BIOMASA Y BIOECONOMÍA ¿DÓNDE ESTÁ LA INDUSTRIA DE PALMA?

Marianny Y Combariza
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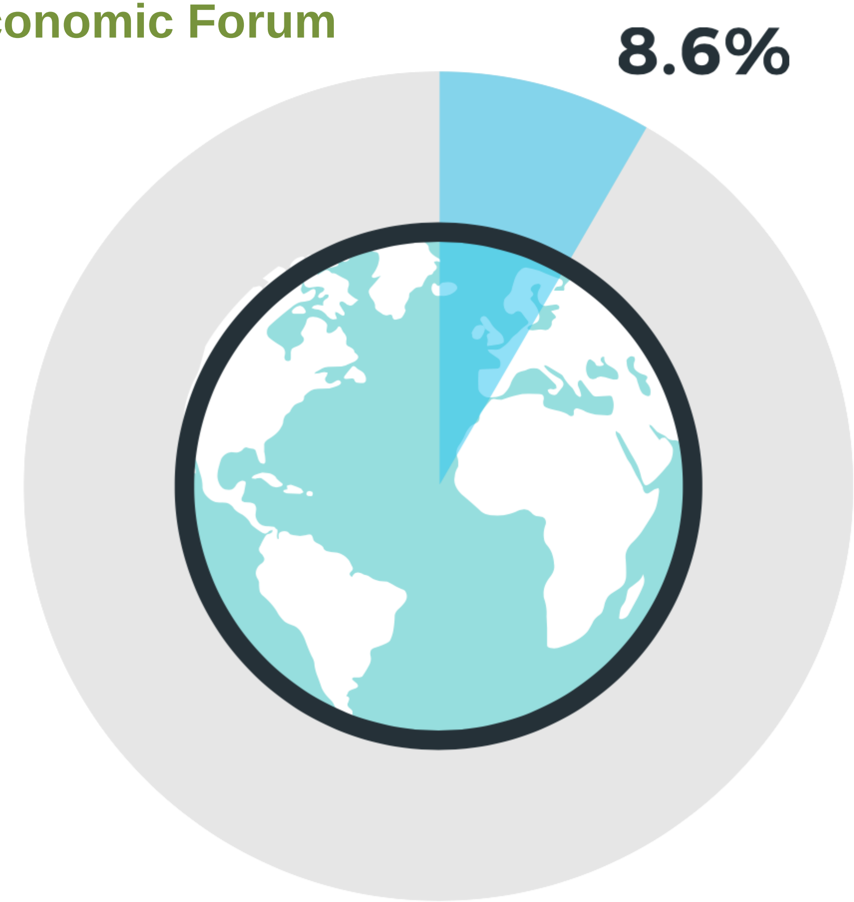
The circularity gap

January 2018 World Economic Forum (Davos)



2021: 100 Gt natural resources

2019: 9.1%

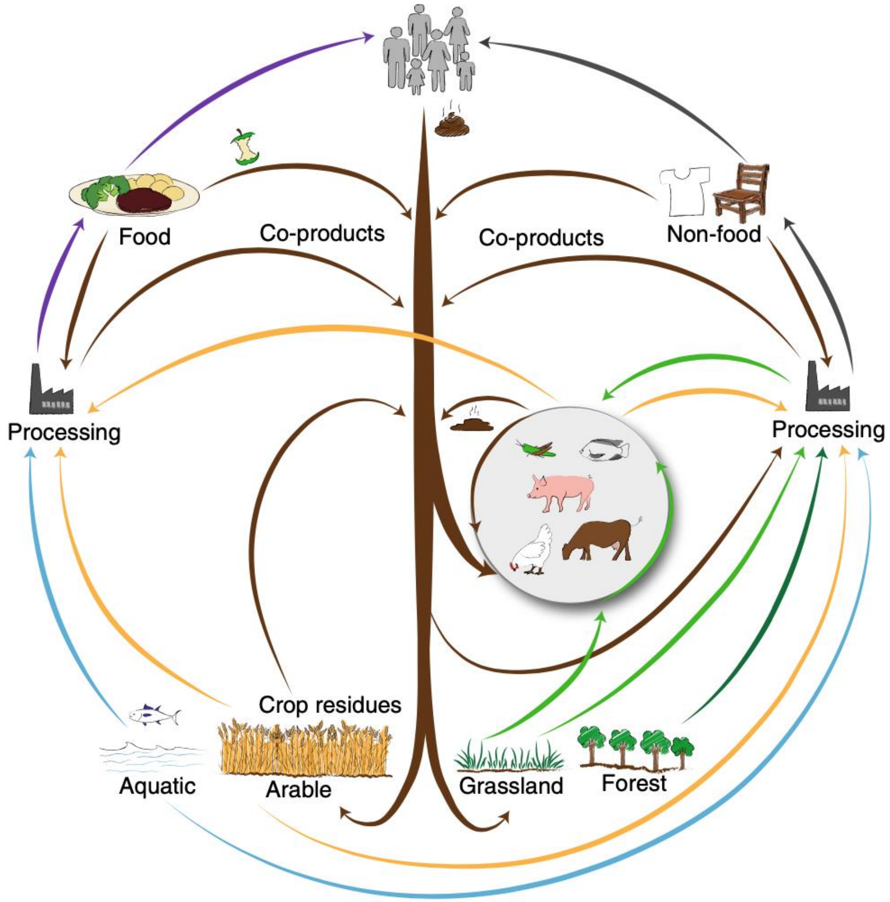
2022: 8.6%

Material handling/use: 70% GHG emissions

Linear economy: Take, make, waste

The Circularity Gap Report 2022. https://www.circularity-gap.world/2022#Download-the-report

Circular Bioeconomy



NARROW: Use efficiently

SLOW: Use longer

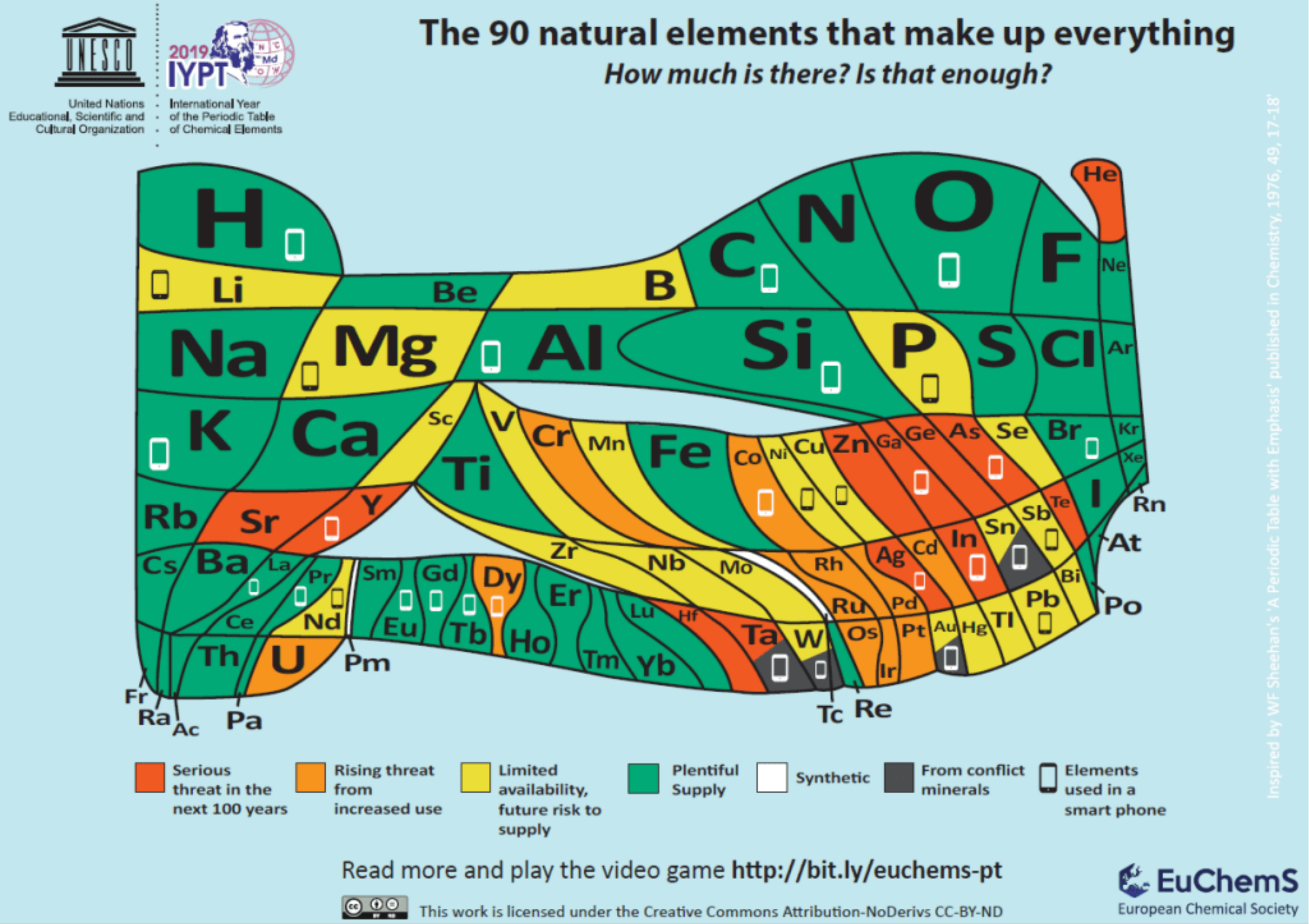
REGENERATE: Make clean

RECYCLE: Use again

Muscat, A., de Olde, E.M., Ripoll-Bosch, R. et al. Principles, drivers and opportunities of a circular bioeconomy. Nat Food 2, 561–566 (2021).
Caetano NS, Xu S, Banu JR, Sani RK and Karthikeyan OP (2022) Editorial: Biomass, Bioenergy and Biofuels for Circular Bioeconomy. Front. Energy Res. 10:851047. doi: 10.3389/fenrg.2022.851047

Circular Bioeconomy

It´s a chemistry problem!



https://i0.wp.com/www.euchems.eu/wp-content/uploads/2021/11/Endangered-ElementsCarbon-Updated.png?ssl=1

Multifunctional Agriculture

Agriculture has many functions in addition to producing food and fiber (OECD, 2001)

Natural resources preservation function

Shaping landscape
Conservation, management, habitats, nutrient recycling carbon sinks

