dominant reinforcing phase in the structure of plants;
- Low cost, biodegradable, low density and extraordinary physical and mechanical properties;
- This material has been the subject of intense research and development with the advent of nanotechnology.

Sources:
Miranda, 2011
Guimaraes 2018
https://www.lge.ibi.unicamp.br/pesquisas/biomassa/

## ❖ Nanocellulose



- Particles with a high degree of crystallinity, with a high specific area, very high rigidity and tubular shape;
- Diameter in the range of 3-20 nm and length between 100-600 nm;
- They are remnants of acid hydrolysis of wood pulp or biomass fibers;
- Dimensions and degree of crystallinity depend on the source of the cellulose;
- Obviously, these characteristics influenced its performance as a reinforcement particle in polymer matrices.



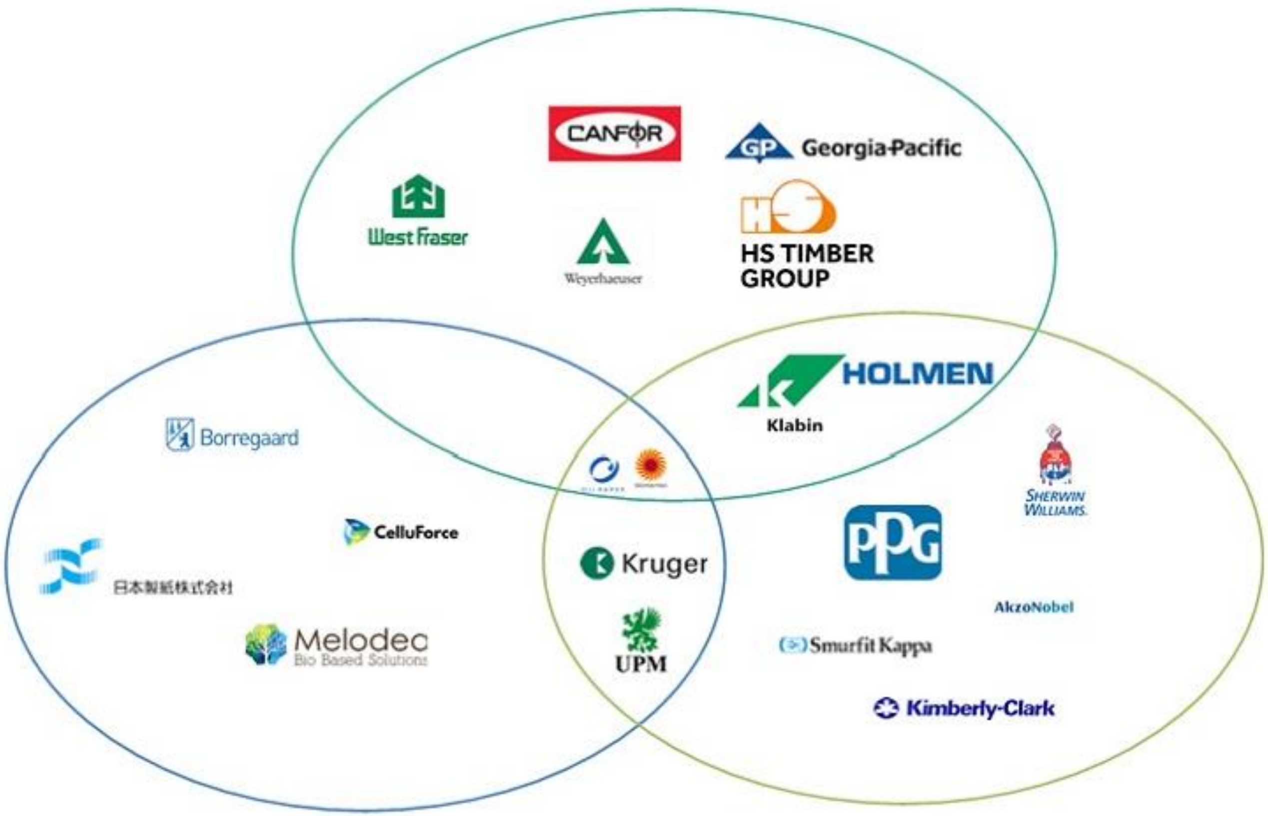

Sources:
Guimaraes 2018
AGROPALMA

## ❖ Nanocellulose Market by Demand


Markets and Markets

Saucers:
https://www.marketsandmarkets.com/Market-Reports/nano-cellulose-market-56392090.html

