Seaweed as a Feedstock for Sustainable Aviation Fuels (SAF)

Bio360 Expo, Nantes – Jan 24th 2024

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www.celignis.com

Celignis Bioprocess

Celignis Analytical

Celignis – Pre-History

- UL Masters desk-study on potential for production of advanced (cellulosic) biofuels in Ireland.
- Literature data severely lacking.
- Obtained funding (Dept of Ag, EPA) to build capacity for biomass analysis within UL.
- PhD focused on developing rapid analysis methods for lignocellulosic composition.
- Secured funding for €3.7m FP7 advanced biofuels research project (DIBANET), coordinated by UL.
- DIBANET - Developed database for composition of Irish feedstocks. Business plan for company commercialising NIR IP and biomass analysis methods.

carbolea

Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

epa

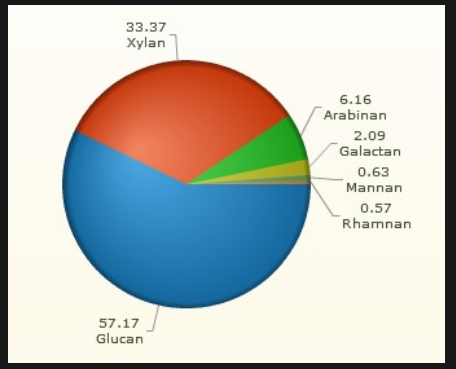
Celignis – History

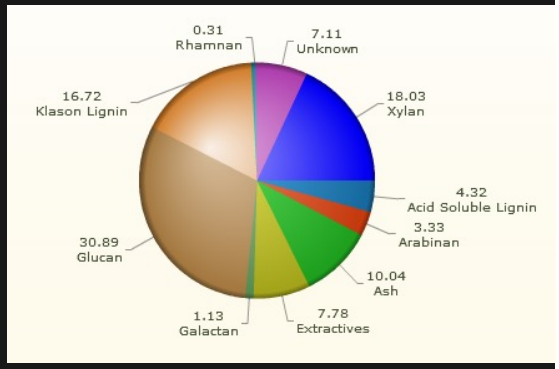
- Registered company July 2013.
- Launched August 2014. Based in UL lab (200 sq ft.), focus on 2G feedstocks.
- 2015 - moved to dedicated own lab (1000 sq. ft) in university enterprise incubation centre.
- 2016 - secured first H2020 research project (BIOrescue, focused on spent mushroom compost). Used to expand personnel and capacities at the company.
- 2018 - Moved to dedicated building (5000 sq. ft). Further expansion of equipment (e.g. AD, full thermal composition) and analytical offerings.
- 2019 – Provision of Bioprocess Development Services (BDS).
- 2020 – Major expansion in funded EU projects (10 currently active).
- 2021 - Expansion into provision of Technoeconomic Analysis (TEA) services. Further expansion of analytical services (biochar, seaweed).
- 2022 – Additional location (4000 sq. ft) for scale-up bioprocess activities.
- 2023 – Massive investment in infrastructure at Celignis Bioprocess for handling projects up to TRL6.

Celignis
Bioprocess

1. Analysis for advanced biofuels and biobased products

- Biological and chemical processes focus on lignocellulosic composition
  - Cellulose
  - Hemicellulose
  - Lignin
  - Extractives
  - Ash





Further details at: www.celignis.com/cellulosic.php

2. Process liquids Analysis

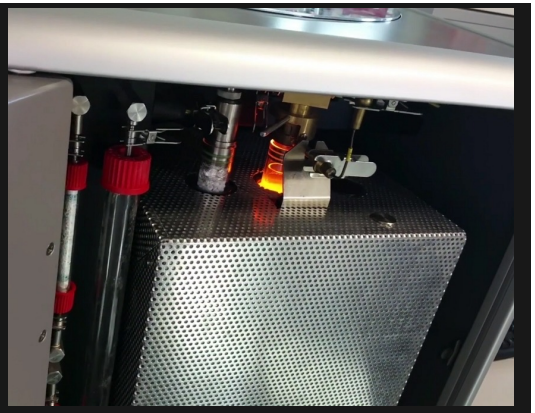
- Can be complex mixtures:
  - Sugars (monomers and oligomers).
  - Sugar degradation products (e.g. organic acids and furans).
  - Extractives.
- Fermentation as-is or develop clean-up techniques to address fermentation inhibitors.
- Important to develop good mass balance for all process outputs (e.g. solids and liquids) and constituents.

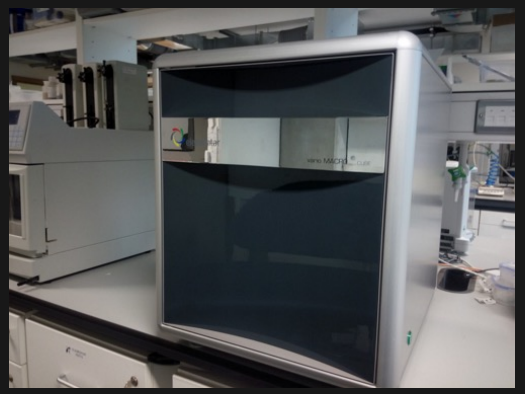
Further details at: www.celignis.com/analysis-of-pretreatment-liquids.php

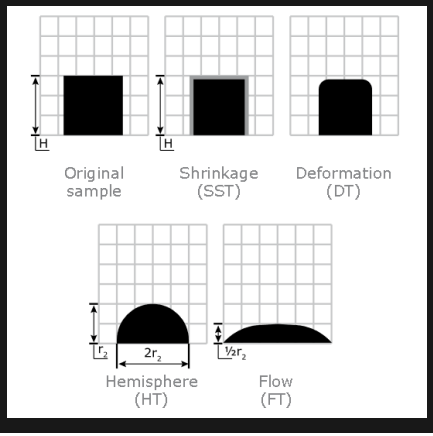
3. Properties relevant to thermal conversion