Economic function

Water management
Quality
Flood control
Harvesting

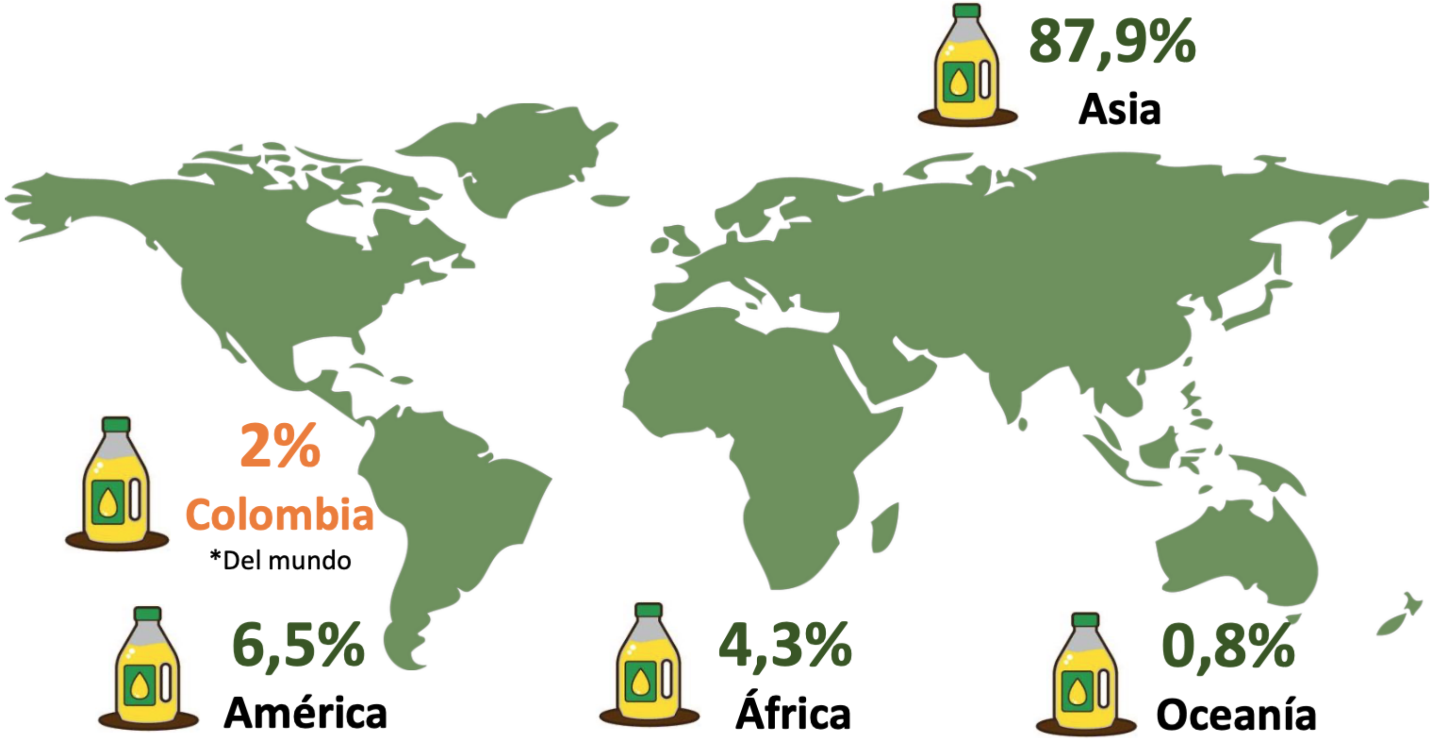
Water management function

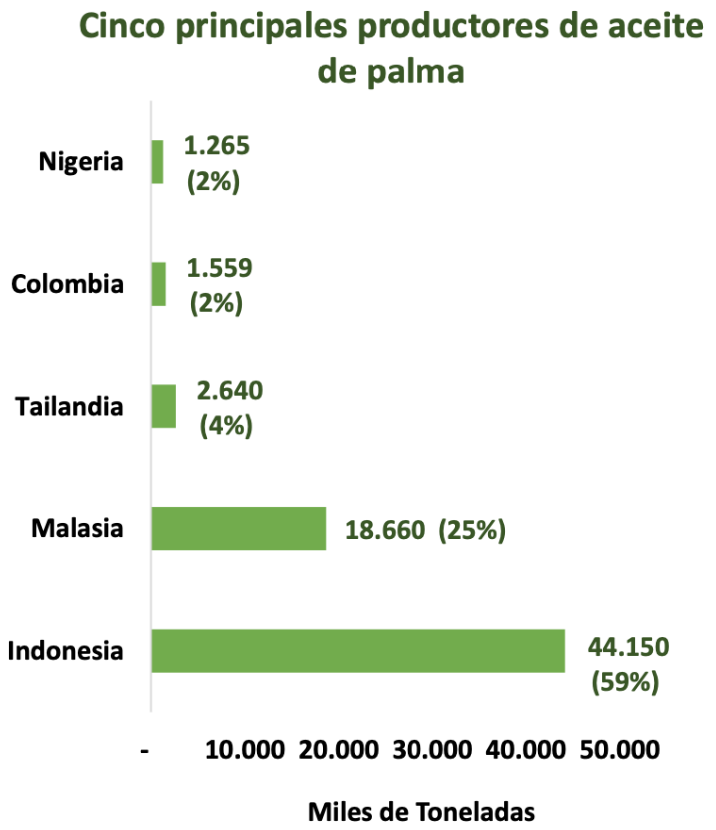
Socio-cultural function

Shaping communities
Cohesion, development, Cultural/historical heritages
Identity
Entertainment.

PASPI2021, Vol. II, No. 01/01/2021. Multifunctional Oil Palm Plantation and Sustainable Development Goals (SDGs), 2021. https://palmoilina.asia/wp-content/ uploads/2021/01/2.1.-MULTIFUNCTIONAL-OIL-PALM-PLANTATION-AND- SUSTAINABLE-DEVELOPMENT-GOALS-.pdf (Accessed September 26, 2022)

Multifunctional Agriculture





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Types of residual biomass in the Palm Oil industry

Frond

Fresh fruit bunch (FFB)

Trunk

Palm oil →

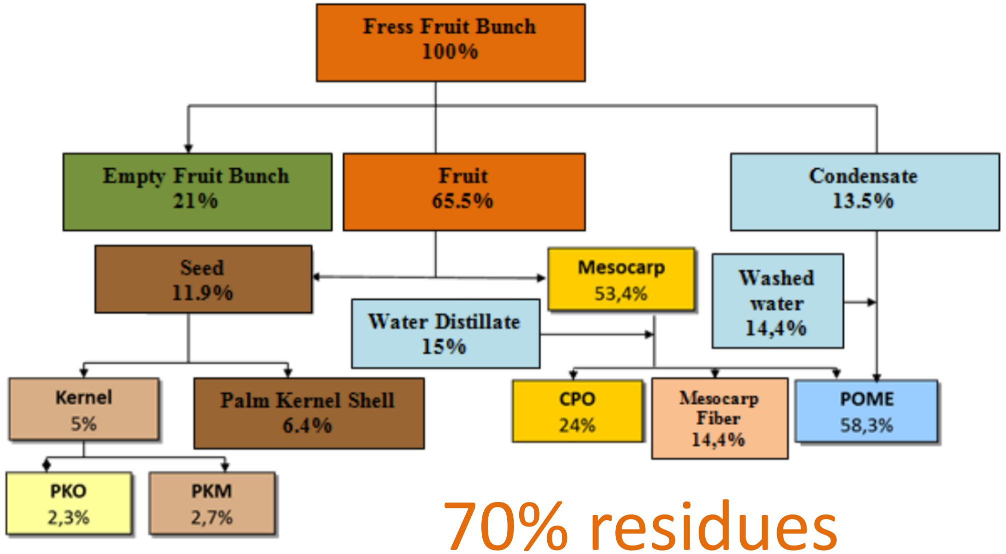
Mesocarp fiber (MF)

Empty fruit bunch (EFB)

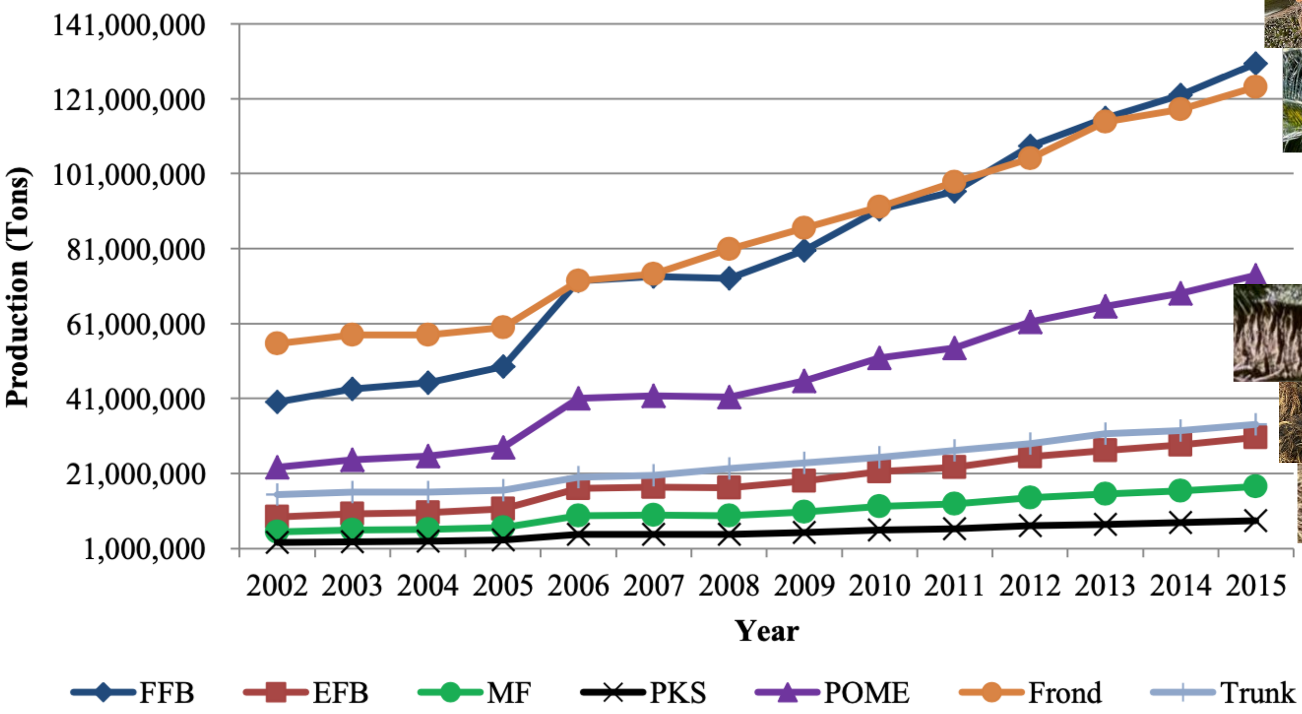
Palm kernel oil →

Palm kernel shell (PKS) and meal (PKM)

