5th Latin American Congress on

Biorefineries

From laboratory to industrial practice

January 7-9, 2019 - Concepción, Chile

Colegio de Ciencias e Ingenierías

Universidad San Francisco de Quito

Departamento de Ingeniería Química

Biorefinery: Micro and nanocelullose fibers from forest and agro-industrial waste

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IDEMA

Grupo de Ingeniería, Ciencias Aplicadas y Simulación (GICAS)

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OUTLINE

- Introduction
- Objectives
- Methodology
- NNC from horticulture and herbaceous materials
- Microcrystalline cellulose fibers from oil palm residues
- Micro/nanocellulose fibers from woody materials
- Nanocellulose applications
- Conclusions

IDEMA

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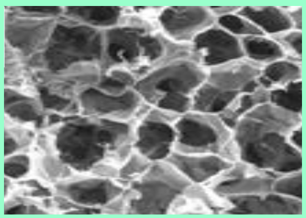
Development of Alternative Energies
and Materials

Biomaterials



- Adsorbents
- Hydrogel
- Biomed (patch)
- Biopolymers (films)

Bioprocesses

- Anaerobic digestion
- Bioethanol
- Citric acid
- Lactic acid- PLA

Thermo-chemical processes

- Thermal / catalytic cracking of used motor oil and plastics
- Pyrolysis of biomass

Advanced materials

- Cellulose/micro/nano
- Xylan/xylose
- Lignins
- Cellulose, hemicellulose & lignin derivatives

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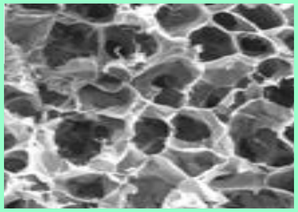
Biomaterials

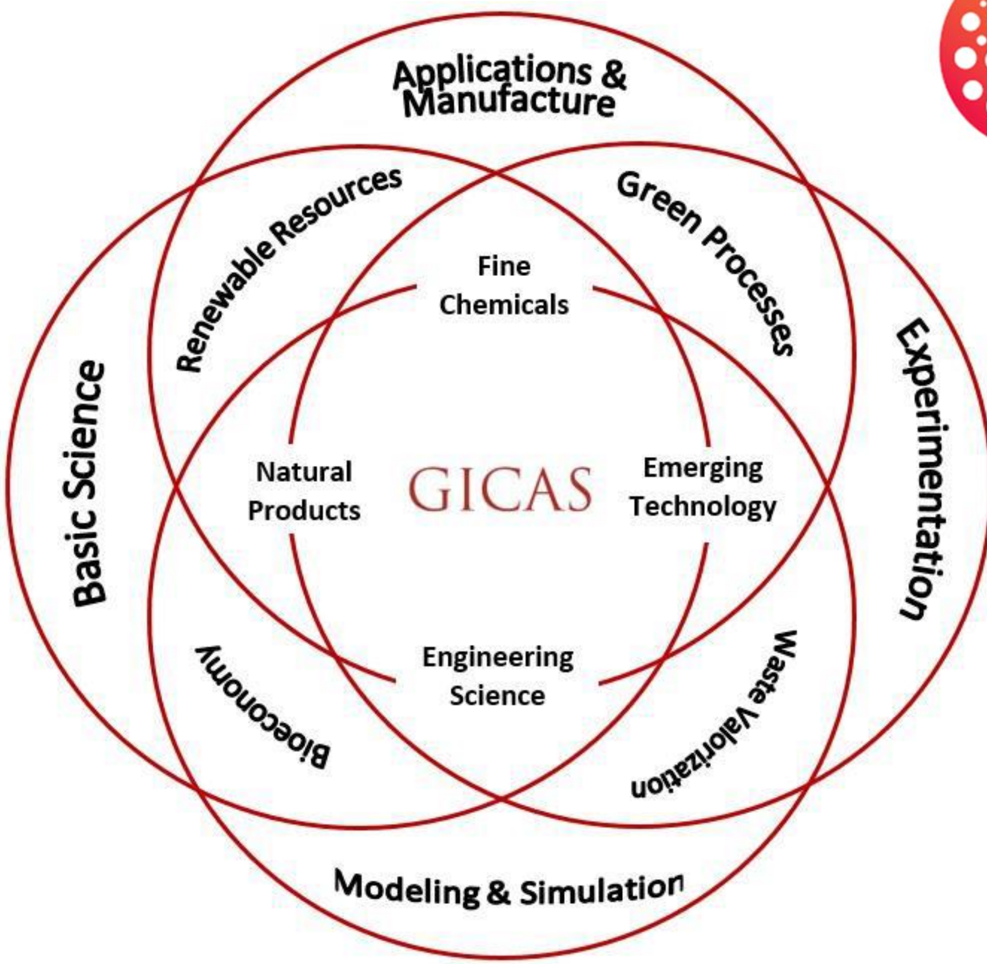


Bioprocesses

Thermo-chemical processes

Advanced Materials

GOAL: Investigate and develop new technologies for the utilization of biomass and other residues as raw renewable materials for the production of alternative energy sources, biomaterials, chemical precursors for further productive processes or advanced materials.



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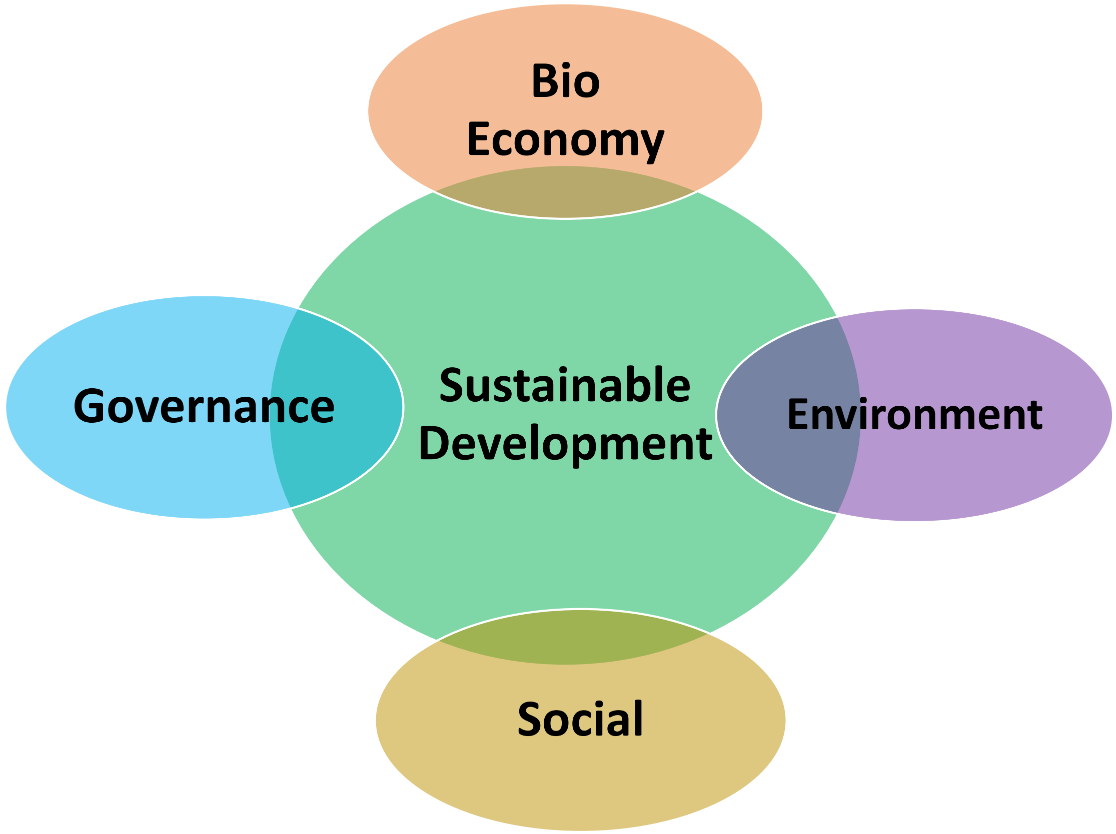
GICAS - Engineering / Applied Sciences and Simulation