# ❖ Nanocellulose Market Ecosystem




RAW MATERIAL MANUFACTURER AND SUPPLIERS

NANOCELLULOSE MANUFACTURERS

END USERS

Markets and Markets

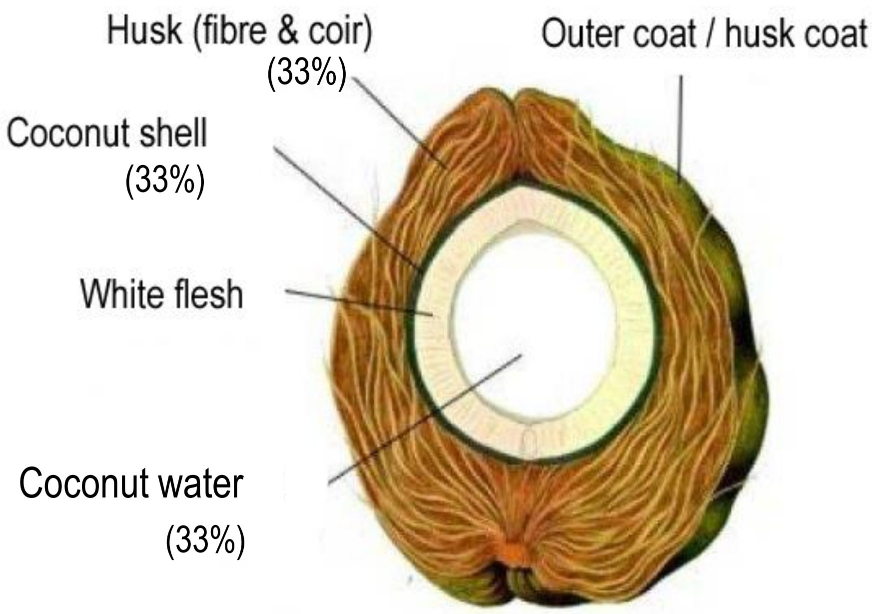
Saucers:
https://www.marketsandmarkets.com/Market-Reports/nano-cellulose-market-56392090.html

## ❖ Nanocellulose Market by Application

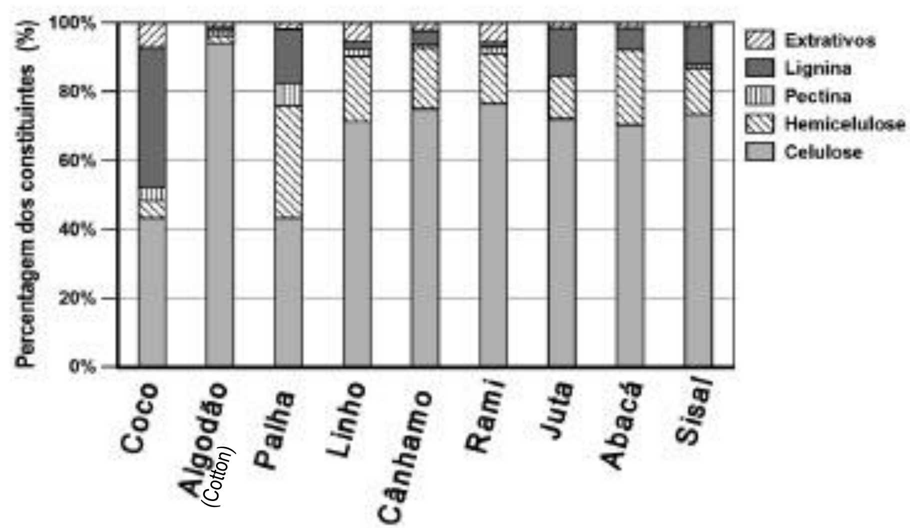

Markets and Markets

Saucers:
https://www.marketsandmarkets.com/Market-Reports/nano-cellulose-market-56392090.html

# ❖ Obtaining Cellulose/Nanocellulose from Coconut Fiber




Coconut component schematics (Salah, 2017)




Biochemical composition of some plant fibers

| Sample | Chemical composition (%) | | |
|---|---|---|---|
| | α-Cellulose | Hemicelluloses | Klason lignin |
| Coconut fiber | 31.6 ± 0.4 | 25.5 ± 0.4 | 35.1 ± 2.2 |
| Delignified pulp | 41.8 ± 4.9 | 42.2 ± 5.3 | 19.1 ± 2.1 |
| Bleached pulp | 70.0 ± 0.6 | 28.0 ± 0.5 | 0 |
| Recovered lignin | – | – | 94.5 ± 0.8 |

Biochemical composition of coconut fiber, delignified pulp, bleached pulp, and recovered lignin (Nascimento, 2016).

Sources:
Nascimento et al, 2016
Salah et al. 2017

# Perspectives with Nanocellulose from Coconut Fiber (revenues bruto)

Calculation Basis
300 Ton Green
Coconnut

Coconut Water 33%
100.000,00 L/day
US$ 50.000,00

Coconut Fiber 33 %
100 Ton/day

Celulose
30% averege
30 Ton Cellulose

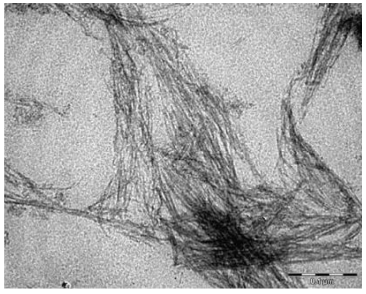
Acid hydrolysis

**Obtaining Nanocellulose**

10% 3 Ton. Nanocel/day

20% 6 Ton. Nanocel/day

30% 9 Ton. Nanocel/day



**Dried Nanocrystalline Cellulose**

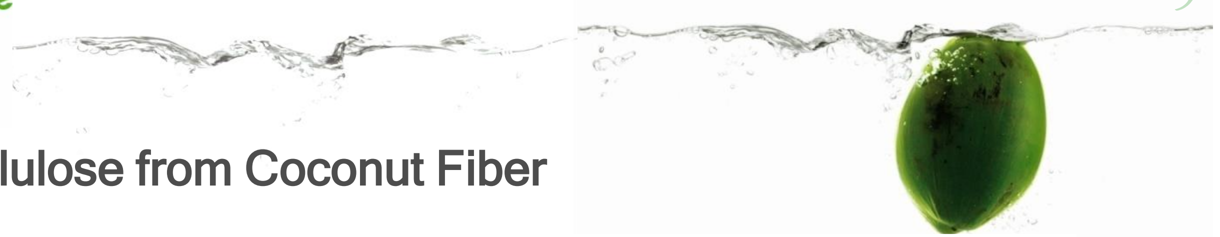
($ 100/Kg)