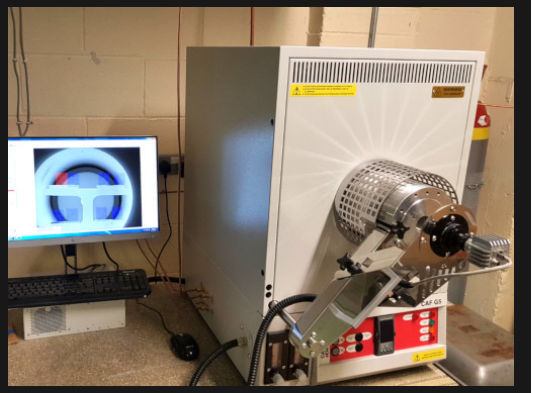
- Proximate analysis.
- Heating (calorific) value.
- Chlorine content
- Ash and ash composition (ICP).
- Ash melting temperature.
- Some processes/technology providers have threshold values for accepting feedstocks.

Further details at: www.celignis.com/combustible.php



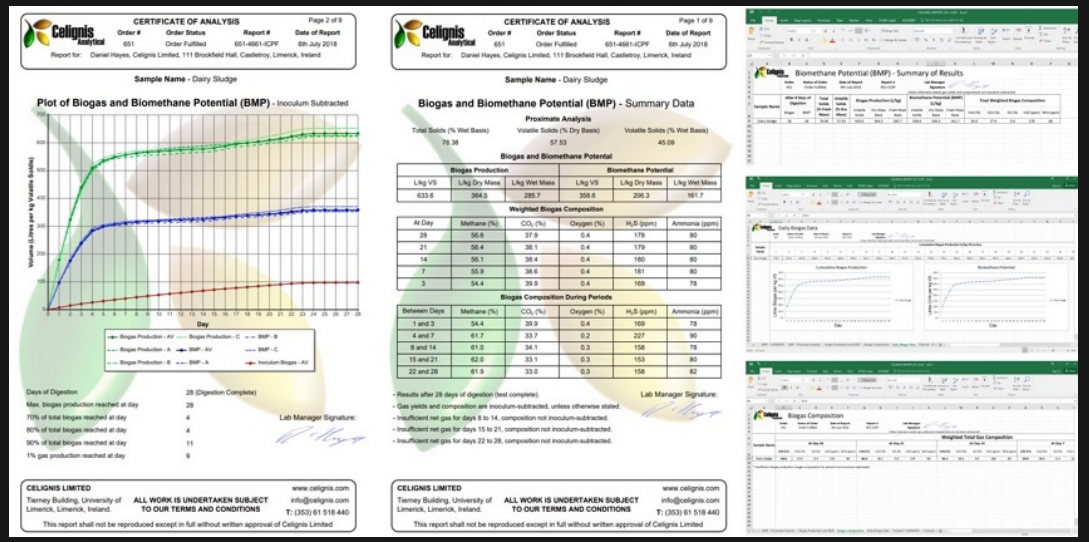






4. Anaerobic digestion

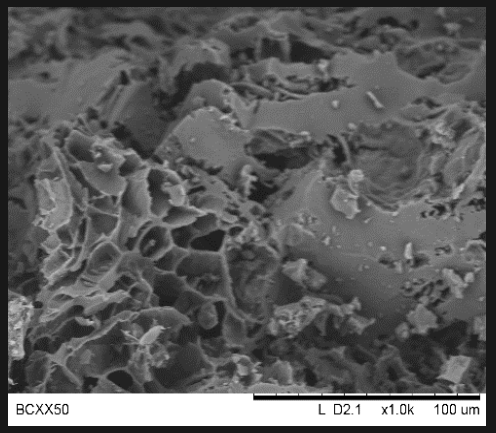
- See the Celignis Biogas Hub for details.
- Biogas production and biomethane potential (BMP).
- Detailed feedstock and digestate analysis.
- Comprehensive reports with written interpretations of the data and experts available.
- Biological advisory services for biogas plants (e.g. changes in trace elements and additives).



Further details at: www.celignis.com/ad.php

5. Biochar Services

- See the Celignis Biochar Hub for details!
- Of increasing interest as a means for carbon sequestration and plant growth enhancement.
- Properties of chars vary greatly according to feedstock and processing conditions.
- Physical properties (e.g. surface area, pore size distribution).
- Thermal properties.
- Soil amendement properties (major/minor elements, water holding capacity, PAH).
- We can produce biochar at lab-scale under various conditions and undertake plant growth (plot trials).



6. Feedstock profiling

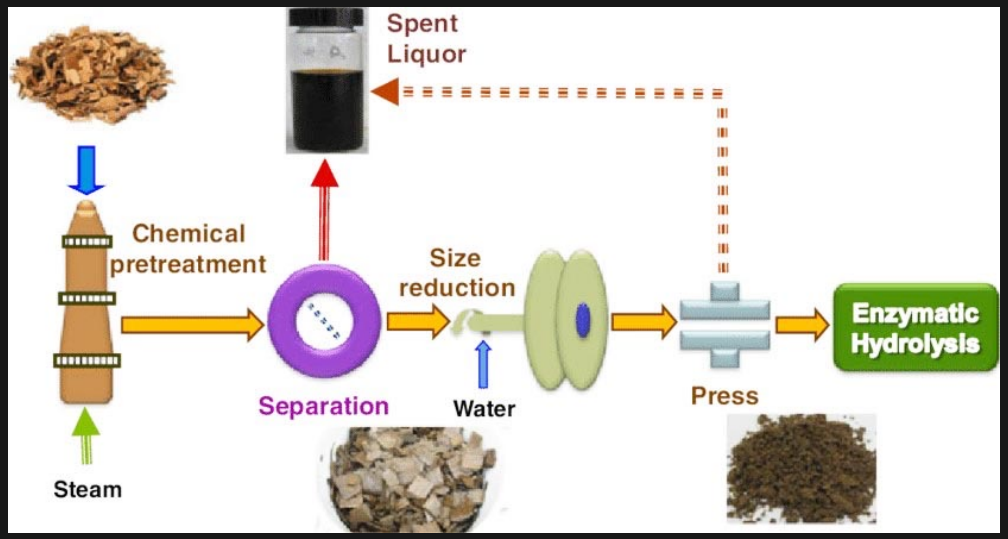
- Advanced analytical techniques to find the hidden gold in biomass.
- QTOF-LC-MS profiling allows identification of high value constituents.
- E.g. CBD, CBG etc.
- Proven capabilities in optimising extraction and isolation of chosen chemicals. Demonstrated in EU projects (UNRAVEL, STEAMBIOAFRICA).