Palm Oil residues in Indonesia



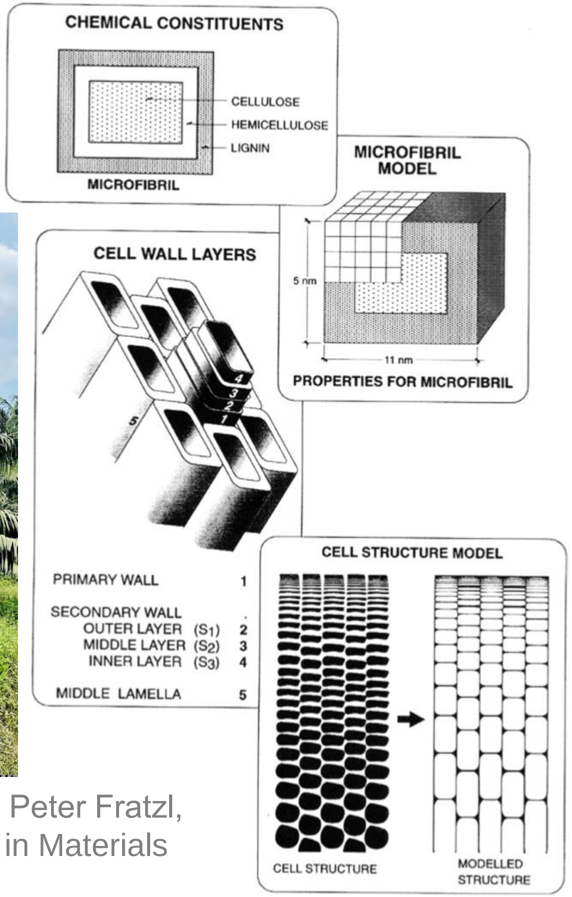
70% residues



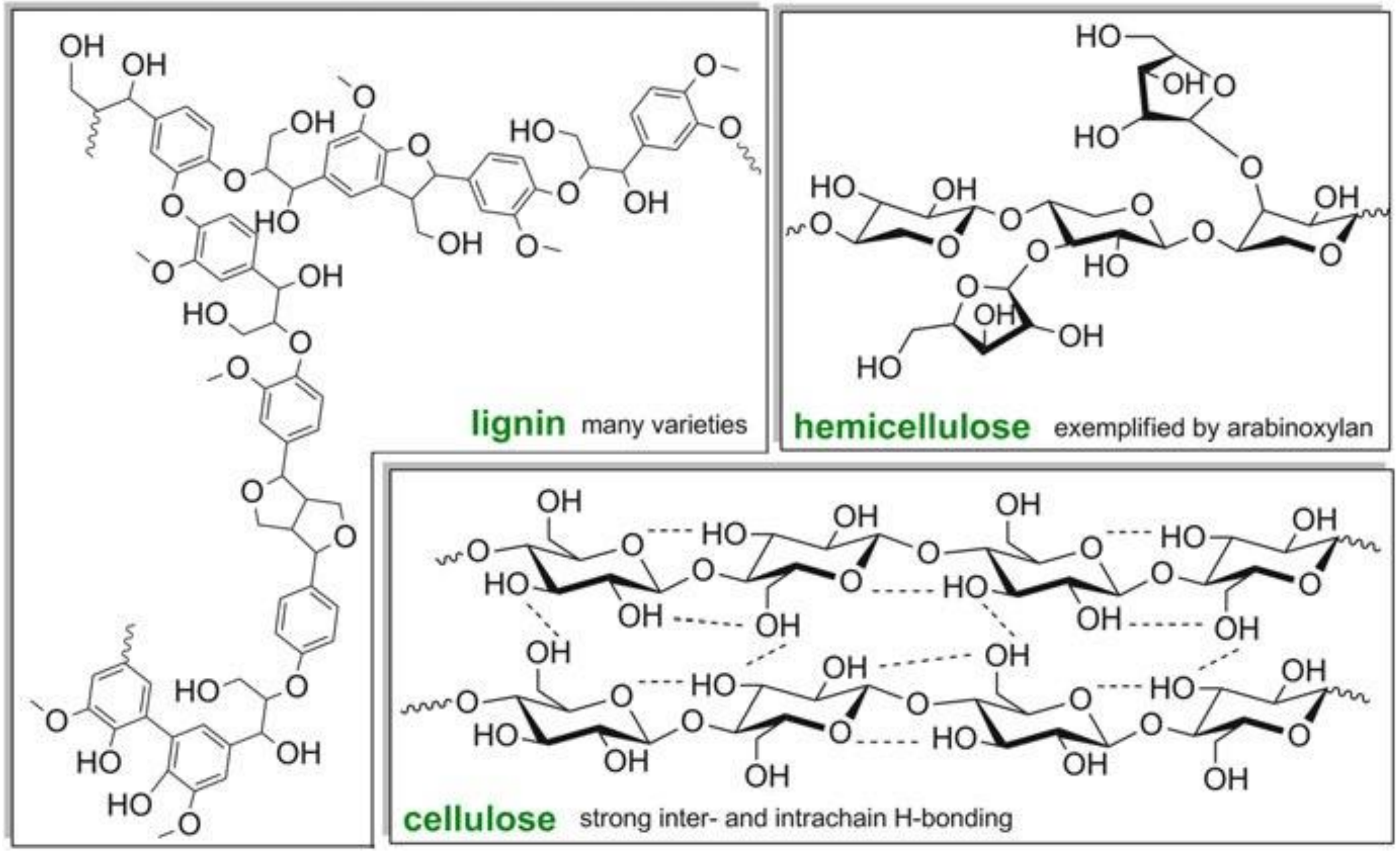
Estimates for 2030 double the amount of residual biomass

Hambali, E., Rivai, M. The Potential of Palm Oil Waste Biomass in Indonesia in 2020 and 2030, 2017 IOP Conf. Ser.: Earth Environ. Sci. 65 012050

Biomass structure and composition



Nature's hierarchical materials Peter Fratzl, Richard Weinkamer, Progress in Materials Science 52 (2007) 1263–1334



Dusselier, M.; Mascal, M.; Sels, B.F. Top Top Chemical Opportunities from Carbohydrate Biomass: A Chemist's View of the Biorefinery, Curr Chem (2014) 353: 1–40, DOI: 10.1007/128_2014_544

Biomass transformation

MICROBIAL ← **BIOMASS** → **CHEMICAL**

↓

THERMAL

Fermentative
Biocatalytical
(Alcohols, acids)

Chemocatalytical
Mechanochemical,
Sonochemical
(Targeted)

Thermochemical
(Gasification, bio-gas, bio-oil)

Biomass transformation

MICROBIAL ← BIOMASS → CHEMICAL

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THERMAL

MATURE

Bioenergy
Bioethanol
Transesterification
Anaerobic digestion

DEVELOPING

Catalytic hydroprocessing
CO_2 Reduction-reuse
Resource recovery-functional products

← TRL

DEVELOPED

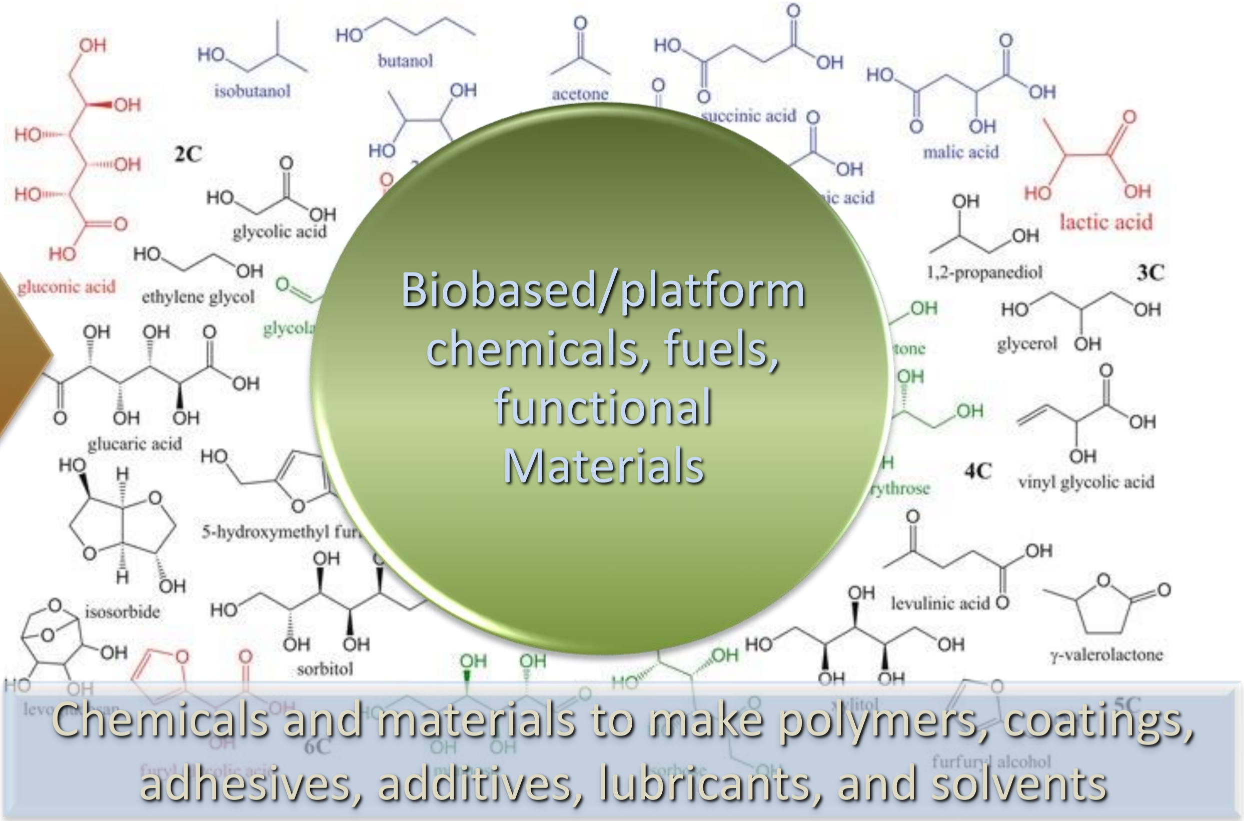
Pyrolysis-Bio-oil
Gasification-Syn Gas
Hydrothermal liquefaction-Fuel

Sadhukhan, J.; et al.Role of bioenergy, biorefinery and bioeconomy in sustainable development: Strategic pathways for Malaysia, Renewable and Sustainable Energy Reviews 81 (2018) 1966–1987

Chemical biomass conversion strategies

Biomass biopolymers

Chemical toolbox



Biobased/platform chemicals, fuels, functional Materials

Chemicals and materials to make polymers, coatings, adhesives, additives, lubricants, and solvents

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Why not?

Factor	Strategy	
	Fermentative/thermal	Chemical
Commercial interest		
Method development, capital expenses on start up		
Potential for cheap, short, and mild processes to transform biomass into platform molecules		

Dusselier, M.; Mascal, M.; Sels, B.F. Top Top Chemical Opportunities from Carbohydrate Biomass: A Chemist's View of the Biorefinery, Curr Chem (2014) 353: 1–40, DOI: 10.1007/128_2014_544