10% US$ 300,000,00/day

20% US$ 600,000,00/day

30% US$ 900,000,00/day

Sources :
https://celluforce.com/shop/



## ❖ Obtaining Cellulose/Nanocellulose from Coconut Fiber

http://dx.doi.org/10.1590/0104-1428.05316

Polímeros
CIÊNCIA E TECNOLOGIA

### Production of biodegradable starch nanocomposites using cellulose nanocrystals extracted from coconut fibers

Jamile Costa Cerqueira[1], Josenai da Silva Penha[1], Roseane Santos Oliveira[1], Lilian Lefol Nani Guarieiro[2], Pollyana da Silva Melo[2], Josiane Dantas Viana[3] and Bruna Aparecida Souza Machado[1]*

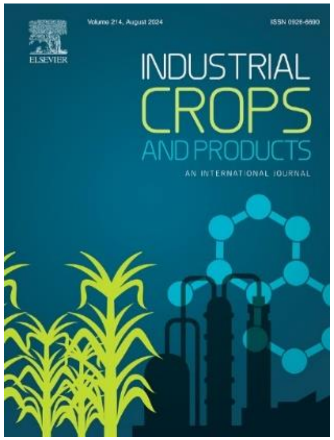
[1]*Applied Research Laboratory of Food and Biotechnology, Department of Food and Beverages, Centro Universitário – SENAI-CIMATEC, Salvador, BA, Brazil*
[2]*Integrated Laboratory of Applied Research in Chemistry, Department of Automotive, Centro Universitário – SENAI-CIMATEC, Salvador, BA Brazil*
[3]*Materials Laboratory, Department of Materials, Centro Universitário – SENAI-CIMATEC, Salvador, BA, Brazil*
**brunam@fieb.org.br*

- **Paper written in 2017 by researchers from SENAI CIMATEC, Brazil;**
- **In this study, cellulose nanocrystals were extracted from coconut fibers and incorporated in cassava and potato starch films at different concentrations (food packing);**
- **Nanocellulose was obtained from coconut fiber through acid hydrolysis process**;
- suspension of the coconut cellulose nanocrystals was examined by an SEM to determine the crystal length (L), diameter (D), and aspect ratio (L/D), and the state of the aggregation of the nanocrystals;
- coconut cellulose nanocrystals examined had length L values of 89–320 nm (average of 264.9±23.0 nm) and average diameter D of 8.10±1.21 nm;
- average aspect ratio (L/D) was 32.7±5.1, which confirms the potential of the coconut cellulose nanocrystals to used as reinforcement agents in polymeric matrixes.

Sources:
Cerqueira et al. 2017

# Obtaining Cellulose/Nanocellulose from Coconut Fiber

http://dx.doi.org/10.1016/j.indcrop.2015.12.078




Contents lists available at ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

A comprehensive approach for obtaining cellulose nanocrystal from coconut fiber. Part I: Proposition of technological pathways

Diego M. do Nascimento[a,*], Jessica S. Almeida[b], Maria do S. Vale[c], Renato C. Leitão[c], Celli R. Muniz[c], Maria Clea B. de Figueirêdo[c], João Paulo S. Morais[d], Morsyleide de F. Rosa[c,*]

[a] Federal University of Ceará (UFC), Department of Chemical, Bloco 940, CEP 60455-760 Fortaleza, Ceará, Brazil
[b] State University of Ceará (UECE), Campus do Itapery, CEP 60455-900 Fortaleza, Ceará, Brazil
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- **This work was developed by Professor Morsyleide's group from the Federal University of Ceará/EMBRAPA, already a green coco partner group**;
- The authors demonstrate that despite the relatively low cellulose percentage (31.6% in this case) in green coconut fiber (compared to other plant fibers), it was possible to obtain cellulose nanocrystals through four different methods;
- Methods: acidic hydrolysis with high acid concentration, acidic hydrolysis with low acid concentration, ammonium persulfate oxidation, and high-power ultrasound;
- Cellulose nanocrystals were analyzed by FTIR spectroscopy, X-ray diffraction, transmission electron microscopy, and TG analysis;
- Using these methods, the whole coconut fiber could be used to produce cellulose nanocrystals and lignin;
- Among the proposed methods, high-power ultrasound showed the highest efficiency in cellulose nanocrystal extraction.

Sources:
Cerqueira et al.

# ❖ Obtaining Cellulose/Nanocellulose from Coconut Fiber

https://www.researchgate.net/publication/377077885

## Coconut Husk Fiber: A Low-Cost Bioresource for the Synthesis of High-Value Nanocellulose

**Chidamparam Poornachandhra [1], Rajamani M. Jayabalakrishnan [1,*], Govindaraj Balasubramanian [2], Arunachalam Lakshmanan [3], S. Selvakumar [4], Muthunalliappan Maheswari [5], Joseph Ezra John [5]**

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[3] Department of Nano Science and Technology, Tamil Nadu Agricultural University, Coimbatore, India; microlaxman@gmail.com (A.L.);
[4] Agricultural Engineering College and Research Institute, TNAU, Coimbatore, India; engineerselva@yahoo.co.in (S.S.);
[5] Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore, India; maheswarisekar2004@yahoo.com (M.M.);ezrajohn4@gmail.com (J.E.J.);
* Correspondence: jayabalphd@gmail.com (R.M.J);

Scopus Author ID 16230026200

https://doi.org/10.33263/BRIAC13...