7. Enzymatic hydrolysis and fermentation

- Enzymatic saccharifcation of biomass and pre-treated samples
- Analysis of activity of enzymes (cellulolytic, amylolytic)
- Fermentation tests for hydrolysates.
- From flasks to bioreactors (100 litres)
- Analysis of fermentation inhibitors.
- Dedicated microbiology lab in new premises.

8. Bioprocess Development Services

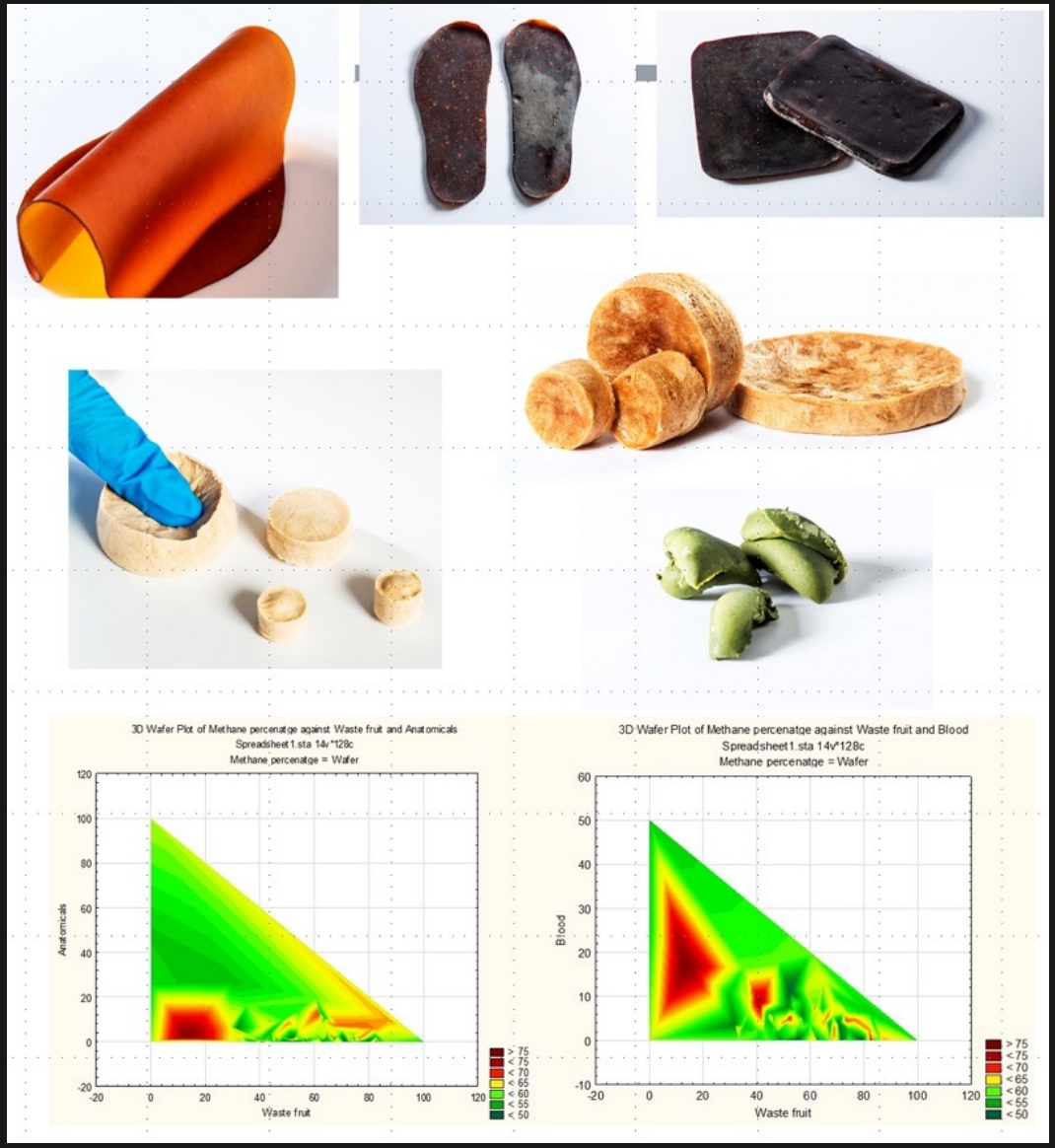
- See the Celignis Bioprocess Hub for all details.
- Expertise in biomass chemistry and conversion technologies provides understanding of what the best valorisation routes are and how bottlenecks can be identified and addressed.
- Range from optimising an existing process to developing an end-to-end valorisation chain for a feedstock.



Further details at: www.celignis.com/bioprocess.php

8. Bioprocess Development Services - Examples

- Examples to date:
  - Optimise pre-treatment and enzymatic hydrolysis for sugar production from pulp mill side-streams.
  - Develop end-to-end process for production of ethanol from palm residues.
  - Bioactives profiling for tropical hardwoods.
  - Produce starch hydrolysis products with applications in medical sector.
  - Fractionation of seaweed polysaccharides.
  - Production of sweeteners from biomass residues.
  - Extraction and purification of pectin from agricultural residues.
  - Optimisation of feedstock mixtures for AD.