Society, Development and Industry

- Development is linked to the economy and it is related to the advancement of knowledge and technology that promote industrialization
- Industry has an impact in the **environment**
- **Sustainable Development?**
- UN, the world's population is 7800 million, in 2030 it will be 8500 and for the year 2050 > 9700 million
- Modern society – life style not sustainable
- **Circular Economy**
- **Zero-waste technology**
- **BIOECONOMY**



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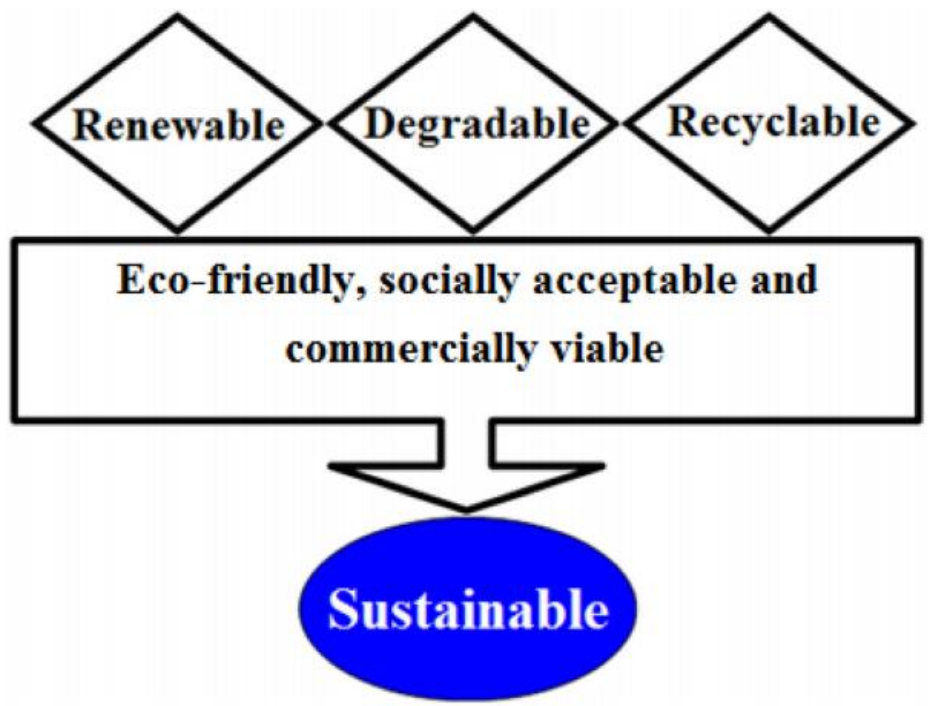
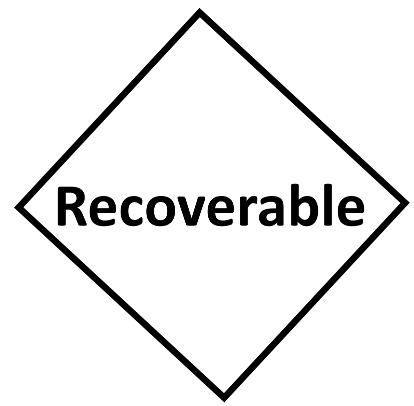
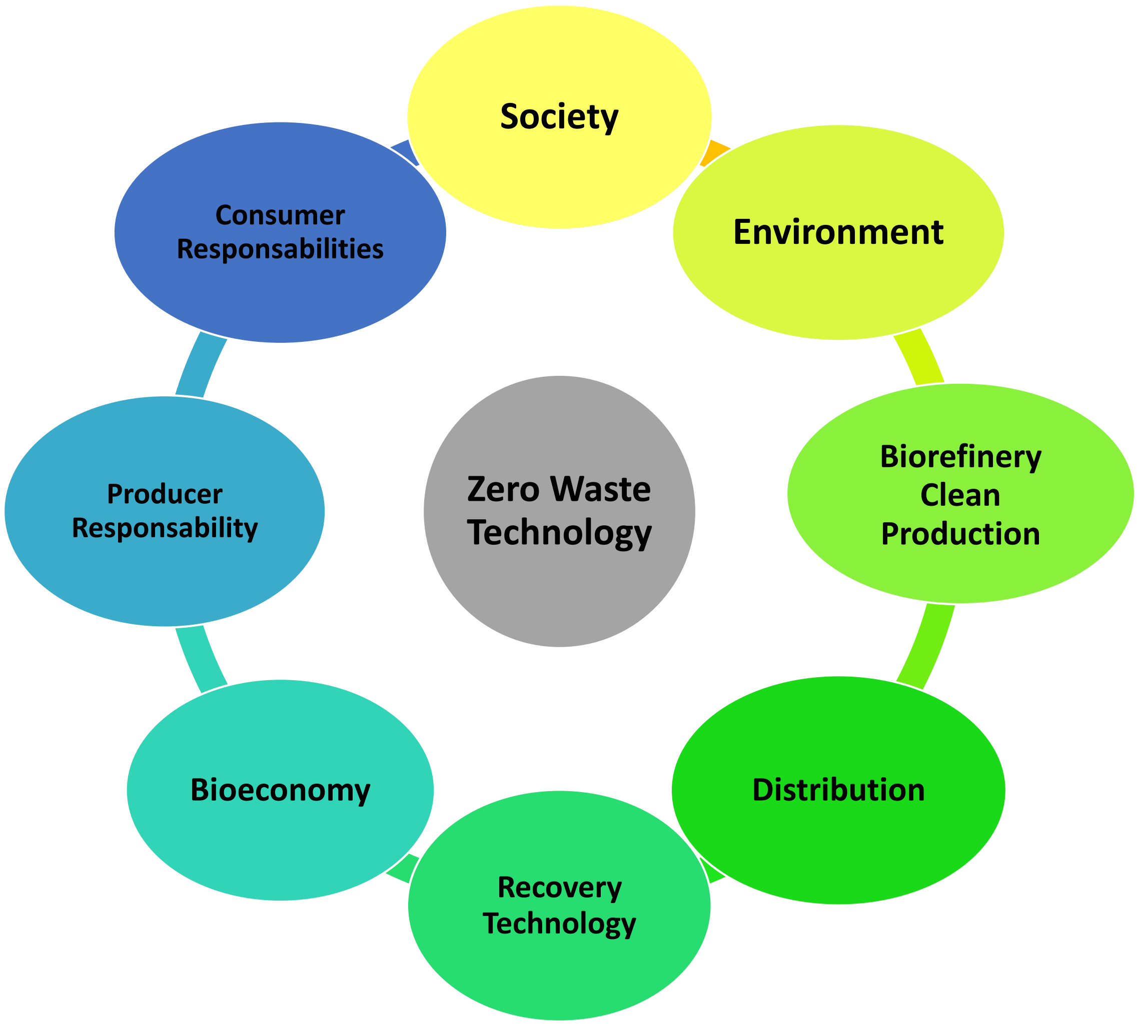
Sustainable Development based on Bio-economy