**Received: 17.10.2022; Accepted: 24.11.2022; Published: 31.01.2023**

- Paper written in 2022 by researchers from different Indian institutions;
- In this study, two methods, steam explosion and alkali-acid hydrolysis, were evaluated for the cellulose extraction from coconut husk fiber;
- Between the two methods, acid hydrolysis yielded 1.8 times higher cellulose content than steam explosion;
- **In order to maximize cellulose content in nanocellulose synthesis, acid concentration, reaction temperature, and hydrolysis time were optimized using Response Surface Methodology (RSM);**
- **The optimum reaction condition for the synthesis of NCC was 50 °C with 45 wt% acid concentration for 60 minutes due to its high cellulose content (85.6 %);**
- Synthesized NCC was spherical in shape with a diameter below 40 nm. NCC had better crystallinity (80.05 %) with a high zeta potential of -72.2 mV.

Sources:
Poornachandhra et al, 2023

# ❖ Obtaining Cellulose/Nonocellulose from Green Coconut Fiber

Dismemberment →

Washing →
Drying
Miling

Merceirization →

NaOH (aq) 5%
Temperature (60°C)
Time (2h)
Filtration
Drying (48h)

Bleaching

NaClO(aq) 2%
NaOH (aq) 5%
CH3COOH(aq) 5% →

Temperatura (70ºC)
Tempo (2h)
1000 RPM
Secagem (48h)

Acid hydrolysis →

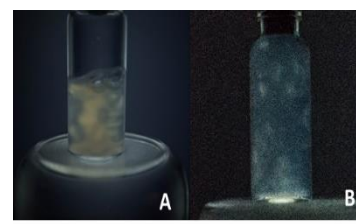
$H_2SO_4$(aq) 45%
Temperature (40°C)
Time (60 min)

Centrifugation →

1000 RPM
Time (3-4h)

Dialysis
(3-4h) →

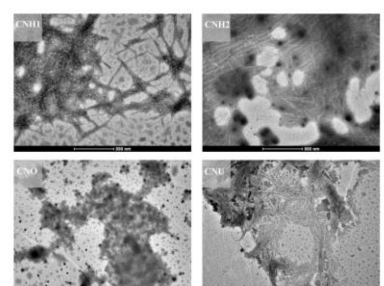
Birefringence




Characterization

Transmission electron microscopy (TEM)

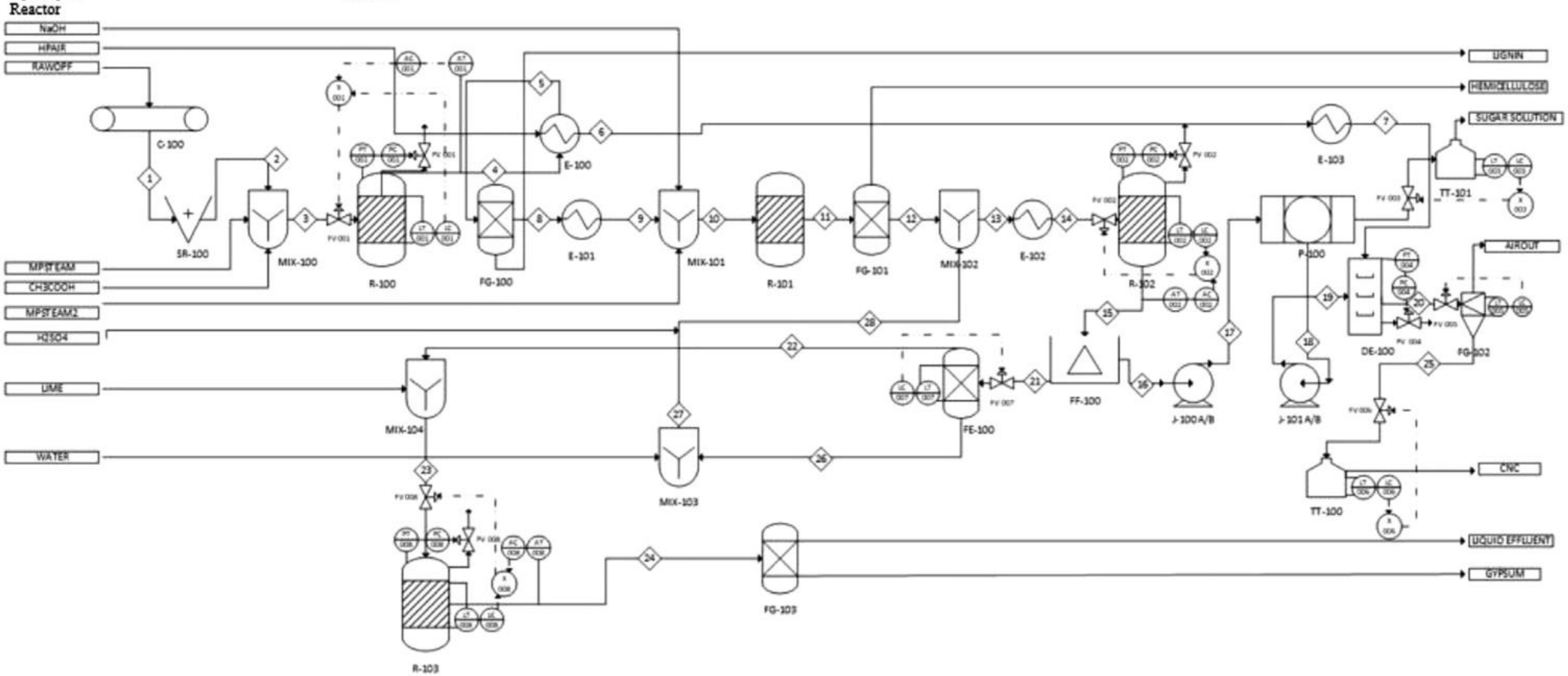
X-ray diffraction (XRD)