EU AND CBE PROJECTS

- Celignis was a spin-out from an EU research project.
- Business – but run by scientists with a passion for advancing the bioeconomy.
- Carefully selected H2020 projects provide an opportunity to couple scientific advances with real commercial progress.

Bio-based Industries Consortium
Full Industry Member

BIO4AFRICA

PERFECOAT

Celignis launched

ALGALVANISE

enabling

UNRAVEL

vamos
creating value from waste

2013 2014 2015 2016 2017 2018 2019 2020 2021 2022

DIBANET

DIBANET completed

BIO RESCUE

SAPHIRE

EnXylaScope

STEAM BIO AFRICA

- Full Industry Member of the Biobased Industries Consortium – shaping future research agendas.

MORE DETAILS AT: www.celignis.com/horizon_projects.php


Medeco
monaghan biosciences
Arigna Fuels
University of Bristol
Quinns
The University of Queensland
TU/e
University of Agder
Protheragen
Fibers 365
University of Eastern Finland
Clearpower
SLU
Swedish University of Agricultural Sciences
universität innsbruck
Universidade Federal de Viçosa
TRICEL
Brunel University London
CAVIMAX
NOVA Q
Loughborough University
GlasPort Bio
Cargill
Coca-Cola
bp
woodco
ENSYN
sappi | biotech
TEXCHEM
Technic Resources Bhd
CORNING
1849 Mazzucchelli
Ørsted
Mushlabs
Trinity College Dublin
TAQNIA
Columbia University in the City of New York
University of Wyoming
South Dakota State University
polygal ag
SPIDERWORT
OCEANIUM
RAGN SELLS
C&C group plc
SUZANO PAPEL E CELULOSE
AMERICAN BIOCARBON
SWEETWATER ENERGY
ARBIOM
ALDER FUELS
ADM
ClonBio GROUP LTD
Biopolis
drax
Fiberight
Anellotech
POET biorefining
avantium
NREL National Renewable Energy Laboratory
LanzaTech
storaenso
BayWa r.e. renewable energy
Iowa State University
MTU
kemira
graanul
TATE & LYLE SUGARS
expur
PHILIP MORRIS INTERNATIONAL
Irish Distillers Pernod Ricard
UCC
BEYOND LEATHER MATERIALS
FLUID QUIP TECHNOLOGIES
AGRIGAS AFRICA
Measurlabs
chempolis Sustainable Results
Trinity College Dublin The University of Dublin
afbi
AGRI-FOOD & BIOSCIENCES INSTITUTE
Umeå Universitet
Stony Brook University
indigo
Antofénol
BANTRY MARINE RESEARCH STATION
Valagro
Opterion Health AG
Megazyme
astellas
PureFiber
University of Nottingham UK | CHINA | MALAYSIA
FMC
demetra
Brunel University London
Cyber Colloids Ltd
BDC Biorenewables Development Centre
DAWN MEATS
STREAM BIOENERGY
energia Switched on
Deep Branch Biotechnology
ASHLEIGH ENVIRONMENTAL
SCION forests · products · innovation
Aston University Birmingham
EBRI European Bioenergy Research Institute
Bigelow Laboratory for Ocean Sciences
cagasc
Stockholms Universitet
NOVAPANGAEA Technologies
Imperial College London
DTU Technical University of Denmark
microlife solutions
Prifysgol Aberystwyth University
ROYAL ADHESIVES & SEALANTS
VOSSEN LABORATORIES
LEAF RESOURCES LIMITED
carboganics
NMIM National Metrology Institute of Malaysia
Sentio BioSciences
Future Blends
plaxica
NUI Galway
BHSL Hydro Creating Value from Waste
UND North Dakota
Premium A Good Proper Company
irstea
BC BIOCARBON
ATHENA
FUTAMURA
Biotricity

The Irish Laboratory Awards 2021

WINNER

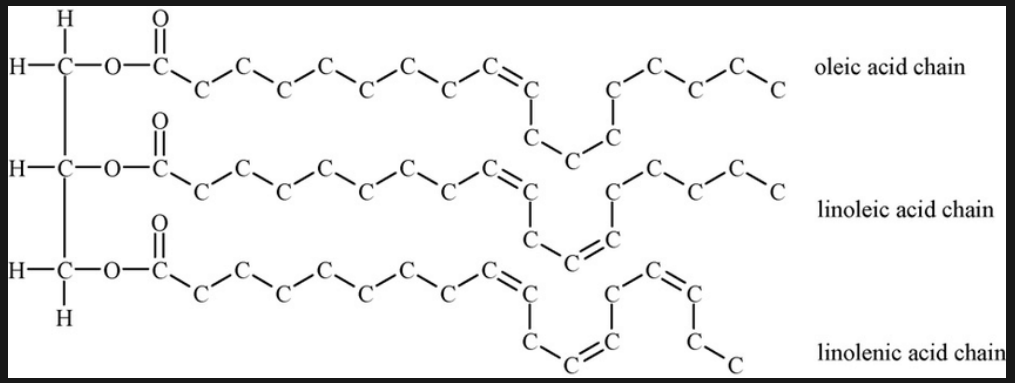
Innovation of the Year Award

- Full Industry Member of the Biobased Industries Consortium – shaping future research agendas.