A. Arevalo-Gallegos et al. / International Journal of Biological Macromolecules 99 (2017) 308–318

Circular Economy, Zero Waste Technology and Biorefinery



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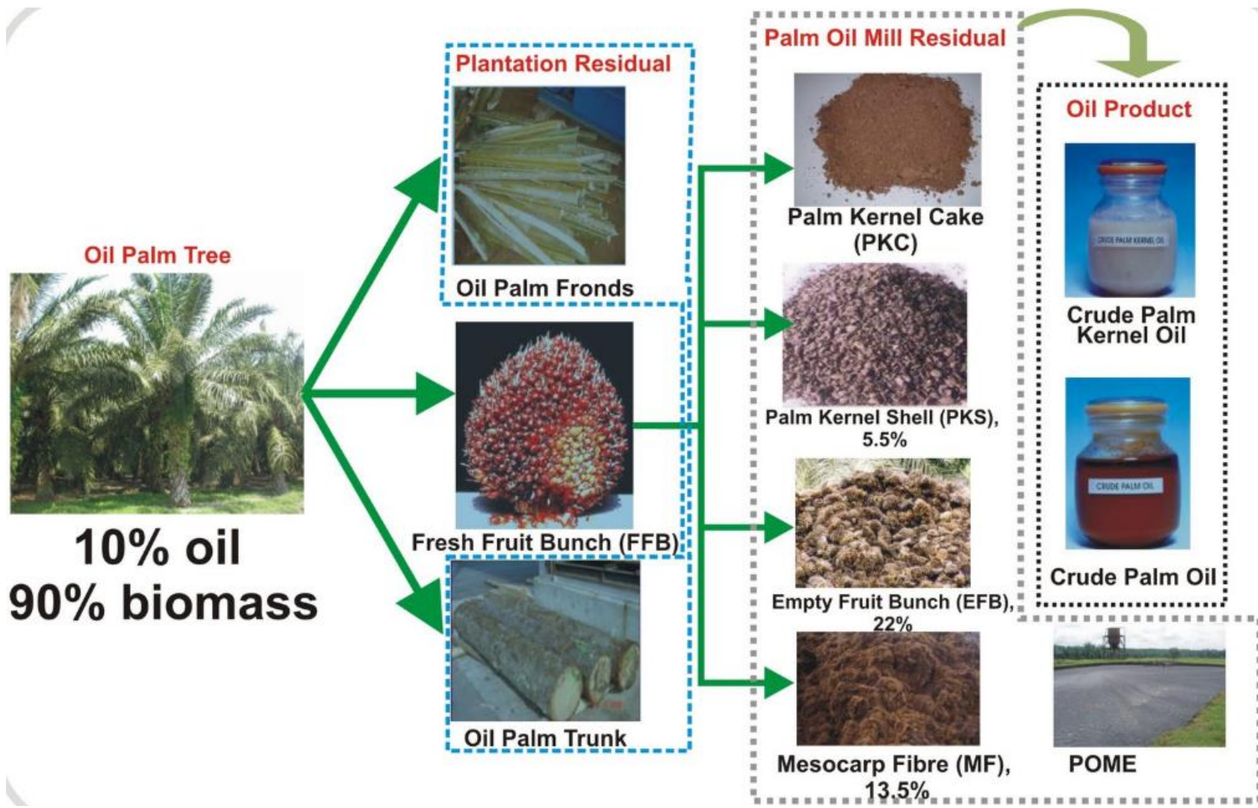
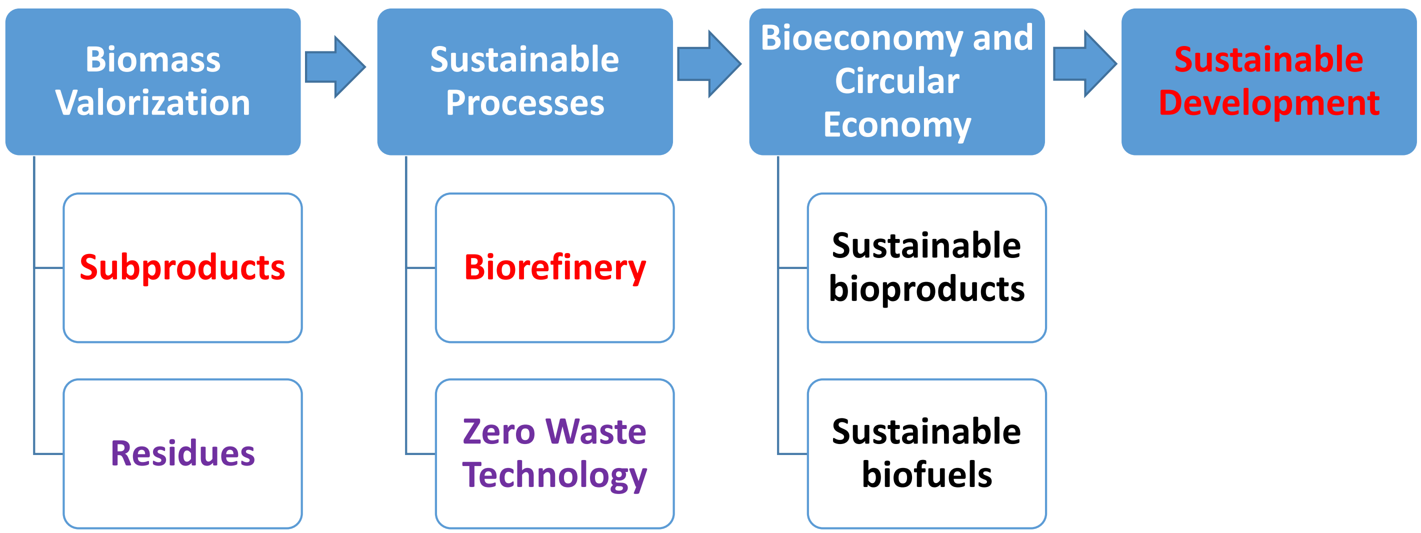
Residues from forest, agriculture and agro-industries