Sourcers:
Guimaraes 2018

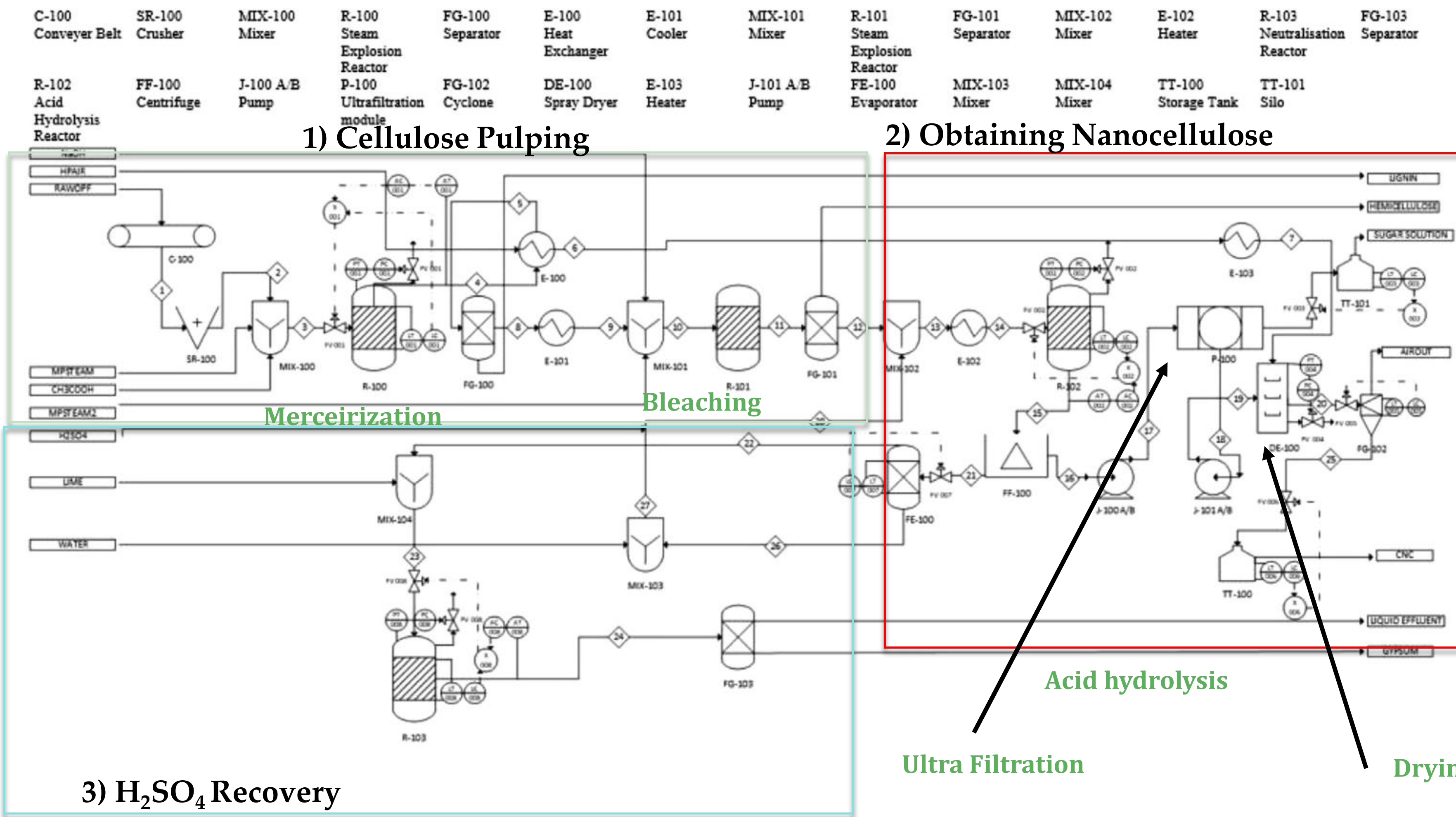
## ❖ Industrial Process for Obtaining Nanocellulose