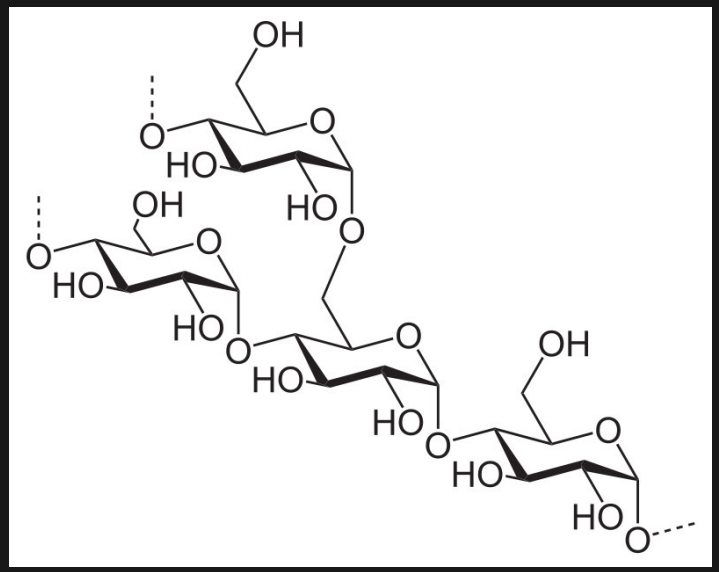
Bio-based Industries Consortium

Terrestrial Biomass Chemistry – 1G Biofuels

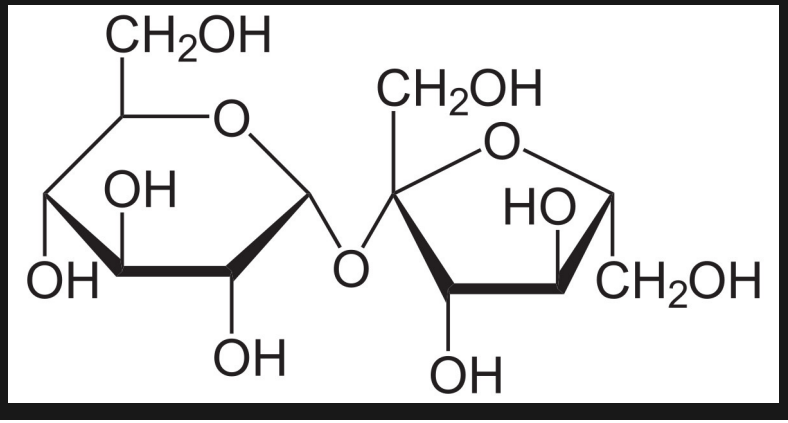
Lipids



Starch

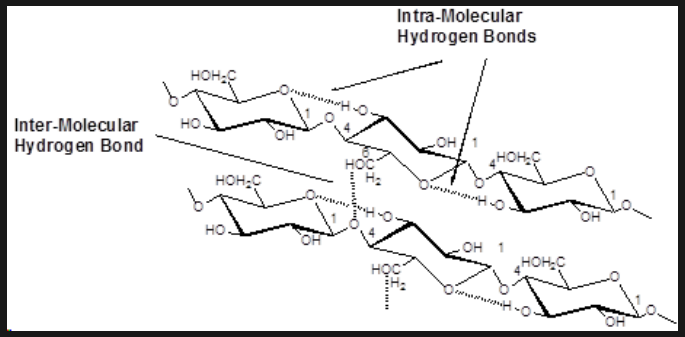


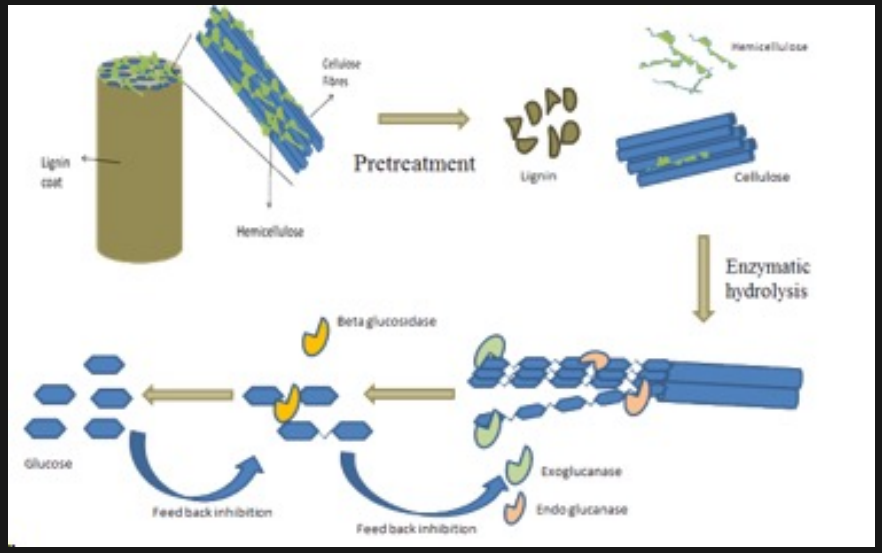
Sucrose



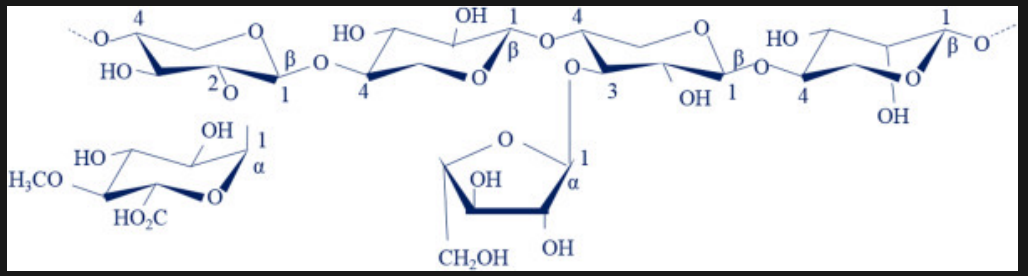
Terrestrial Biomass Chemistry - 2G Biofuels