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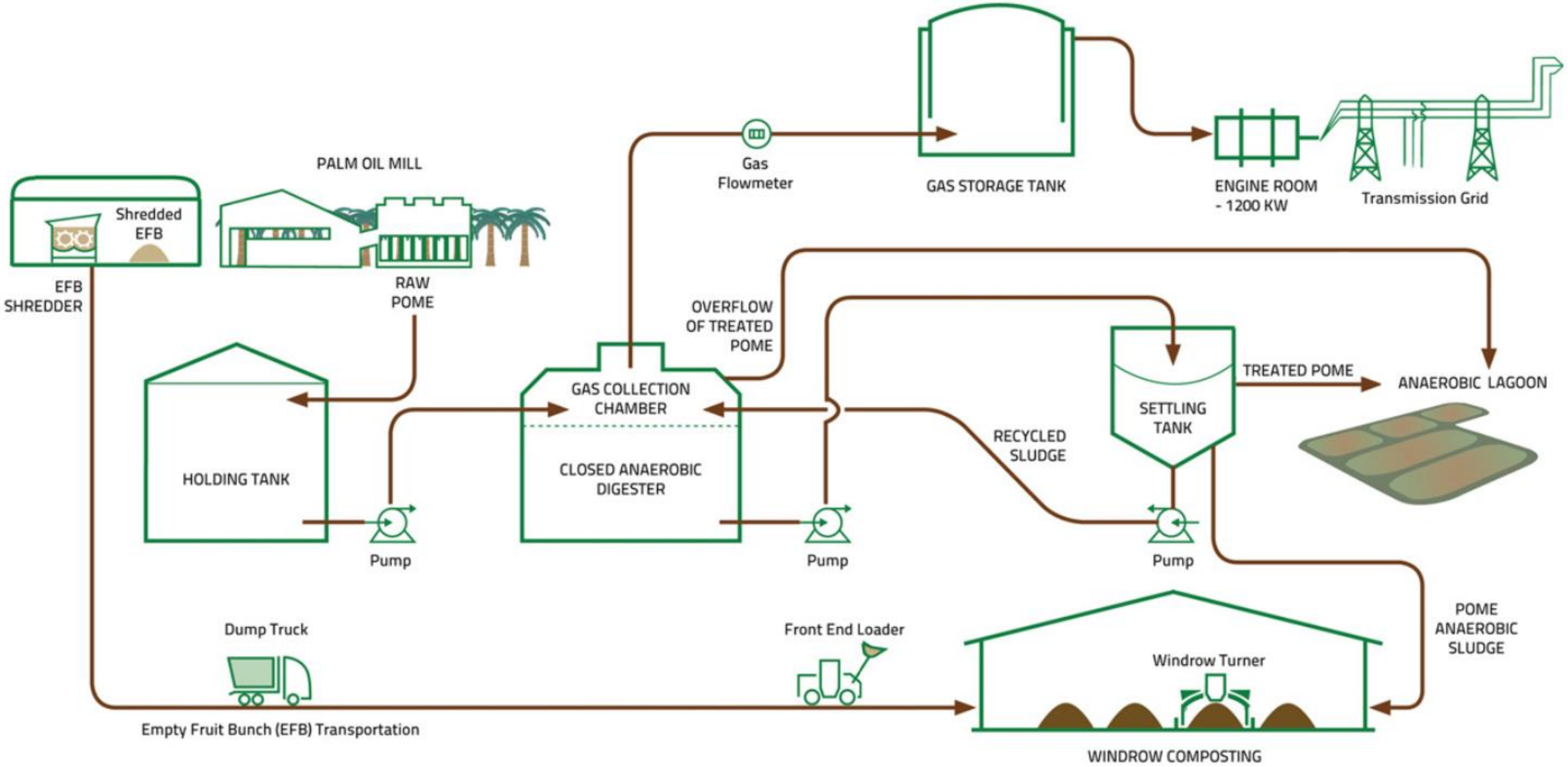
First steps: integrated biogas/compost technology

Serting Hilir Palm Oil Mill:
54 t FFB/h
300,000 t FFB/Y
Energy: 15 - 17 kWh elect/t FFB
Water: 300,000 - 450,000 t
CPO: 60,000 t
PKO: 18,000 t
EFB: 69,000 t (incineration, mulching, nutrient recycling)
POME: 150,000 - 225,000 t



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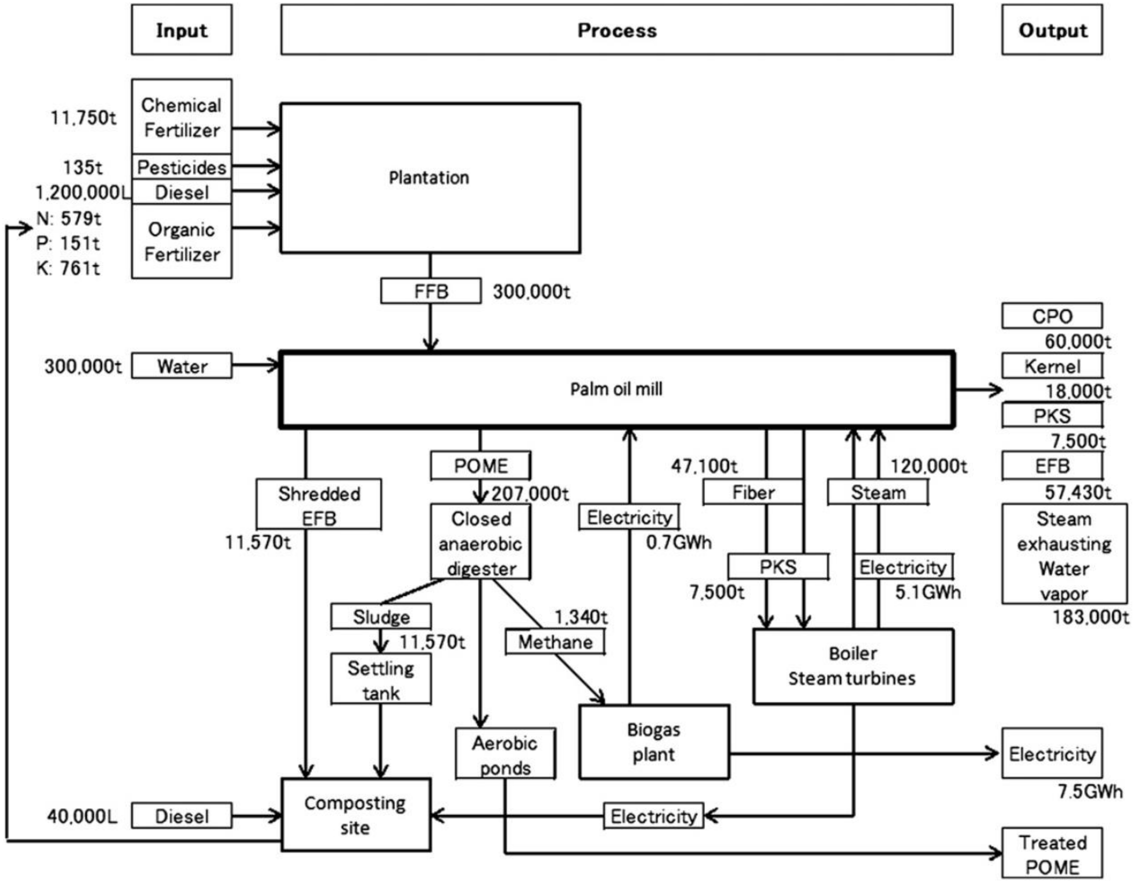

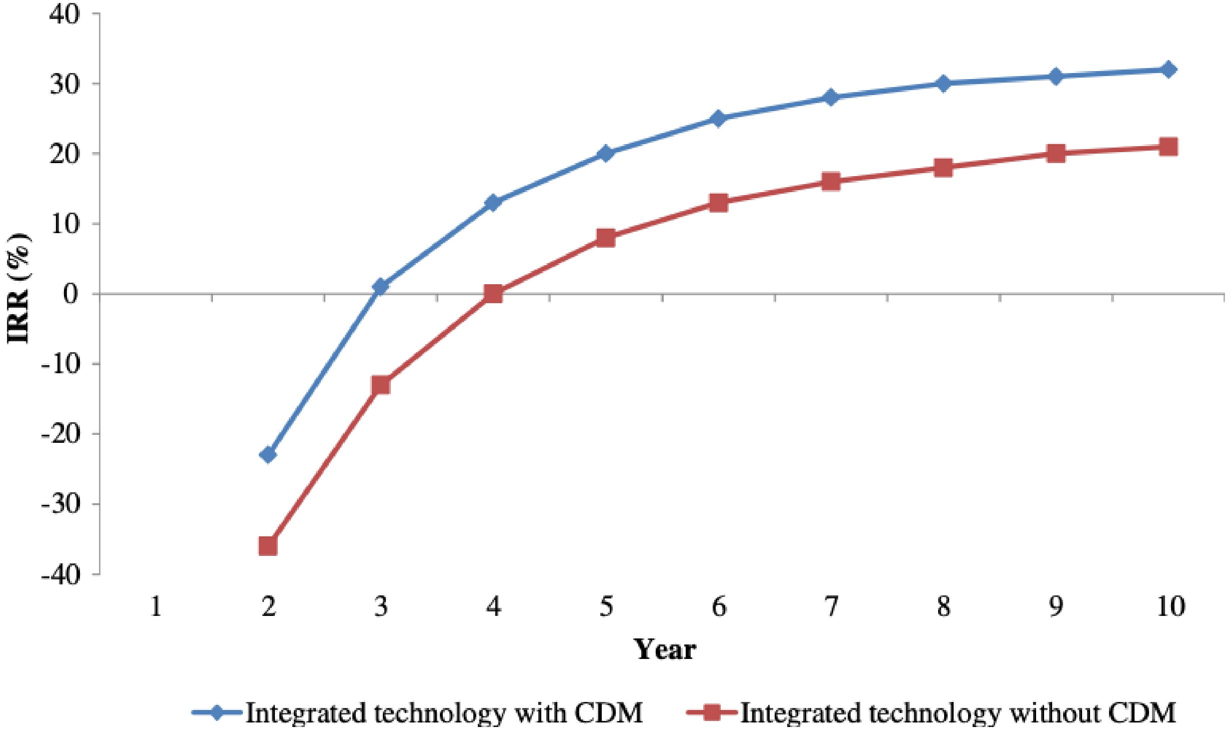

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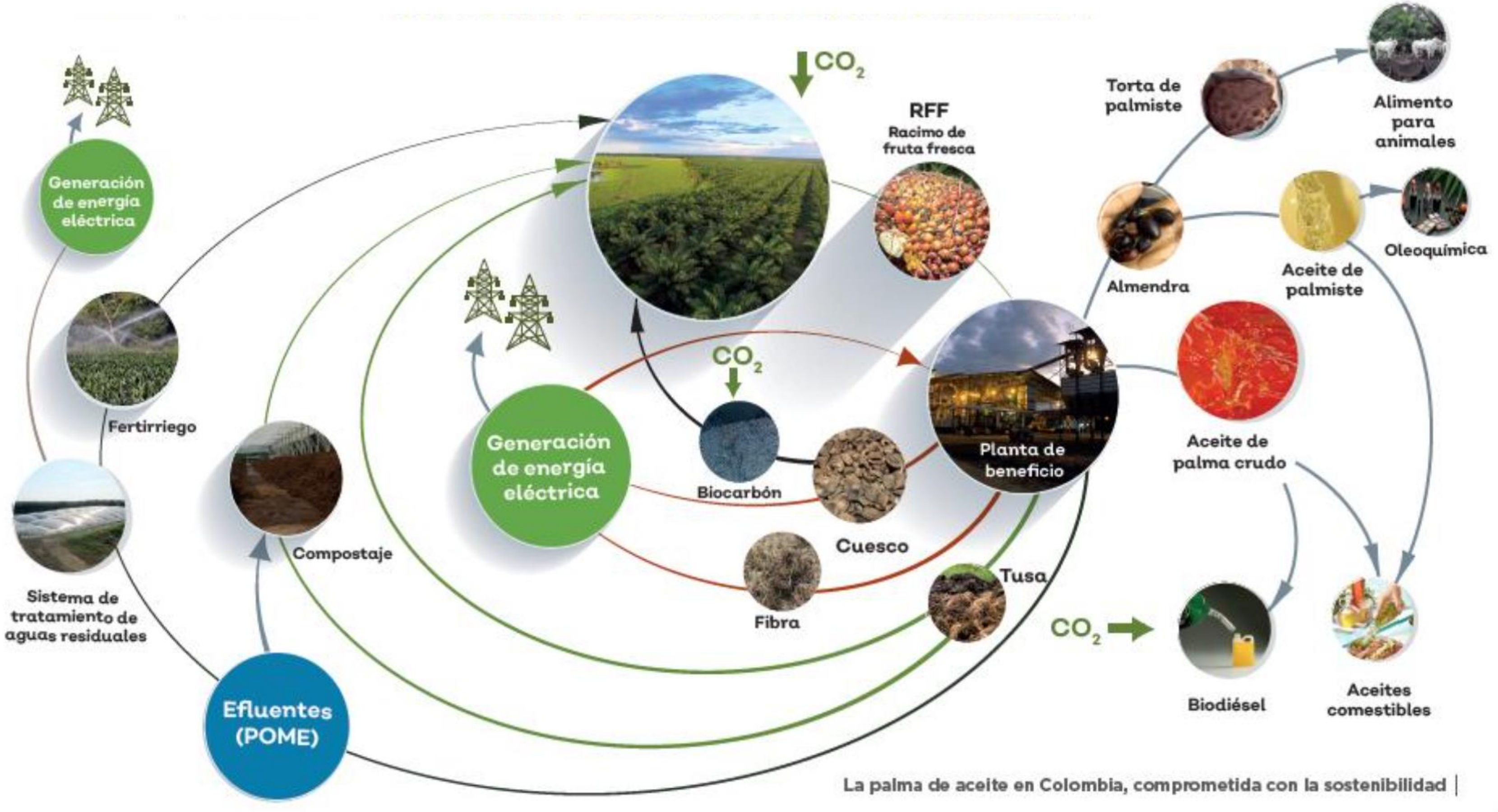
First steps: integrated bioenergy/compost technology