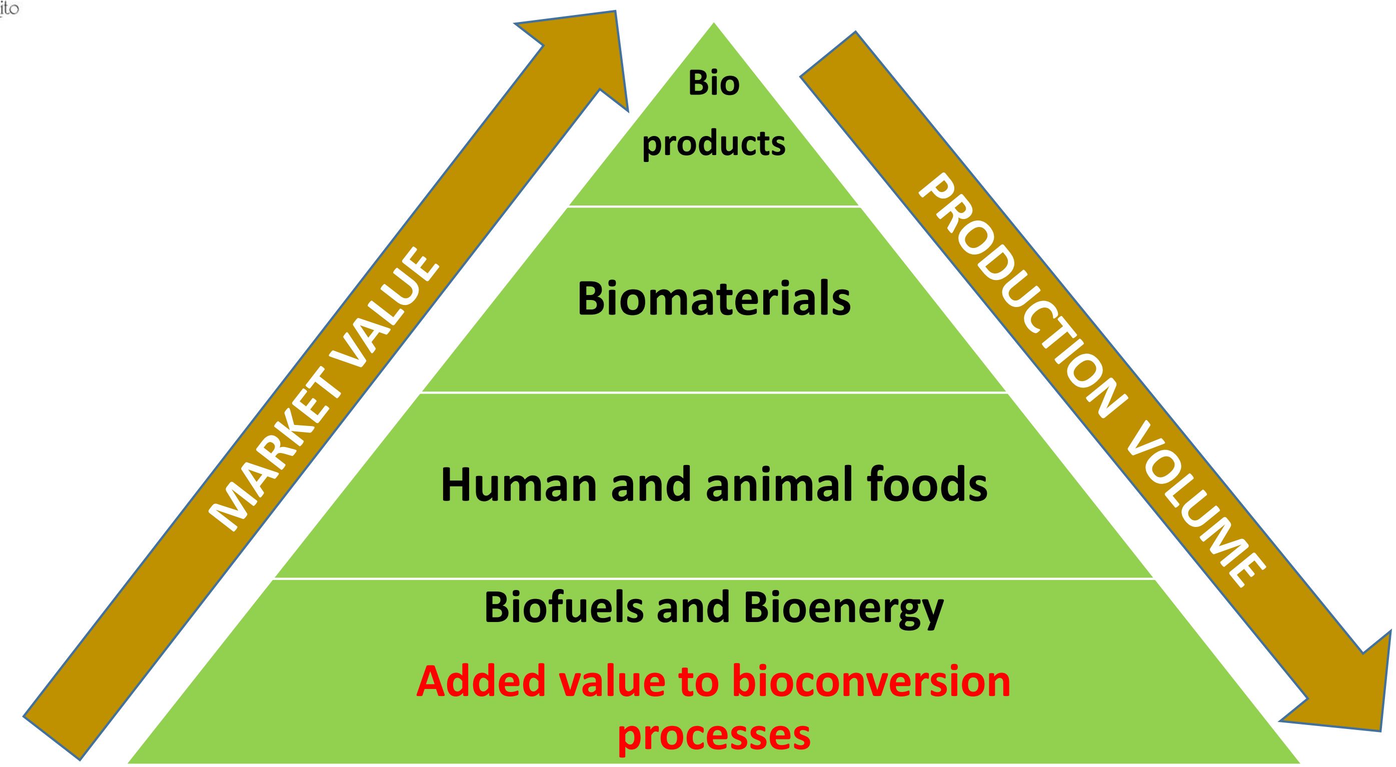
Oil Extraction Industry from oil palm trees



Process Integration for Sustainability based on Zero Waste Technology and biorefinery



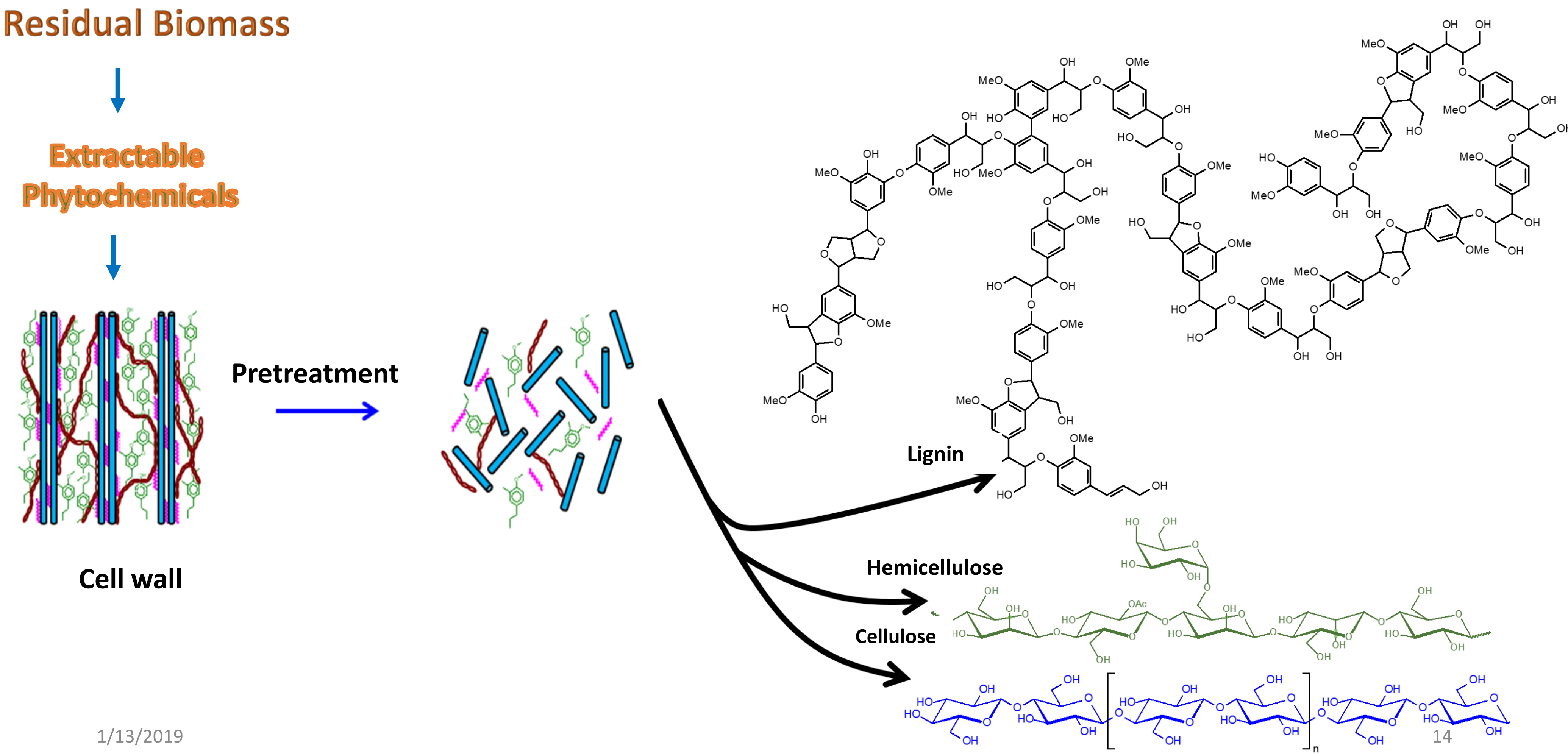
Biomass Conversion



Value added and volume of products in the biomass conversion

Adapted from reference [Hilbert, 2017]