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C-100 Conveyer Belt | SR-100 Crusher | MIX-100 Mixer | R-100 Steam Explosion Reactor | FG-100 Separator | E-100 Heat Exchanger | E-101 Cooler | MIX-101 Mixer | R-101 Steam Explosion Reactor | FG-101 Separator | MIX-102 Mixer | E-102 Heater | R-103 Neutralisation Reactor | FG-103 Separator |
| R-102 Acid Hydrolysis Reactor | FF-100 Centrifuge | J-100 A/B Pump | P-100 Ultrafiltration module | FG-102 Cyclone | DE-100 Spray Dryer | E-103 Heater | J-101 A/B Pump | FE-100 Evaporator | MIX-103 Mixer | MIX-104 Mixer | TT-100 Storage Tank | TT-101 Silo | |




Sources:
Qing et al 2020

# ❖ Industrial Process for Obtaining Nanocellulose




Sources:
Qing et al 2020

greencoco europe

# ❖ Industrial Process for Obtaining Nanocellulose

Global status of production of Nanocellulose [42,84].

| Country | Company name | Source /Method | Production capacity | Product /trade name |
|---|---|---|---|---|
| Canada | Alberta Innovates (AITF) | MCC, bleached Kraft pulp, acid hydrolysis | 20 kg/day | CNCs |
| | Blue Goose Biorefineries Inc. | Wood, cereal straws, and grasses; oxidative and nanocatalytic processing | 10 kg/day | CNCs |
| → | CelluForce | Kraft pulp; bleaching and acid hydrolysis | 1 ton/day | NCCTM |
| | FP Innovations | bleached chemical pulp and others/ acid hydrolysis | 2 kg/day | CNCs |
| | GreenCore Composites Inc. | Wood/ agricultural fibres; microfibers; PP/ PE reinforced cellulosic microfibrils | – | NCellTM, natural fiber-reinforced thermoplastics |
| | Kruger Bioproducts Inc. FILOCELL | Kraft pulp; TMP and mechanical treatments | 5 tons/day | cellulose filaments |
| | Performance BioFilaments Inc. | Kraft pulp; TMP and mechanical treatments | 21 tons/ day | Filament formed cellulose, wet fluff rolls or forms. |
| China | Tianjin Haojia Cellulose Co., Ltd. | Cotton or Kraft pulp; mechanical treatments and combined acid and enzymatic hydrolysis | Pilot-scale plant | CNCs, CNFs |
| Finland | UPM-Kymmene Ltd.* | Wood fibres/mechanical treatment | Pilot-scale plant | BiofibrilsTM |
| | VTT* -Aalto U, UPM | Birch fibril pulp/mechanical treatment | Pilot-scale plant | CNFs roll-to-roll film |
| France | CTP/FCBA, InTechFibres | Lignocellulose residues; TEMPO-xidation; meca-enzymatic pretreatments, homogenization and lab microfluidization | 0.1 ton/day, 100 g – 80 kg CNF capacity | CNFs |
| India | CentralInstitute for Research on Cotton Technology(ICAR-CIRCOT) | Cotton linters, sugar cane bagasse, other agro-residues; novel chemico-mechanical, microbial, and enzymatic hydrolysis | 10 kg/day pilot plant | CNFs, CNCs |
| Iran | Iran Nano Novin Polymer Co | Bacterial cellulose; bottom-up approach for BNC; top-down approach for CNFs | 2 million tons/day | BNCs ,CNFs |
| JAPAN | Chuetsu Pulp and Paper | Kraft pulp, bamboo, softwood and hardwood; counter collision technique | 50 ton/year | CNFs, CNF/plastic composites |
| | Dai-ichi Kogyo Seiyaku Co., Ltd. | TEMPO oxidation | 50 ton/year, 2% solids | cellulose single nanofiber": RheocrystaTM |
| | Daicel | purified pulp; mechanical treatments | 10–35% solids | Nano CelishTM, food, filtration, and industrial applications |
| | Daio Paper | Mechanical treatment | 150 tons/day | CNFs |
| | Nippon Paper Industries | Wood pulp; TEMPO oxidation; carboxymethylation; mechanical treatments | >30 ton/year (>0.1 ton/day) | CNFs, CellenpiaTM |
| | Seiko PMC | Wood pulp; mechanical treatment and hydrophobization | 30 tons/year | CNF nanocomposites |
| Sweden | MoRe Research Institute, Sweden | Paper industry sludge; controlled acid hydrolysis and sonication. | 0.1 ton/day pilot plant | CNCs |
| → Switzerland | Swiss Federal Laboratories, Empa | Wood and other lignocelluloses residue; enzymatic pretreatments and microfluidization | 15 kg/day | CNFs |
| UK | CelluComp | Waste streams of root vegetables/ proprietary technology | Small plant running | CNFs, Curran, paste/slurry, powder, thin sheets, composites |
| | Sappi in partnership with Edinburgh NapierUniversity, UK | Wood fibres; CNFs surface modified for hydrophobic/ hydrophilic nature | 8 tons/year target, (pilot plant), | CNFs, powder with 100% redispersibility in water |
| → USA | American Process Inc. (AVAPCO) | Wood chips, agricultural residue/ ethanol/ $SO_2$ pulping; mechanical treatments | 0.5 ton/day | Nanocellulose BioPlusTM, CNFs& CNCs, lignin-coated hydrophobic CNFs & CNCs |
| | University of Maine | Wood pulp/mass collider grinder | 1 ton/week | CNFs aqueous suspensions |
| | USDA-Forest Products Laboratory | Wood pulp/sulfuric acid hydrolysis | 50 kg/week | Aqueous suspensions freeze-dried CNCs & CNFs |