Bioenergy (biodiesel, bioethanol, and bioelectricity)

Composting (nutrient recycling, carbon sink)



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First steps: Biogas energy and compost

MICROBIAL ← BIOMASS → CHEMICAL
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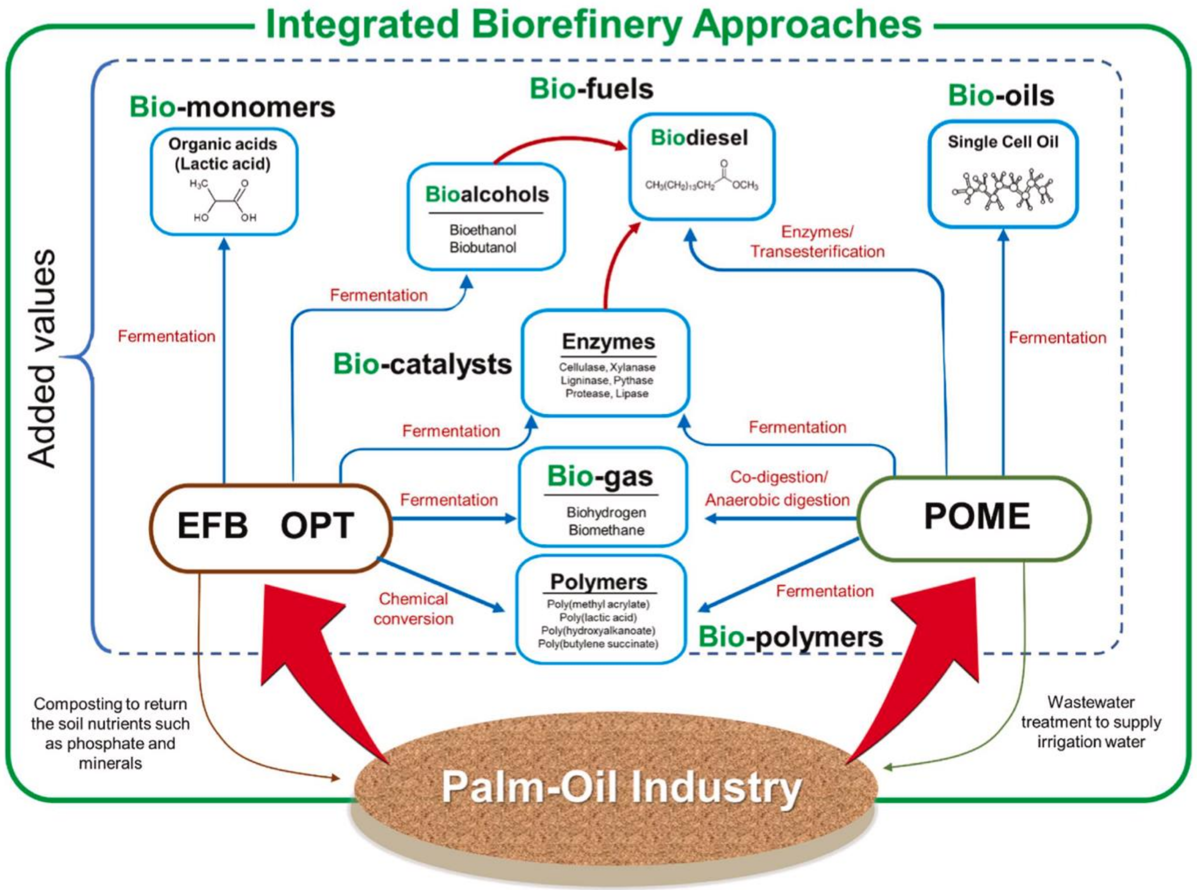
Present and future: high- value marketable biochemicals

- ✓ Zero-waste
- ✓ Sustainability
- ✓ Bio-based chemicals for energy, food, polymer, and cosmetics
- ✓ Decrease environmental impacts



Kahar, P.; Rachmadona, N.; Pangestu, R.; Palar, R.;Adi, D.T.N.; Juanssilfero, A.B.; Yopi; Manurung, I.; Hama, S.; Ogino, C. Review An integrated biorefinery strategy for the utilization of palm-oil wastes, Bioresource Technology 344 (2022) 126266

Present and future: high- value marketable biochemicals

BIOMASS COMPOSITION*

DEFINES ITS USES

* LOCATION AND ABUNDANCE ALSO MATTER

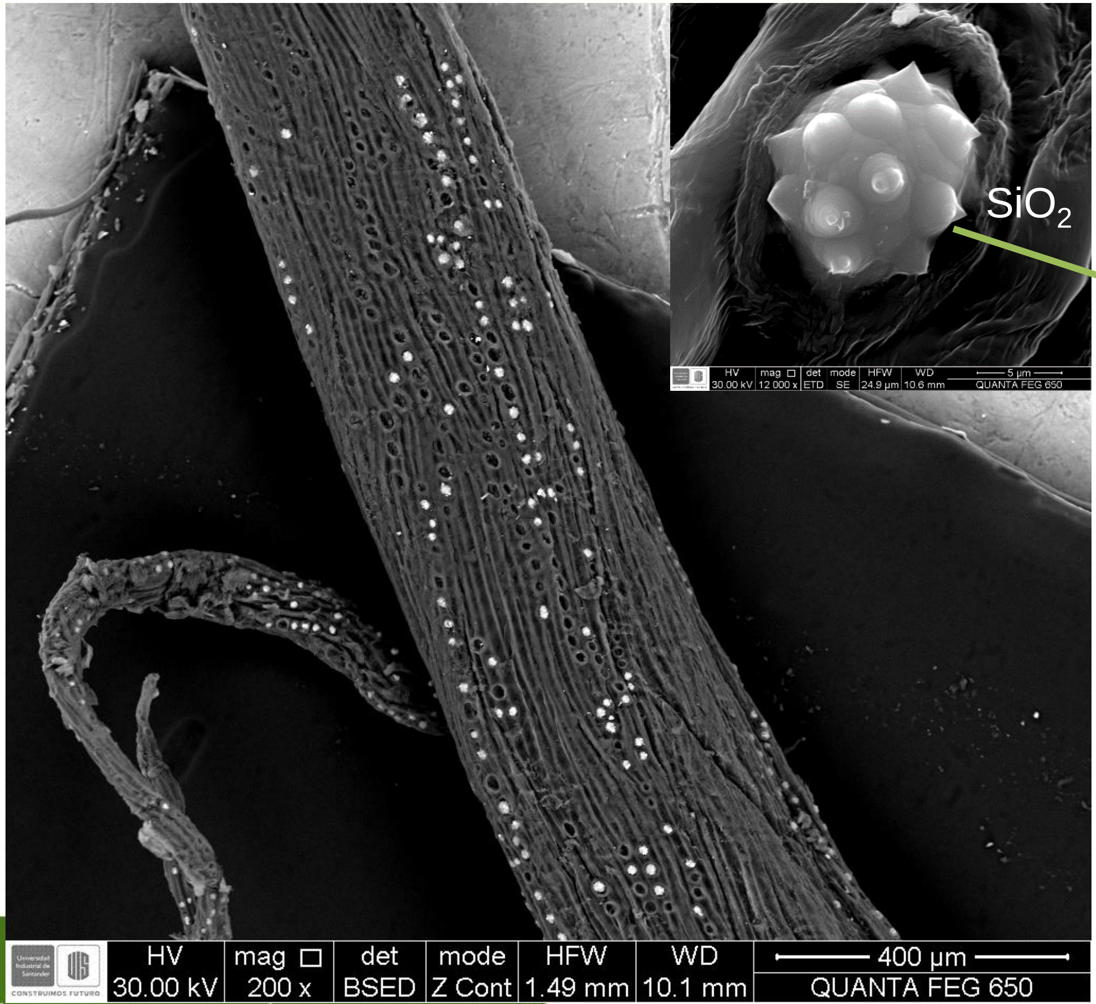
EFB Composition: Hybrid *E. oleifera* x *E. guineensis*

EFB

Spikes and central axis of the rachis

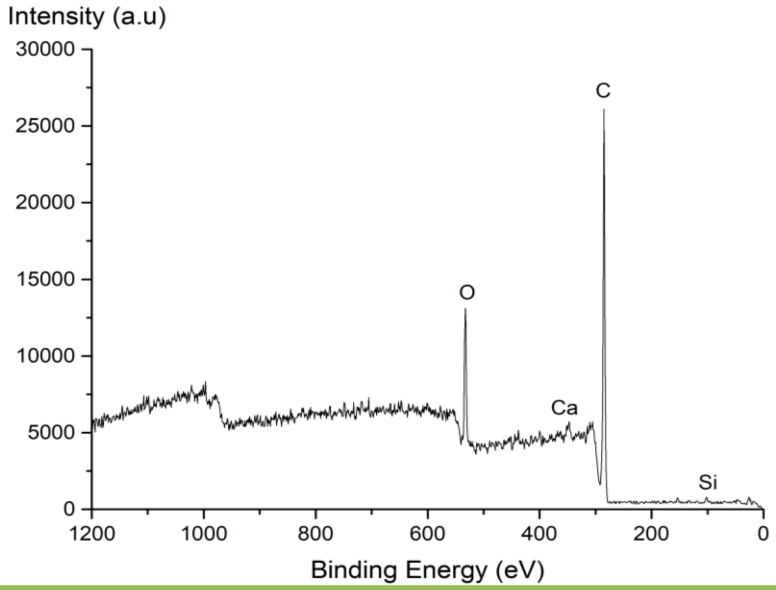
Component	Content [Wt%]	Method
Moisture	4.5 ± 0.15	NREL-TP-510 42621
Ash	2.2 ± 0.11	NREL-TP-510 42622
Waxes, fats, resins, and oils	4.2 ± 0.04	ASTM-D1107
Lignin	24.5 ± 0.09	NREL-TP-510 42618; TAPPI 222
Cellulose	52.1±0.05	Kurscher & Hoffer
Hemicellulose	15.2 ± 0.04	Jayme-Wise
K_2O	1.30	X-ray fluorescence
SiO_2	1.95	
Cl	0.27	
CaO	0.30	
MgO	0.29	
SO_3	0.27	
P_2O_5	0.24	
Al_2O_3	0.03	
Fe_2O_3	0.02	