Integration of phytochemicals extraction and lignocellulose deconstruction



Objetives

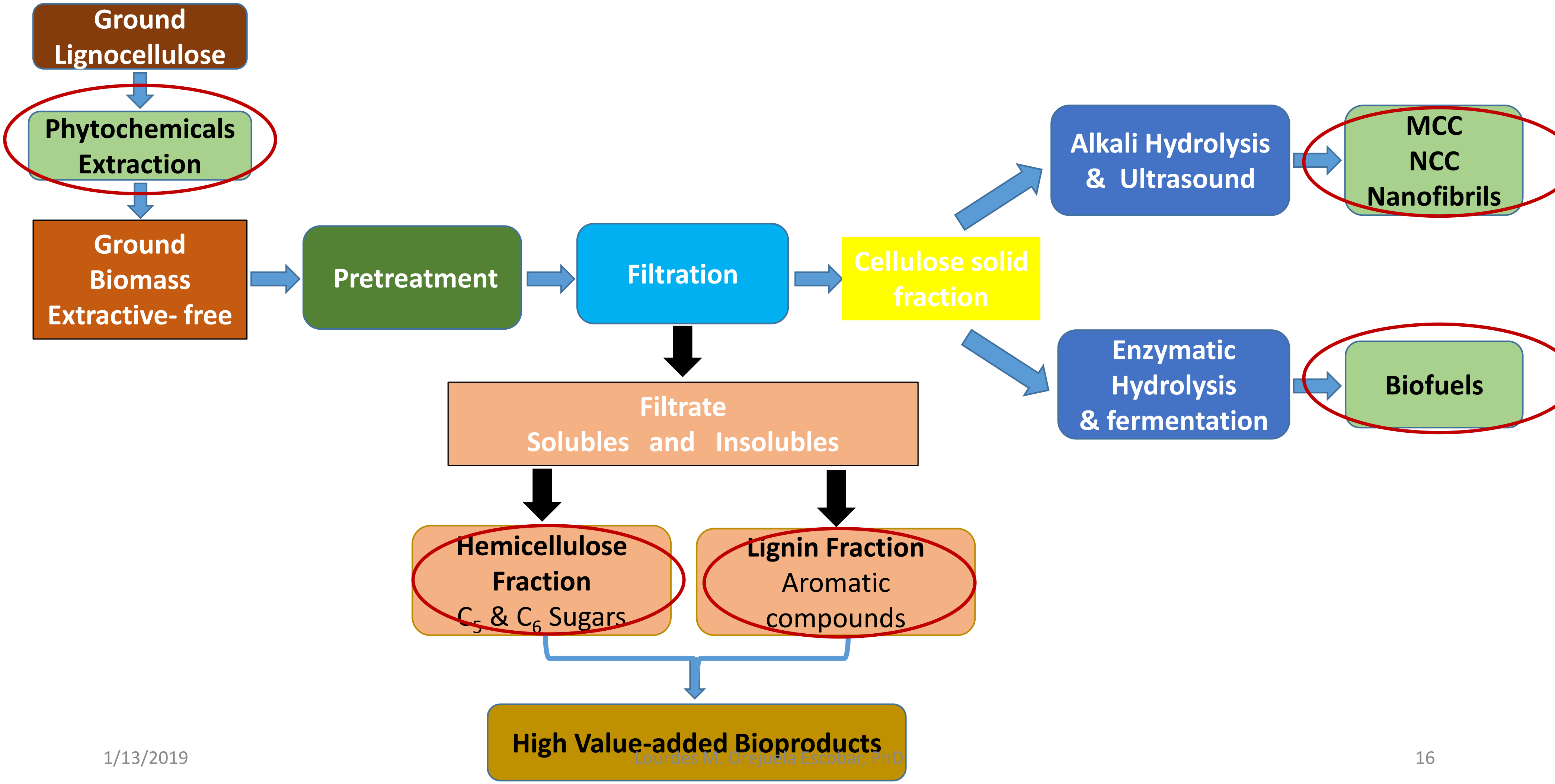
Develop advanced bioproducts and materials through biorefinery of residual biomass from forest/wood, agricultural and food industry.

- Apply the biorefinery technology to obtain biofuels, bioproducts and advanced materials (e.g. micro/nanocellulose)

- Supply novel technologies to recover valuable biomass components

- Provide value to residual biomass components

Lignocellulosic Biomass Fractionation – Biorefinery Approach



Nanocellulose crystals and fibers from horticultural and herbaceous residues

Production of nanocellulose crystals

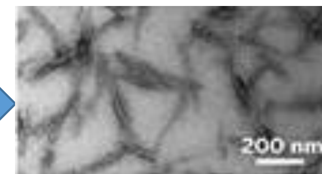
Agricultural Waste Collection → **Pretreatment** → **Treated Biomass Bleaching** → [micrograph] → **NCC's Characterization**

Agricultural Waste Collection

Pretreatment
- Auto hydrolysis
- Soda Hydrolysis
- Organosolv

Treated Biomass Bleaching
- 2% NOH w/w Troom Overnight

Black Liquor (Lignins + Hemicelluloses)
- Recovery



- Acid hydrolysis
- Washing
- Dyalisis

NCC's Characterization
- DLS
- X-Ray Diffraction
- TGA
- Titration
- AFM

DLS - Dynamic Light Scattering
X-Ray Diffraction – Crystallography
TGA – Thermal Gravimetric Analysis
AFM – Atomic Force Microscopy

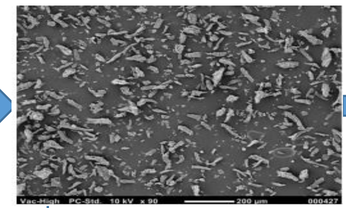
García, A., et al., *The nanocellulose biorefinery: woody versus herbaceous agricultural wastes for NCC production.* Cellulose, 2017. **24**(2): p. 693-704.

Physicomechanical properties of NCC samples Morphology, Surface Charge and Thermal Behavior

Technique	Property	Apple trimming Auto hydrolysis	Apple Trimming Soda hydrolysis	Apple Trimming Acetosolv	Pea stalks Auto Hydrolysis	Pea stalks Soda Hydrolysis	Pea stalks Acetosolv
DLS	Hydrodynamic diameter (nm)	428	445	363	394	422	385
	PDI (nm)	0.14	0.13	0.10	0.20	0.19	0.17
AFM	Length (nm)	436	676	300	490	184	325
Conductometric Titration	Total acid groups (µmol/g)	282	983	507	169	308	706
TGA	Maximum Degradation Temperature (°C)	315	269	268	301	310	250