Sources:
Reshmy et al 2022

## ❖ Industrial Process for Obtaining Nanocellulose

https://doi.org/10.1016/j.mset.2020.01.001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CHINESE ROOTS
GLOBAL IMPACT

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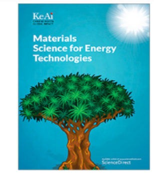



### Pilot study of synthesis of nanocrystalline cellulose using waste biomass via ASPEN plus simulation

Elvin Boo Chen Qing, Julian Kirzner Chong Kai Wen, Lee Seh Liang, Lim Qian Ying, Lim Quan Jie, N.M. Mubarak *

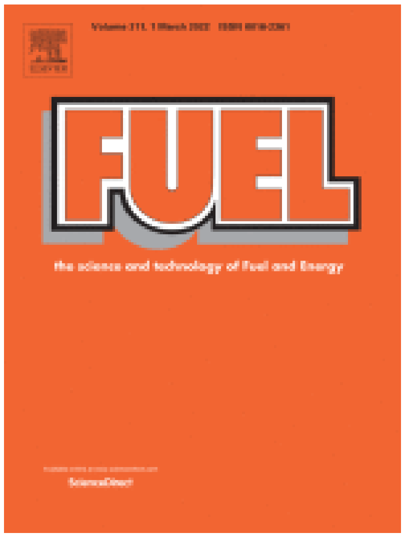
*Department of Chemical Engineering, Faculty of Engineering and Science, Curtin University, 98009 Sarawak, Malaysia*

- Paper by a research group from the University of Sarawak in Malaysia;
- It presents a study on the technical and financial feasibility of a nanocellulose pilot plant fed with palm fiber through simulations using **ASPEN Plus**;
- Authors propose a batch process based on three stages;
- The first stage consists of a group of pulping reactors, where the lignin and hemicellulose extraction and pulp bleaching stages take place;
- Second stage consists of an acid hydrolysis reactor, where the amorphous and crystalline phases of cellulose are separated by differences in reaction kinetics, resulting in cellulose nanoparticles;
- A third stage consists of a CSTR sulphuric acid recovery reactor. Process is completed with product purification and effluent treatment stages;
- In addition to a complete process flow diagram, the authors propose mass and energy balance calculations, a heat exchanger network and an estimate of the plant's operating cost. Using Aspen's Chemical Engineering Plant Cost Index (CEPCI) tool, they estimated the total value of the detailed asset purchase;
- Finally, by comparing three different local economic scenarios (Malaysia), the authors propose a breakeven point to determine the payback period.

Sources:
Qing et al 2020

## ❖ Industrial Process for Obtaining Nanocellulose

https://doi.org/10.1016/j.fuel.2021.122575

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Fuel

journal homepage: www.elsevier.com/locate/fuel

ELSEVIER

**Biorefinery aspects for cost-effective production of nanocellulose and high value-added biocomposites**

R. Reshmy [a,1], Eapen Philip [a,1], Aravind Madhavan [b,1], Ayon Tarfdar [c], Raveendran Sindhu [d], Parameswaran Binod [d], Ranjna Sirohi [e,f], Mukesh Kumar Awasthi [g], Ashok Pandey [f,h,*]

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[b] Rajiv Gandhi Center for Biotechnology, Jagathy, Thiruvananthapuram, Kerala 695 014, India
[c] Livestock Production and Management Section, ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly, Uttar Pradesh 243 122, India
[d] Microbial Processes and Technology Division, CSIR-National Institute for Interdisciplinary Science and Technology, Trivandrum - 695 019, Kerala, India
[e] Department of Chemical and Biological Engineering, Korea University, Seoul, Republic of Korea
[f] Centre for Energy and Environmental Sustainability, Lucknow-226 029, Uttar Pradesh, India
[g] College of Natural Resources and Environment, Northwest A & F University, Yangling, Shaanxi 712 100, China
[h] Centre for Innovation and Translational Research, CSIR- Indian Institute for Toxicology Research, Lucknow - 226 001, Uttar Pradesh, India

- This article presents an overview of various strategies for obtaining nanocellulose, with a focus on enzymatic ones;
- It also provides current data (2021) on all the nanocellulose plants in the world;;
- No industrial-scale plant exists for the time being;
- All industrial plants are on pilot (experimental) or demonstration (commercial) scale;
- There are 25 plants around the world, in different countries;
- Most of the cellulose processed comes from pulpwood or pulpwood pulp, but there are already plants that process lignocellulosic waste [(IntechFibers/France) and (Swiss Federal Laboratories/Switzerland)].

Sources:
Reshmy, et al 2020

greencoco europe

# ❖ Industrial Process for Obtaining Nanocellulose

http://dx.doi.org/10.4236/jnbn.2013.42022


***Journal of Biomaterials and Nanobiotechnology*, 2013, 4, 165-188**
http://dx.doi.org/10.4236/jnbn.2013.42022 Published Online April 2013 (http://www.scirp.org/journal/jbnb)
Scientific Research

## State of the Art Manufacturing and Engineering of Nanocellulose: A Review of Available Data and Industrial Applications

**Serge Rebouillat[1], Fernand Pla[2]**

[1]Currently with DuPont Int. Op. European Headquarter, Geneva, Switzerland; [2]Laboratoire Réactions et Génie des Procédés, UMR 7274, CNRS-Université de Lorraine, Nancy, France.
Email: sergereb@yahoo.com

Received January 18th, 2013; revised March 8th, 2013; accepted April 8th, 2013



- Interesting review article demonstrating other processes for obtaining nanocellulose besides acid hydrolysis, as well as methods for modifying the surface of nanocellulose;
- The publication also contains proposed process flowcharts;
- It is interesting to note that in 2013, when this publication was published, there were 7 pilot plants in the world;
- Today there are 25.