EFB Composition: Hybrid *E. oleifera* x *E. guineensis*



EFB fibers thermal stability < 200 °C

Silica bodies: defensive barrier against bacterial and fungal attacks

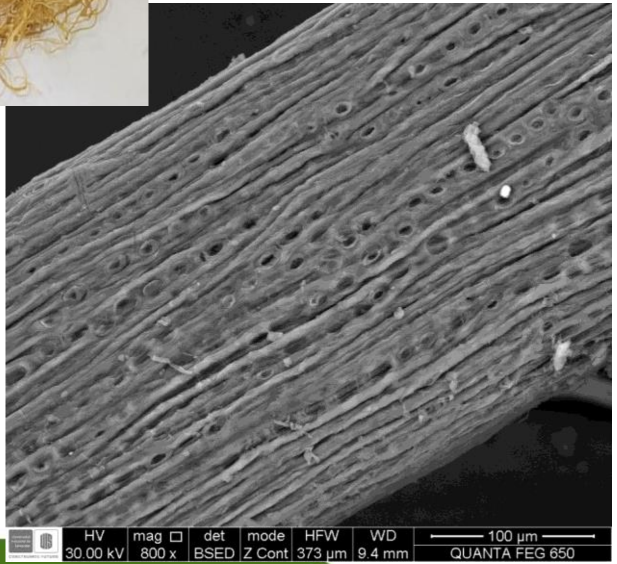


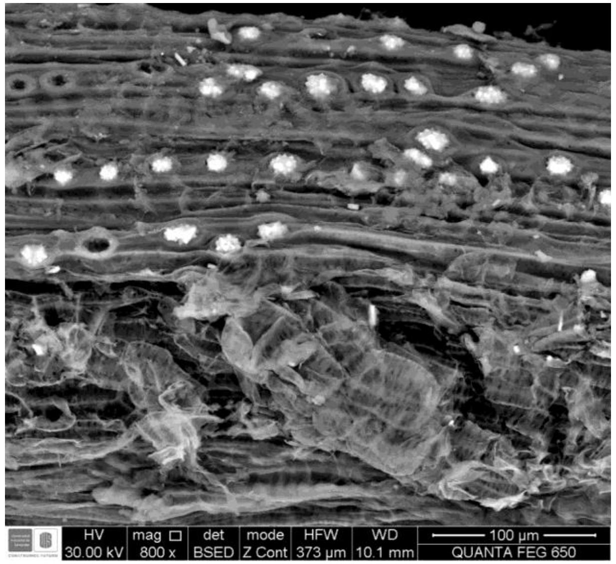
Atom	Si 2p	C 1s	Ca 2p	O 1s
Atomic percentage [%]	2.10	84.65	1.32	11.93

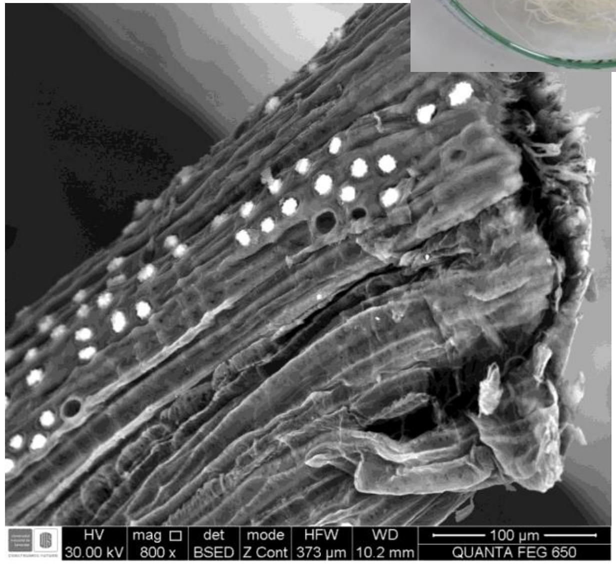
EFB Composition: Hybrid *E. oleifera* x *E. guineensis*

NaOH/HCL treatment

Alkaline treatment

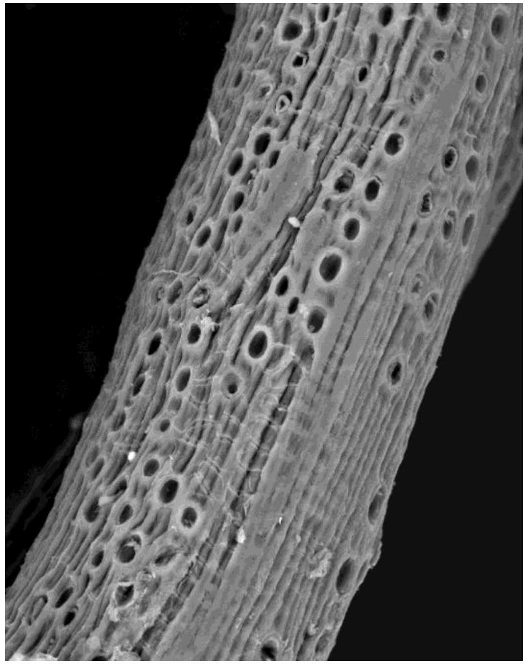




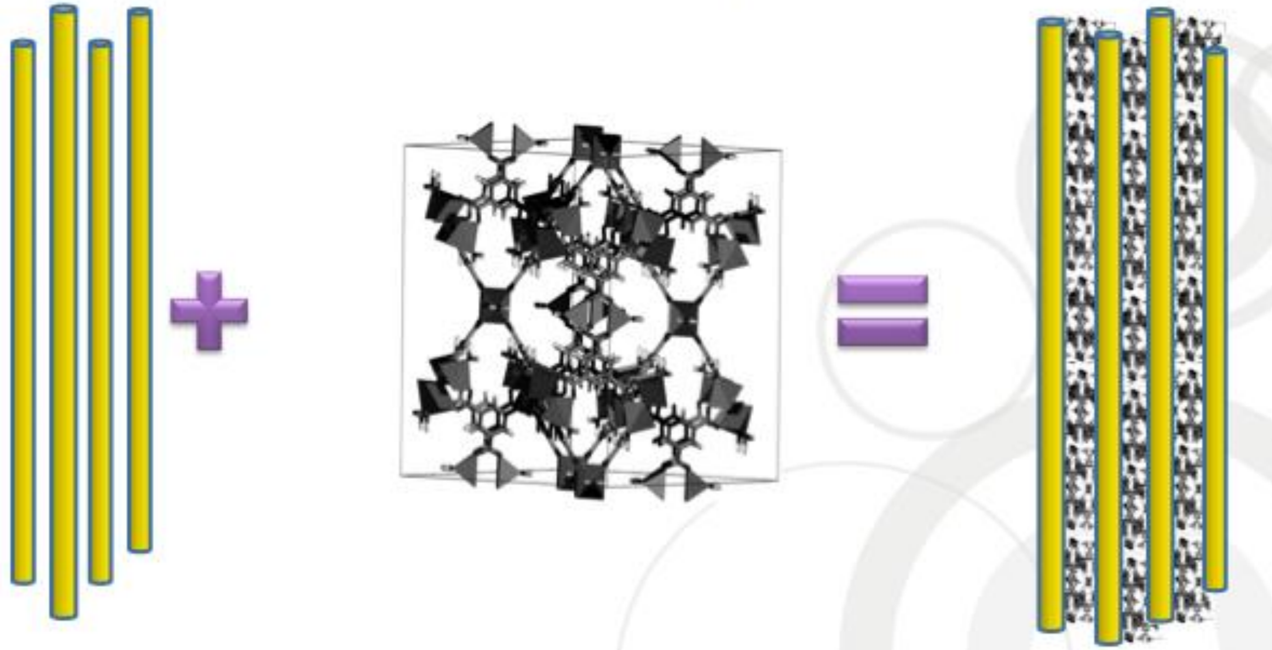


Ovalle-Serrano, S.; Blanco-Tirado, C.; Combariza, M. Exploring the composition of raw and delignified Colombian fique fibers, tow and pulp. Cellulose 2018 , 25, 151–165.

EFB Fibers applications



Natural Fibers + Nanostructured materials = Biocomposites



Natural Fibers

- Raw: High oxygen density
- Modified: Cationic, anionic

Nanostructured materials

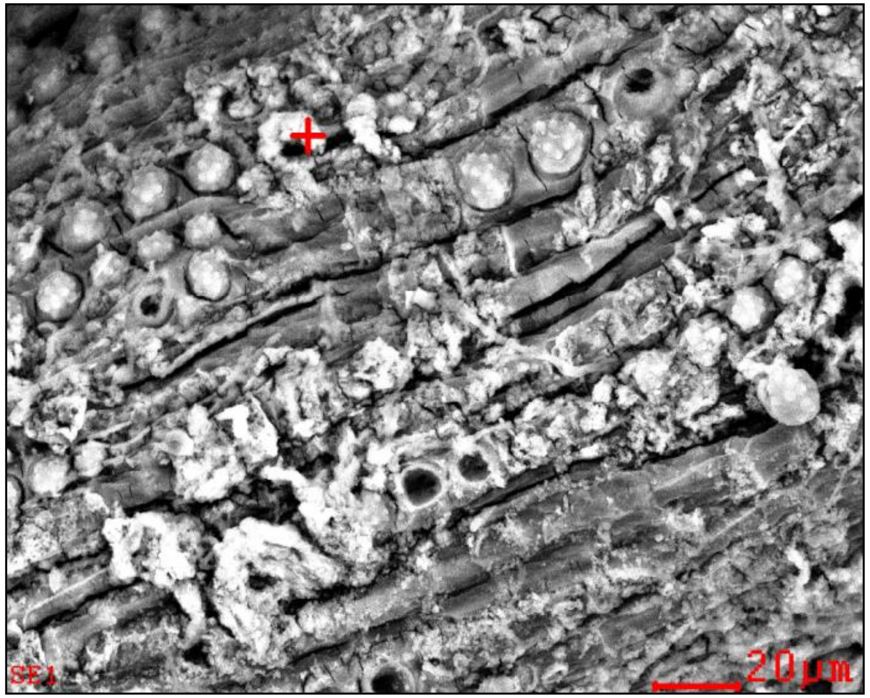
- Noble metals: Ag, Au
- Transition Metal oxides: Fe, Mn, Cu, Zn
- Metal Organic Frameworks: MOFs

Biocomposites

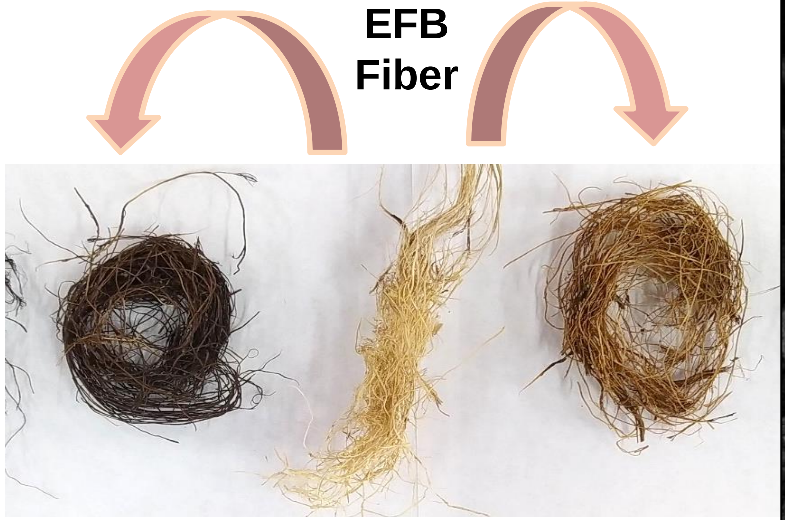
- Functional materials (dye & phenol degradation, sulfur compound removal)
- Environmentally friendly
- Improved thermal and mechanical properties