Microcrystalline cellulose fibers from oil palm residues

Production of microcellulose crystals - MCC

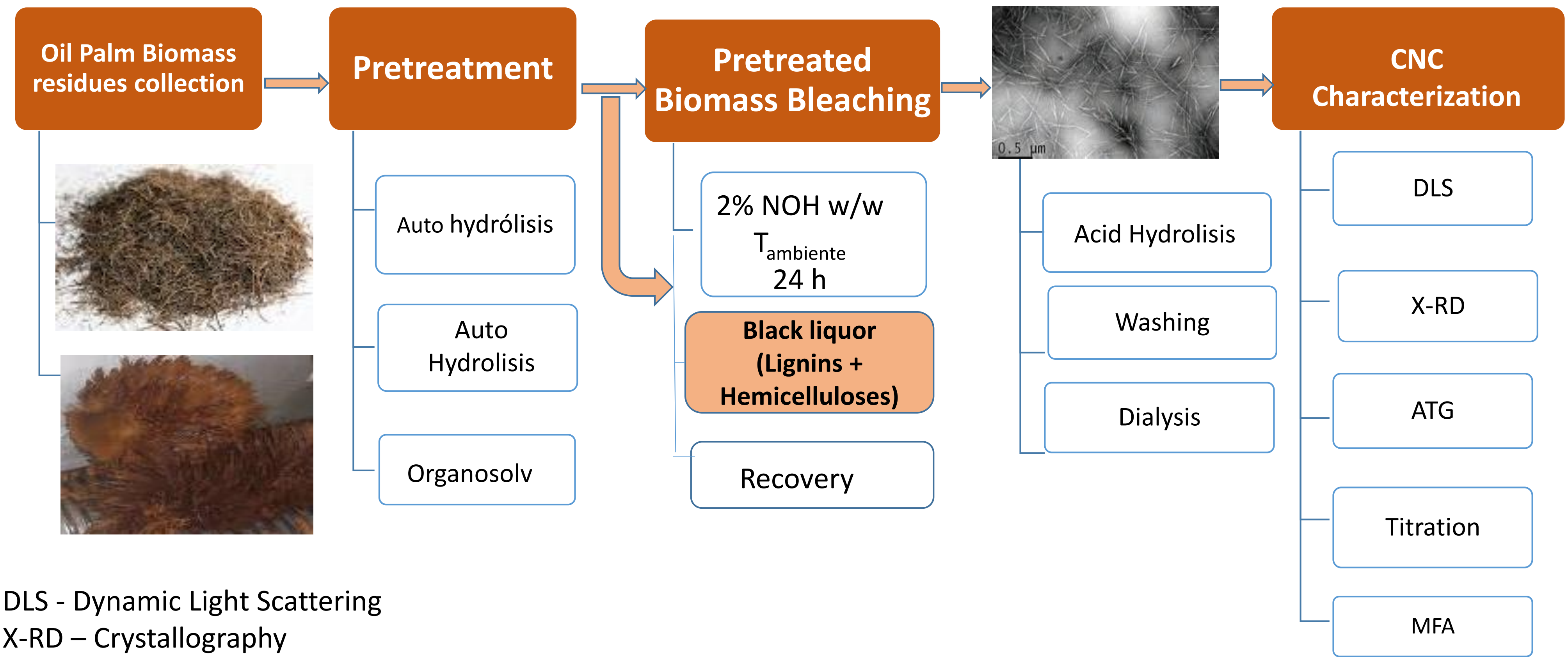
Oil palm fronds → **Pretreatment** → **OPF pulp fiber Bleaching** →  → **MCC Characterization**

- Pretreatment
  - Alkaline hydrogen peroxide hydrolysis
- OPF pulp fiber Bleaching
  - Acidified Sodium Chlorite sol.
- Black Liquor (Lignins + Hemicelluloses)
  - Recovery
- Acid hydrolysis
- Washing
- Drying
- MCC Characterization
  - FESEM
  - X-RD
  - TGA
  - FT-IR
  - TEM

FESEM – Field Emission Scanning Electron Microscopy
X-Ray Diffraction – Crystallography
TGA – Thermal Gravimetric Analysis
TEM – Transmission Electron Microscopy
FT-IR – Fourier Transformed Infrared Spectroscopy

Owolabi, A.F., et al., *Influence of alkaline hydrogen peroxide pre-hydrolysis on the isolation of microcrystalline cellulose from oil palm fronds.* International Journal of Biological Macromolecules, 2017. **95**: p. 1228-1234.

Crystalline Nanocellulose from Oil Palm Empty Fruit Bunch



DLS - Dynamic Light Scattering
X-RD – Crystallography
ATG – Thermal Gravimetric Analysis
AFM – Atomic Force Microscopy

Souza et al., 2016; Orejuela et al. 2018

Technique	Property	OPF - Raw	OPF – MCC 1	OPF –MCC 2	OPF – MCC 3
TGA	Maximun Degradation Temperature (°C)	341	346	340	341
XRD	Crystallinity Index (%)		55.8	59.0	62.3
FESEM	Morphology		Irregular size and shape	Irregular size and shape	Irregular size and shape

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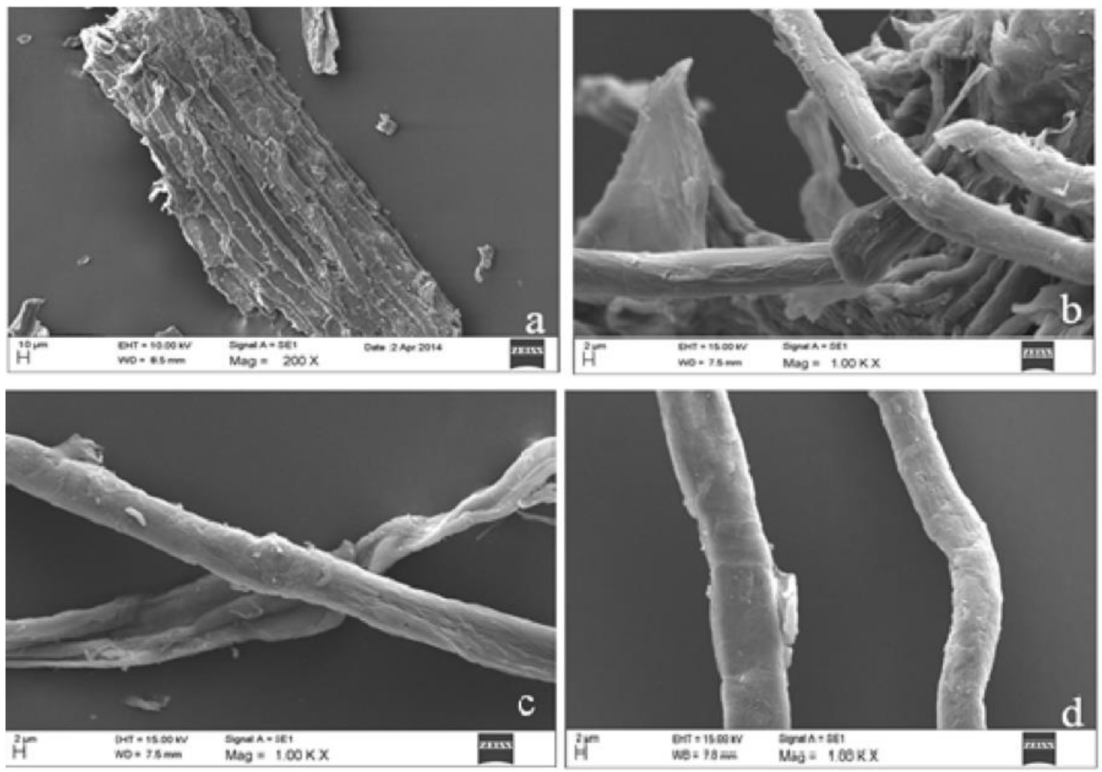
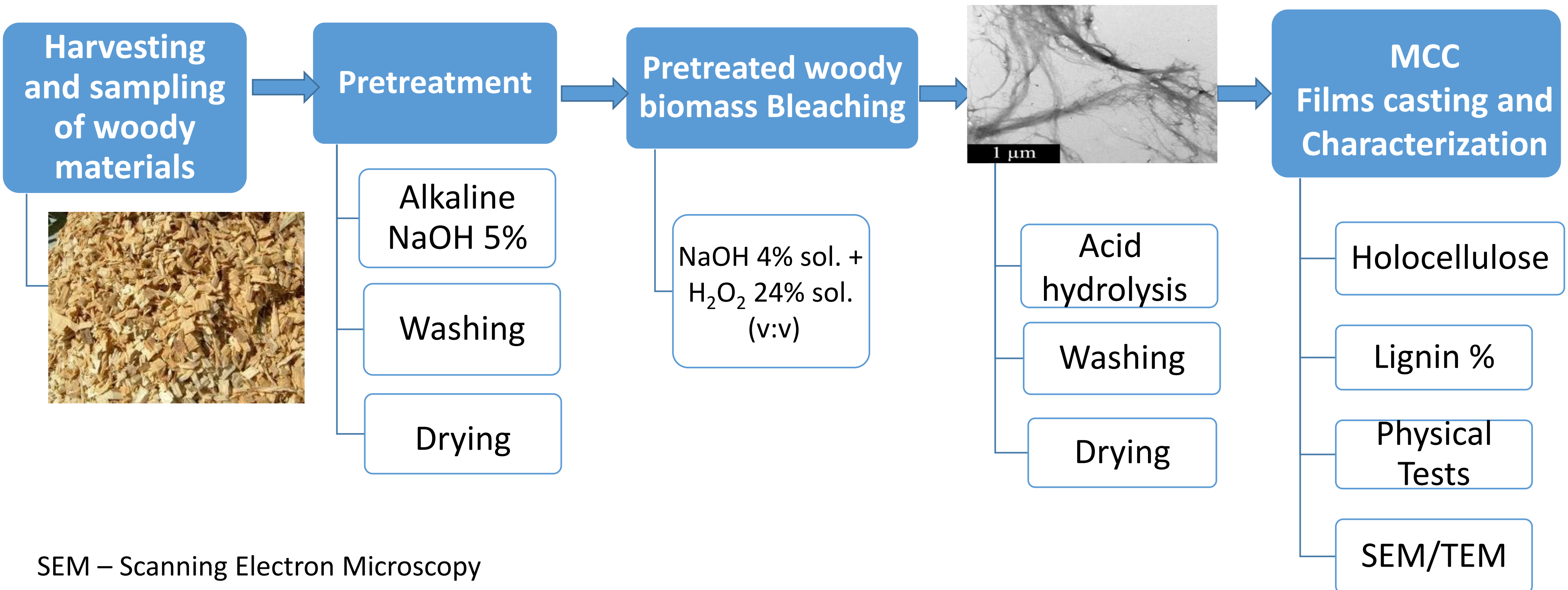
FE-SEM Micrograph of a raw oil palm fiber (a), a AHP OP MCC (b), AHP MCC x100 (c), and AHP MCC x1000 (d)