Cellulose

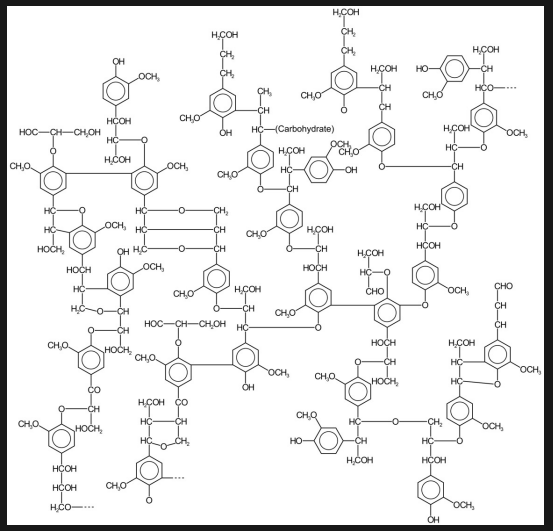




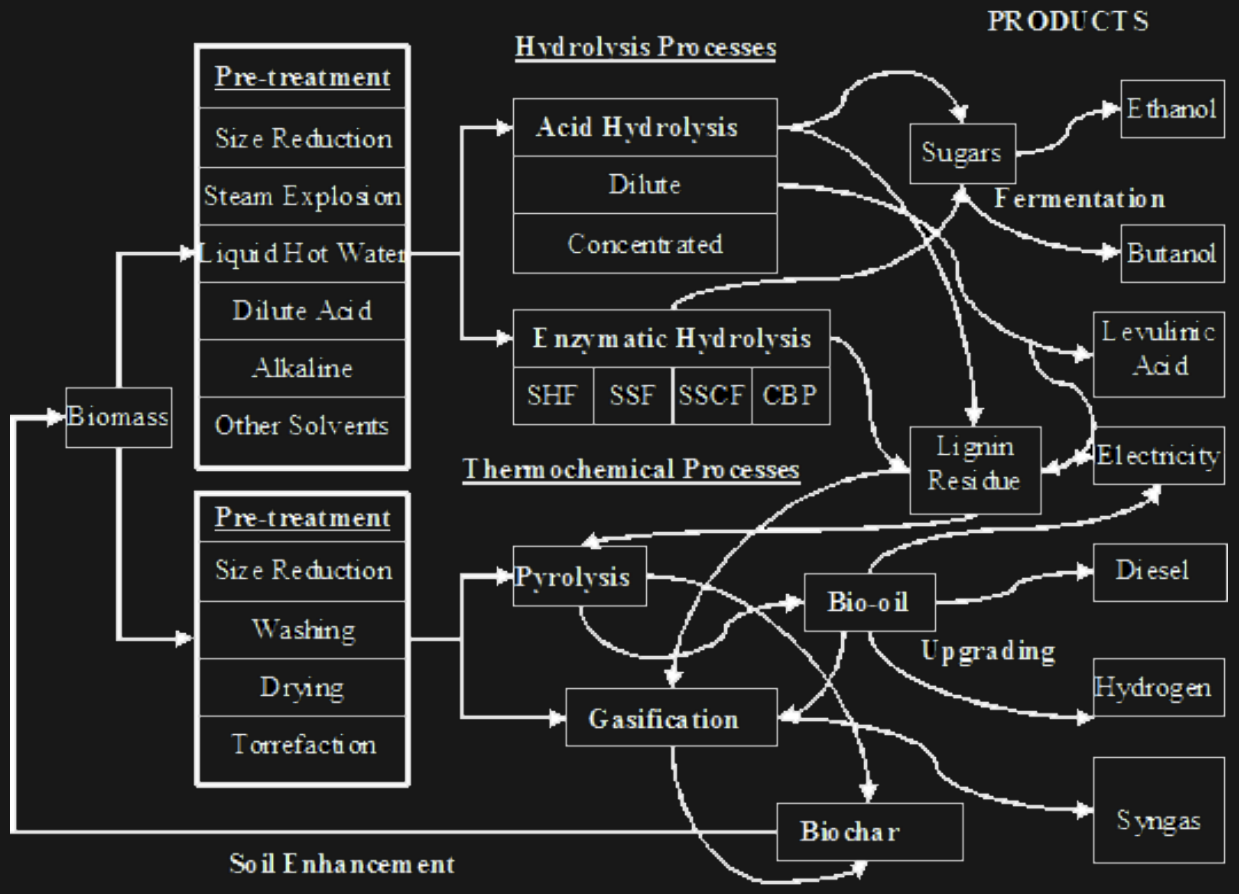
Hemicellulose



Lignin



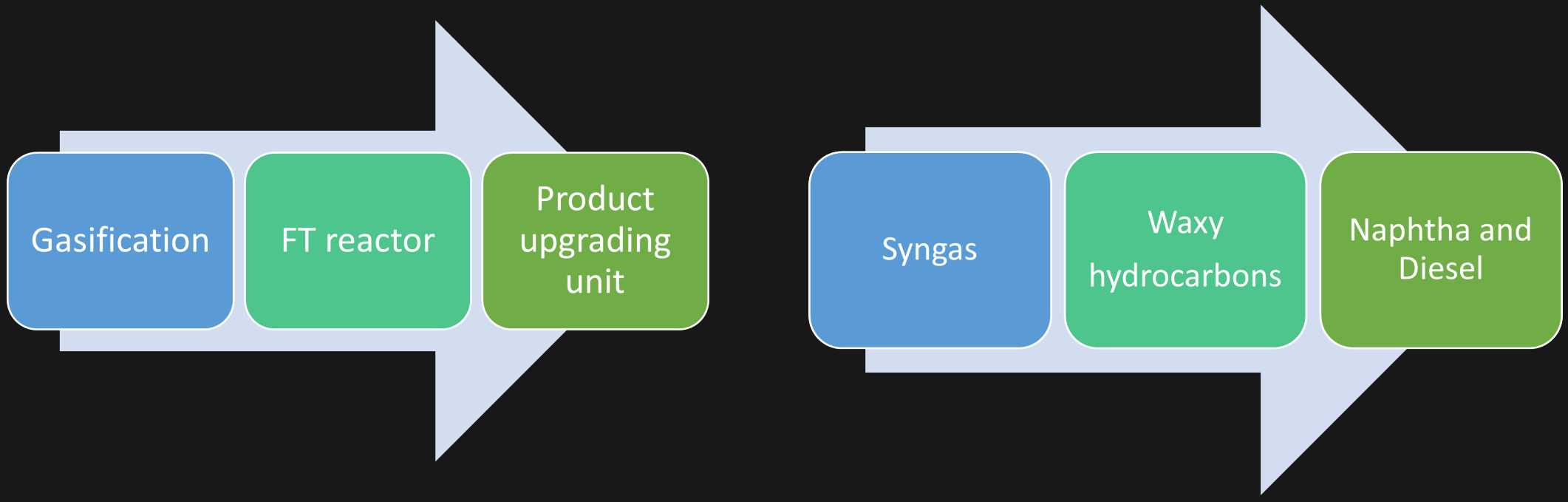
Technology Platforms for Lignocellulose to 2GB



Further details at: www.celignis.com/2gb.php

Approved SAF Pathways

Oldest Approved Pathway: Fischer-Tropsch (FT) Synthetic Paraffinic Kerosene (SPK)



Further details at: www.celignis.com/2gb.php

Gasification

Temperature: 1200 to 1600 degrees Celsius
Gases: 30 to 60% carbon monoxide (CO), 25 to 30% hydrogen (H_2), 0 to 5% methane (CH_4), 5 to 15% carbon dioxide (CO_2)