EFB : Hybrid *E. oleifera* x *E. guineensis*

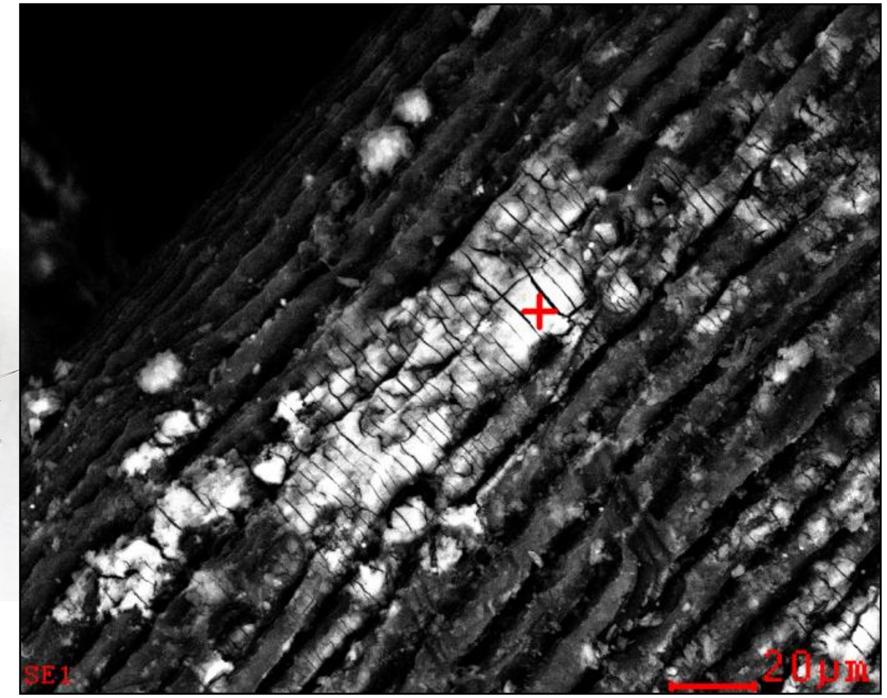
EFB Fibers applications



EFB fiber/MnO_2 NPs composite



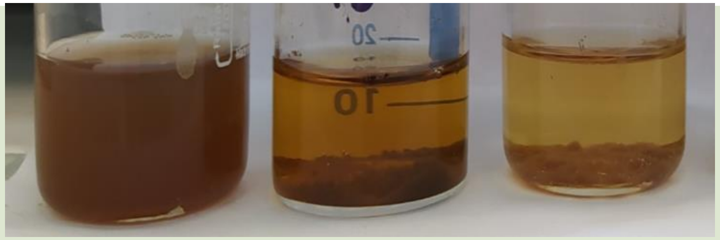
Chemical and sonochemical NP deposition



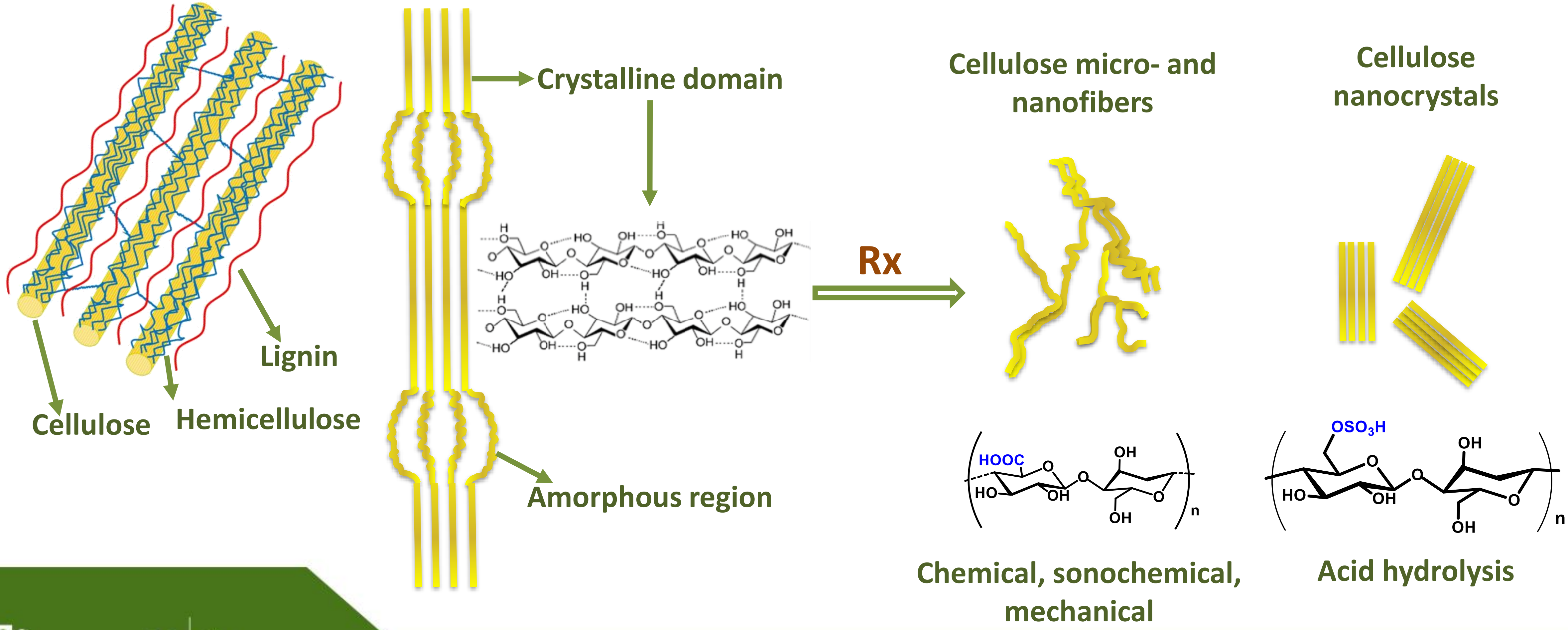
EFB fiber/Fe_xO_y NPs composite

EFB Fibers applications

POME treatment with EFB fiber/Fe_xO_y NPs composite

Sample	Color	Removal %	Time	
POME – raw	436, 525, 620 nm	94% Color 60% COD	6 h	
POME – w/o SS		72 % Color	2 h	

EFB Composition: Hybrid *E. oleifera* x *E. guineensis*



XX Conferencia Internacional sobre PALMA DE ACEITE

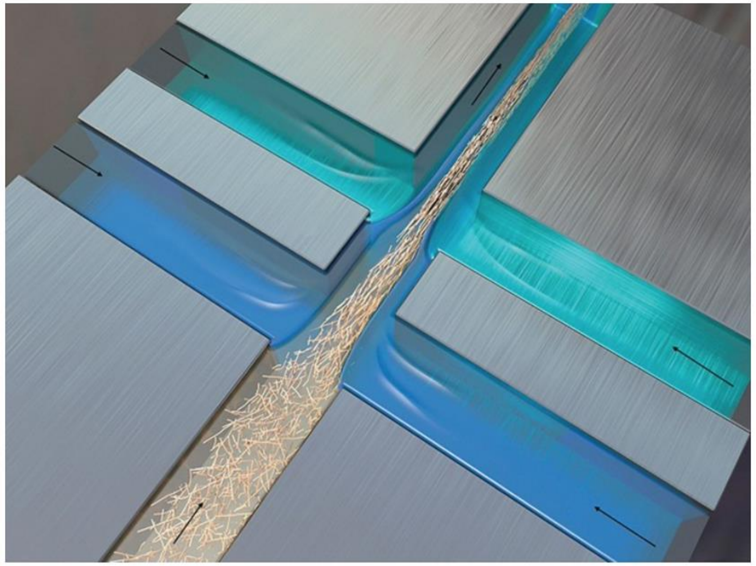
BIOMATERIALS

World's strongest biomaterial now comes from a tree

A new method creates superstrong fibers out of cellulose

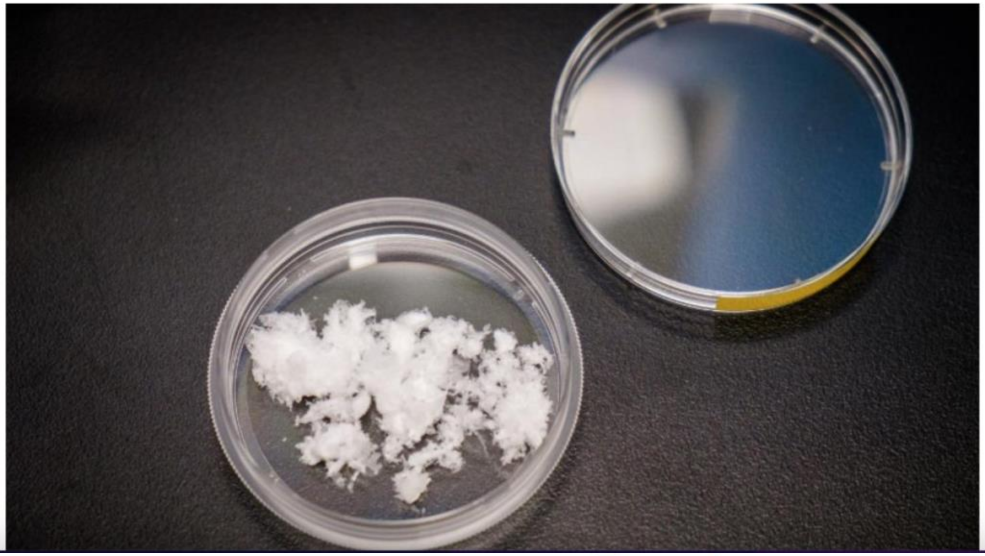
by ***Katharine Gammon***

June 19, 2018



Nanocellulose Fibers Block Fat Uptake By Half

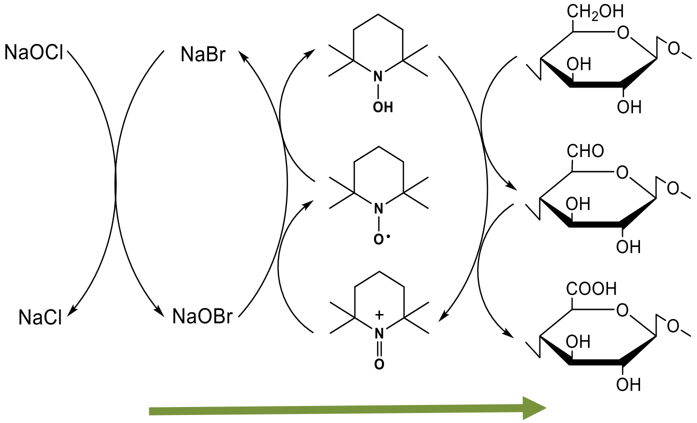
Nanocellulose fibers prevented the absorption of dietary fat from the guts of mice, researchers say.