Micro/nano cellulose fibers from woody materials

Micro/nanocellulose fibers from woody materials



SEM – Scanning Electron Microscopy
TEM – Transmission Electron Microscopy

Scatolino, M.V., et al., *Impact of nanofibrillation degree of eucalyptus and Amazonian hardwood sawdust on physical properties of cellulose nanofibril films.* Wood Science and Technology, 2017. **51**(5): p. 1095-1115.

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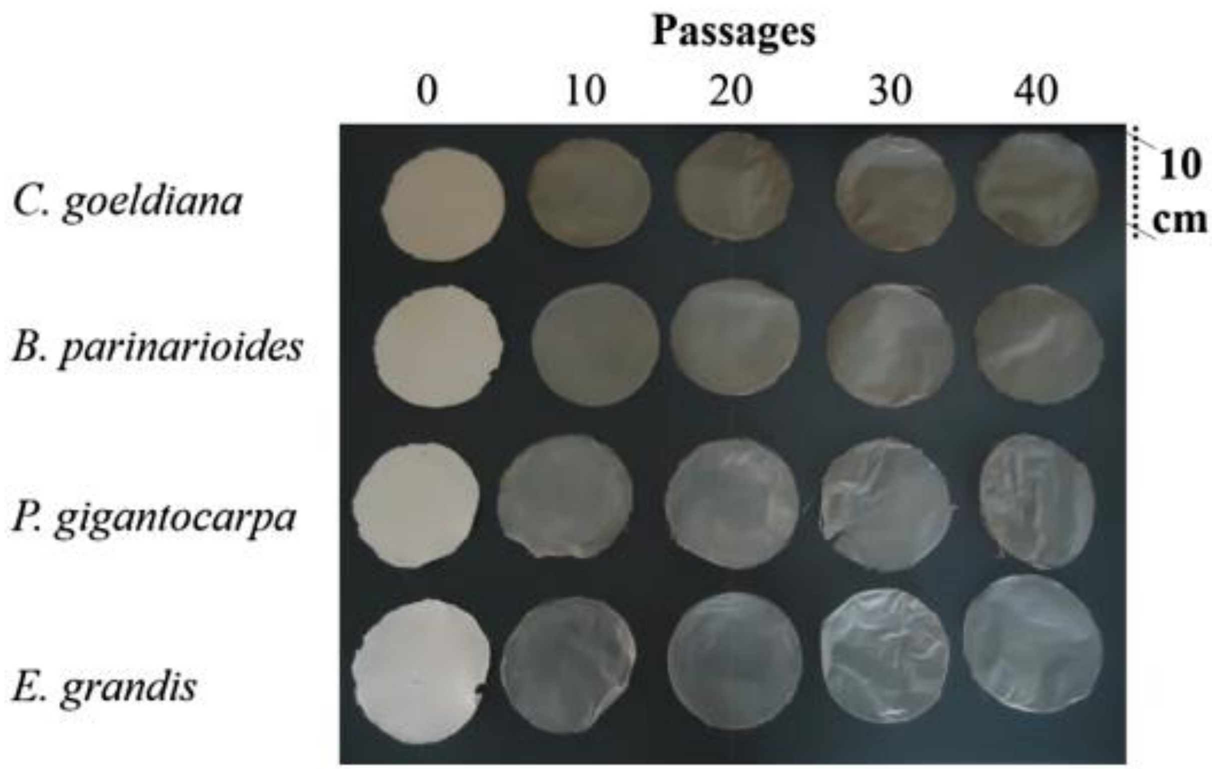
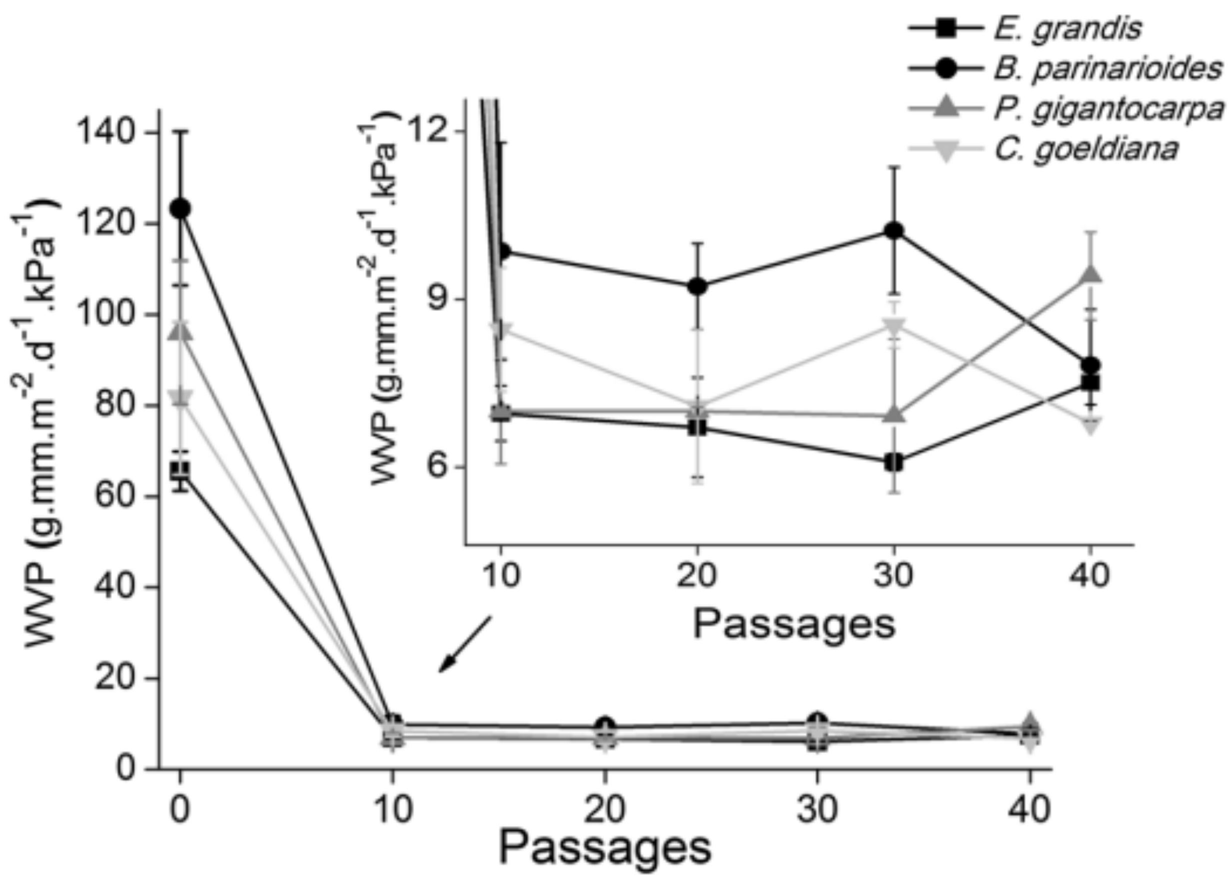