Effect of Composition on Process

Moisture: Conventional process requires dry feedstock but modern technologies like SCWG allow high moisture feedstock

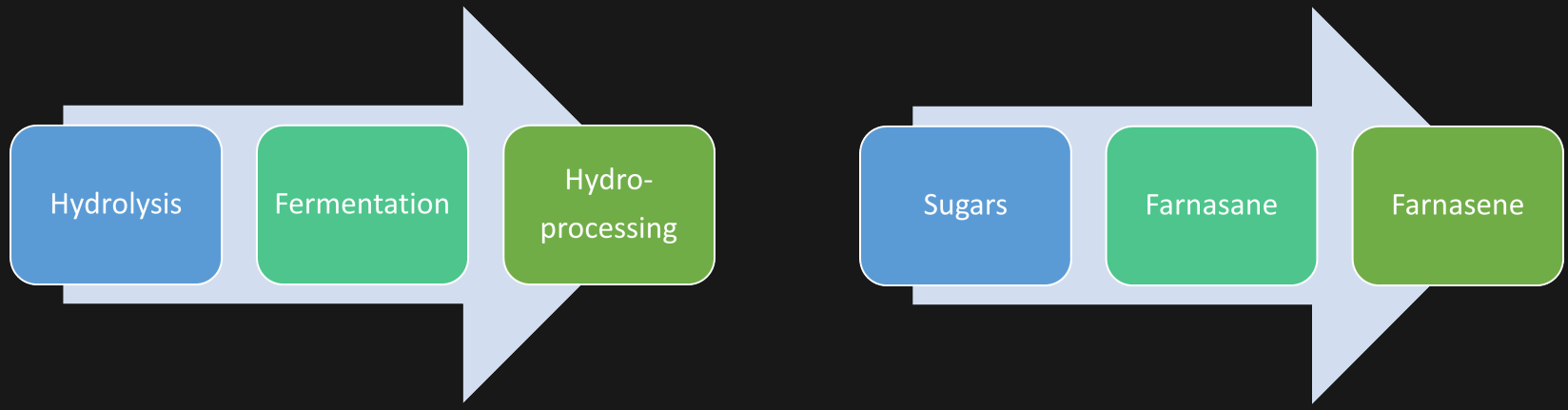
Inorganics: Depending on the metal type, they can aid in improved catalysis but are also known to hinder the continuous process by forming unwanted clogging of the catalysts

Sulphur and Nitrogen Rich Feedstocks: Require removal of NOx and SOx in the final gases

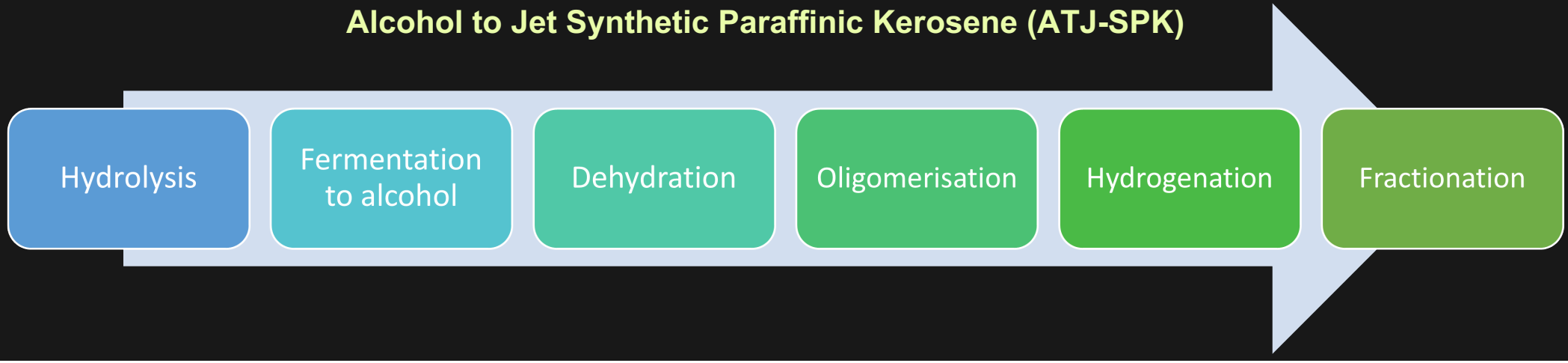
Further details at: www.celignis.com/2gb.php