EFB Composition: Hybrid *E. oleifera* x *E. guineensis*

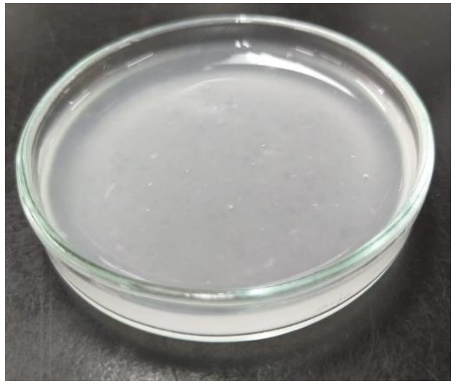
Nanocellulose isolation from EFB

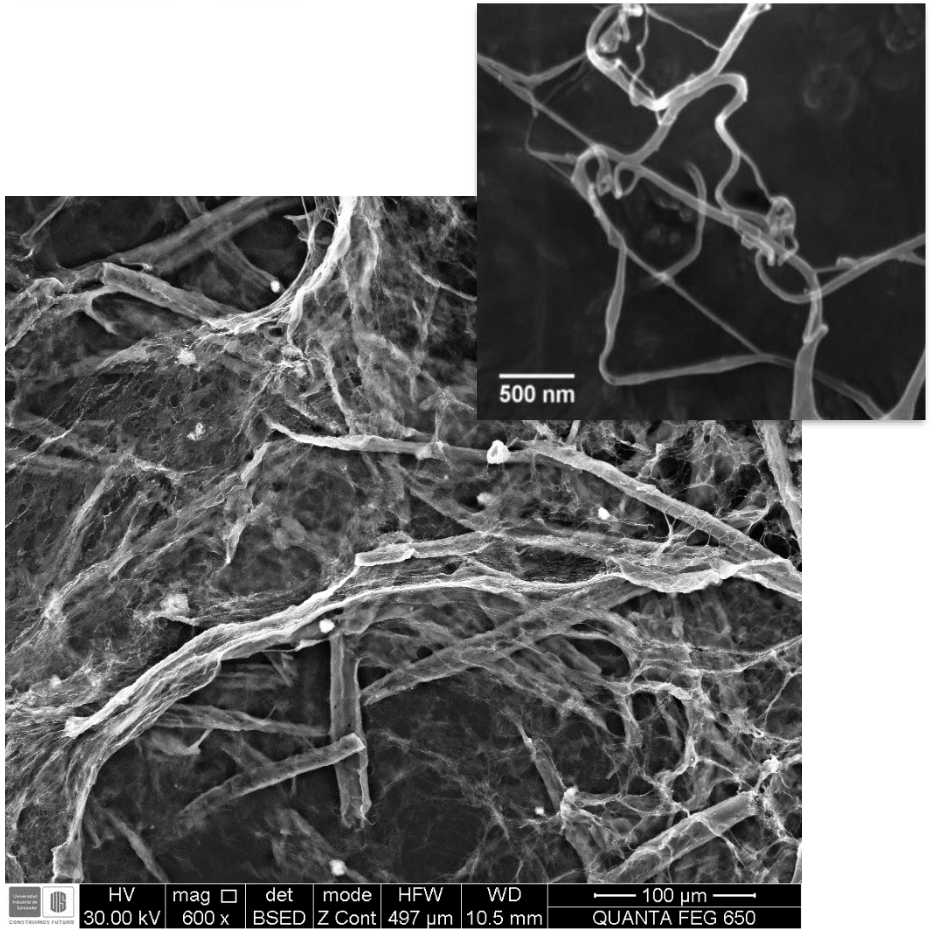
Delignified EFB fibers



TEMPO Oxidation
60% efficiency

EFB nanocellulose





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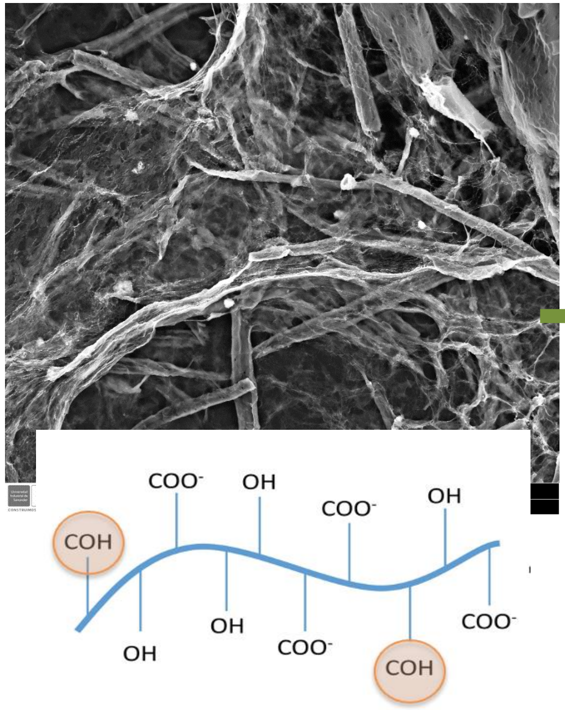
EFB : Hybrid *E. oleifera* x *E. guineensis*

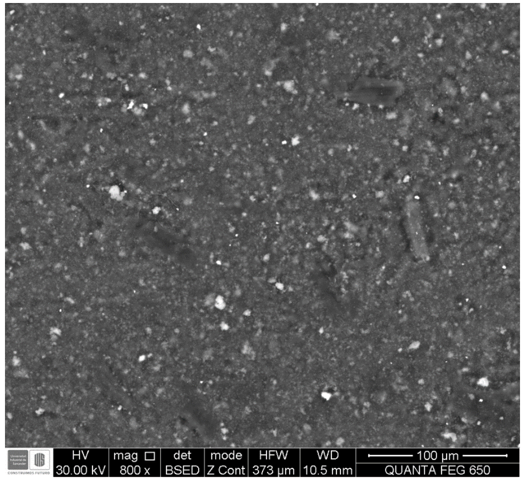
EFB Nanocellulose applications



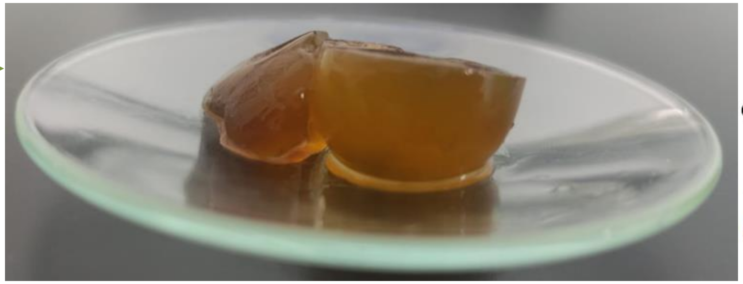
EFB nanocellulose

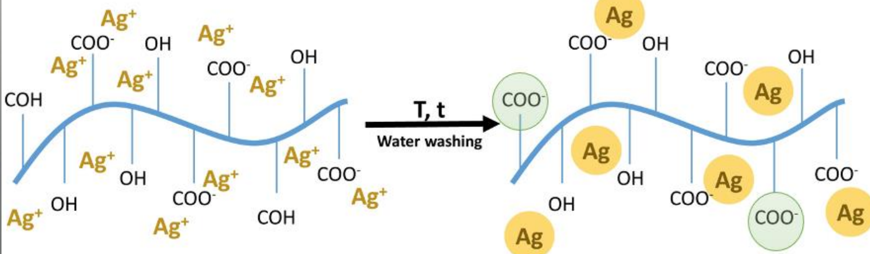
$[Zn(H_2O)_6]^{2+} + 2\ OH^- \rightarrow Zn(OH)_2 + 6H_2O$

$Zn(OH)_2 \rightarrow ZnO + H_2O$



EFB nanocellulose/ZnO NPs composite





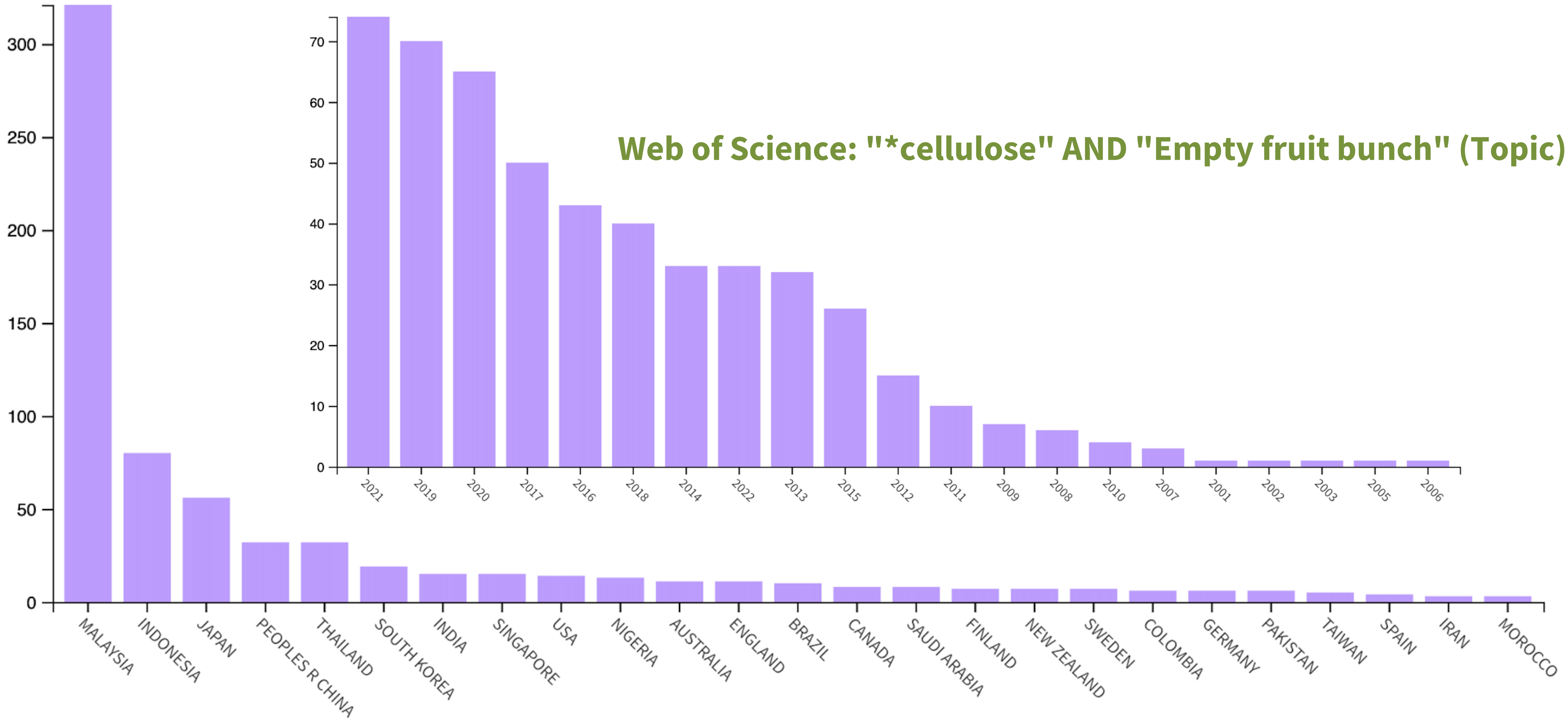
EFB nanocellulose/Ag NPs hydrogel

Nanocellulose applications

Web of Science: "*cellulose" AND "Empty fruit bunch" (Topic)

EFB cellulose applications

Web of Science: "*cellulose" AND "Empty fruit bunch" (Topic)



CONCLUSIONS

Carbohydrate chemistry depends on biomass composition.

Biopolymeric functional materials require sustainable and cheap biomass fractionation strategies (cellulose, hemicellulose, lignin).

Research in biopolymer isolation and functional material synthesis from Palm Oil residual biomass is steadily growing.

Widely distributed in Colombia, Palm Oil Mills have readily access to abundant lignocellulosic biomass. We have the what and the where, we need the when and the how… Chemistry can help!

Acknowledgements

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cenipalma

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César Augusto Díaz

Neila Milena Mantilla

Cristian Blanco

Campo experimental de las Corocoras

Campo experimental Palmar de la Vizcaína

AGROINCE

César Díaz

XX Conferencia Internacional sobre PALMA DE ACEITE

EL PODER TRANSFORMADOR DE LA PALMA DE ACEITE

Gracias