Sources:
Rebouillat, et al 2013

# ❖ Industrial Process for Obtaining Nanocellulose

## CelluForce restarts production of cellulose nanocrystals at its newly modernized facility

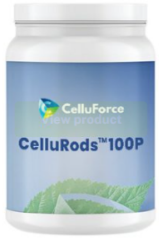
Published On: 6 February 2019   Categories: CelluForce News

## 15 tons of CelluForce NCC® ready to ship!

Published On: 19 November 2019   Categories: CelluForce News

Sources:
https://celluforce.com/celluforce-restarts-production-of-cellulose-nanocrystals-at-its-newly-modernized-facility/
https://celluforce.com/15-tons-of-celluforce-ncc-ready-to-ship/

## ❖ Industrial Process for Obtaining Nanocellulose




**CelluRods™ 100P**

SPRAY-DRIED HYDROPHILIC sulfated cellulose nanocrystals

1 kg - 100.00 US$ + shipping (max 10 ur

- 1 + **Add to cart**

**USD100.00**


**CelluRods™ 100L**

6% w/w WATER SUSPENSION HYDROPHILIC sulfated cellulose nanocrystals (avg particle size 95 nm)

**AVAILABLE TO SHIP IN APRIL 2024**

3.8L - 100.00 US$ + shipping (max 10 u

- 1 + **Add to cart**

**USD100.00**


**CelluRods™ 110L**

6% w/w WATER SUSPENSION HYDROPHILIC sulfated cellulose nanocrystals (avg particle size 88 nm)

3.8L - 100.00 US$ + shipping (max 10 u

- 1 + **Add to cart**

**USD100.00**

## Product Specification

**Product Name:** NanoCrystalline Cellulose (NCC™)
**Product Code:** CelluForce NCV100
**Chemical Name:** Cellulose hydrogen sulphate sodium salt
**CAS No.:** 9005-22-5

| PARAMETER | SPECIFICATION |
|---|---|
| Product form | Spray dried powder |
| Appearance (color) | White |
| Product bulk density | 0.7 g/cm$^3$ |
| Molecular formula | $[(C_6O_5H_{10})_{22\text{-}28}\ SO_3\ Na]_{4\text{-}6}$ |
| Specific surface area | 400 m$^2$/g |
| Gram molecular weight | 14,700-27,850 |
| Moisture content (powder) | 4-6% |
| Particle size (powder) | 1-50 µm |
| Particle diameter (crystallite)* | 2.3-4.5 nm (by AFM) |
| Particle length (crystallite)* | 44-108 nm (by AFM) |
| Crystalline fraction* | 0.88 (by XRD) |
| Crystallite density | 1.5 g/cm$^3$ |
| Sulfur content* | 0.86-0.89 % |
| Sulfate content* | 246-261 mmol/kg |
| pH (dispersed in water) | 6-7 |
| Hydrodynamic diameter* | 70 nm (by DLS) |
| Ionic strength | 230-270 mmol/kg |
| Zeta potential* | -37 mV |

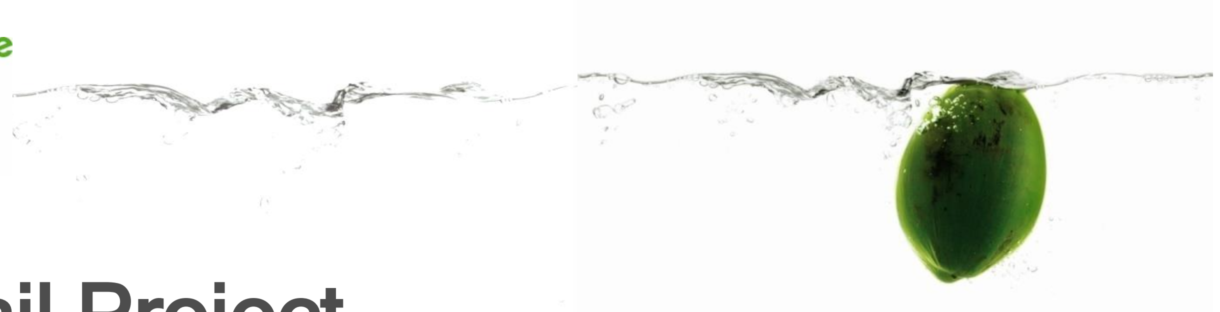
Sources:
https://celluforce.com/shop/

## ❖ Our current status

**SENAI CIMATEC**

- Delivery: Pilot Industrial Plant
- Fiber: Coconut Fiber
- NDA;
- Approved Project Scope;
- Pilot Plant Feeding Capacity: 23 Kg.Fiber/day;
- ProductionTarget: 3,5 Kg.Nanocel/day;
- Minimal Efficiency: 50 %
- Project Start Preview: 2° semester 2024

future pilot plant installations



# Green Coco Brasil Project

## Natural Fiber Nanotechnology

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