Microstructures of sheets and CNF of woody samples

Ref. Scatoli et al., 2017 [26]


E. grandis
B. parinarioides
P. gigantocarpa
C. goeldiana
WVP (g.mm.m-2.d-1.kPa-1)
140
120
100
80
60
40
20
0
0
10
20
30
40
Passages
12
9
6
10
20
30
40
Passages

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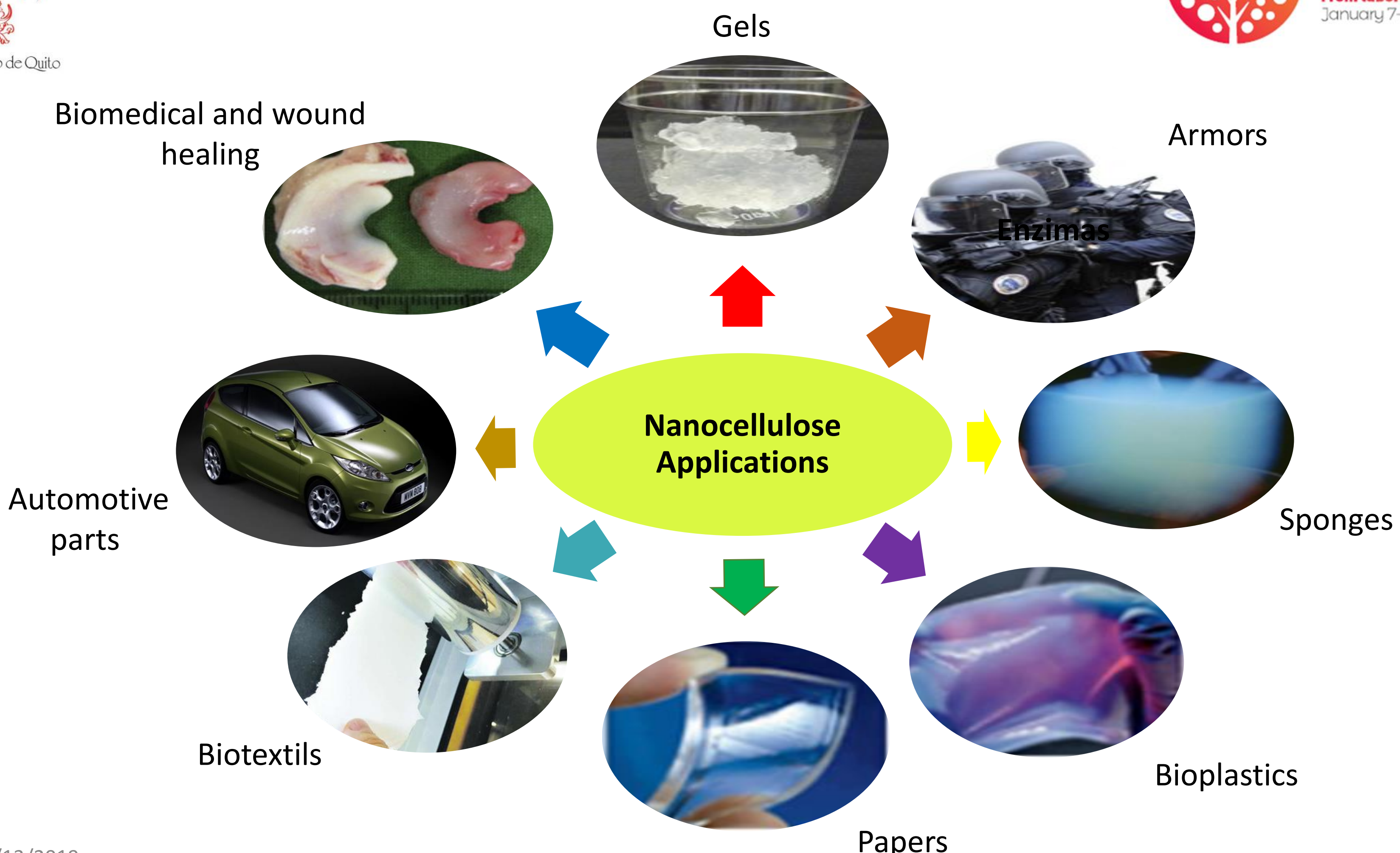
Xylan from Brewer's spent Grain

Cellulose from BSG

Cellulose from Oil Palm Empty Fruit Bunch

Cellulose from Roses Stalks

Dye from Avocado Seeds


Gels
Biomedical and wound healing
Armors
Enzimas
Nanocellulose Applications
Automotive parts
Sponges
Biotextils
Bioplastics
Papers

Conclusions

- Residual biomass is a valuable renewable resource
- Biorefinery assures the integral biomass valorization through Green processes (sustainable) that promotes a cleaner production
- The efficient use of forest, agricultural and agroindustrial residues in biorefinery settings facilitates the production of high value-added chemicals and advanced materials such as micro/nanocellulose and cellulose/hemicelulose derivatives and composites with potential applications as biofilms, especialty papers, biomaterials, hydrogels, coatings, bioplastics, biotextiles, resistat and light armors, automotive parts, etc.)
- Sustainable development based on bioeconomy is posible by applying the zero waste technology integrated to biorefinery concept and the use of renewable raw materials and industries will meet the Circular Economy principles developing recovery technologies and clean production to decrease negative environmental impact.

Thank you!

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