SAF Fermentation Pathways

Hydroprocessed Fermented Sugars to Synthetic Isoparaffins (HFS-SIP)

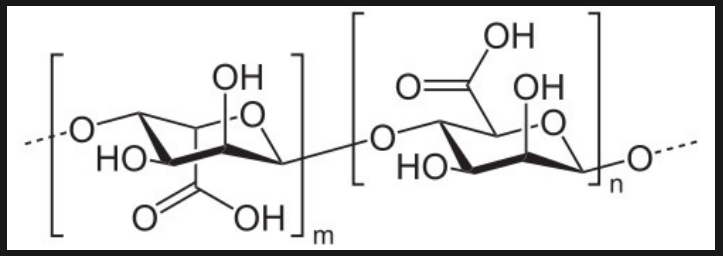


Alcohol to Jet Synthetic Paraffinic Kerosene (ATJ-SPK)

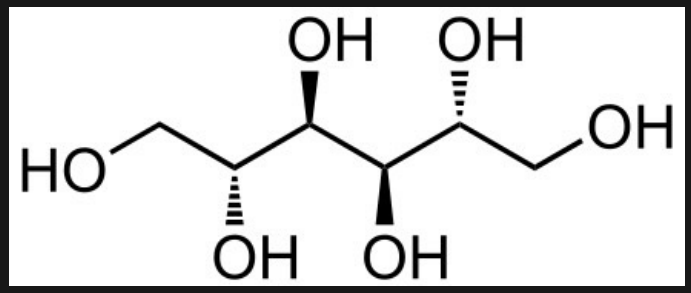


Brown Seaweed Chemistry

Alginate



Mannitol

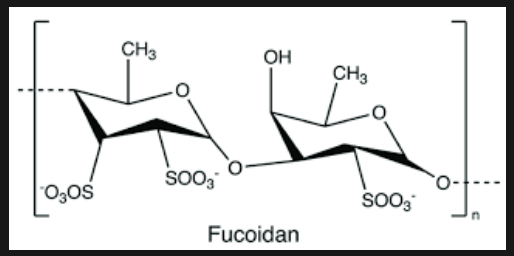


Kelps (Laminariales): e.g. Laminaria digitata and Saccharina latissima.

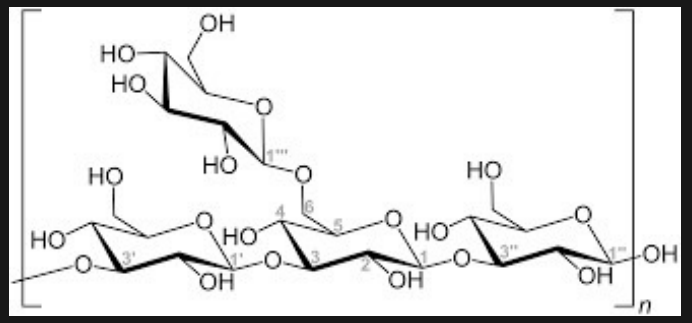
Ascophyllum (Fucales): e.g. Ascophyllum nodosum.

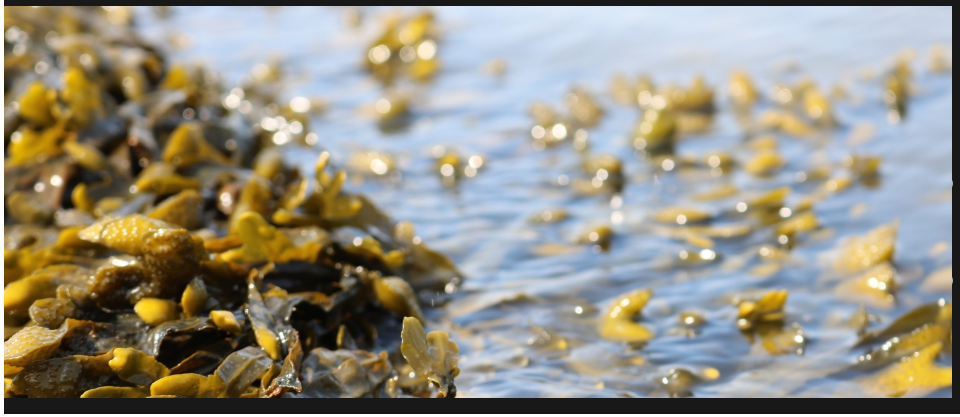
Sargassum (Fucales)

Fucoidan



- Laminarin - mainchain of glucose (DP ~25) with some glucose side chains.



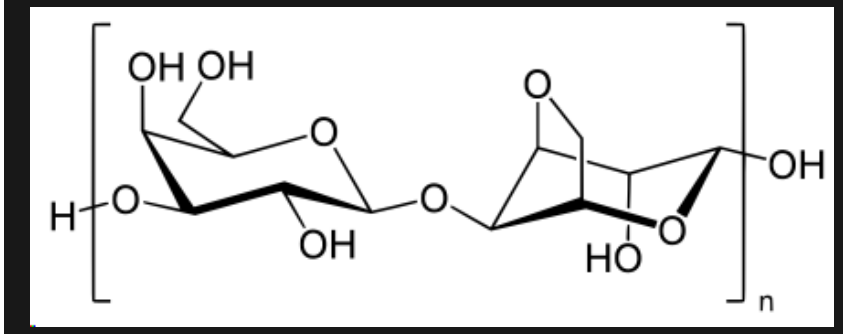


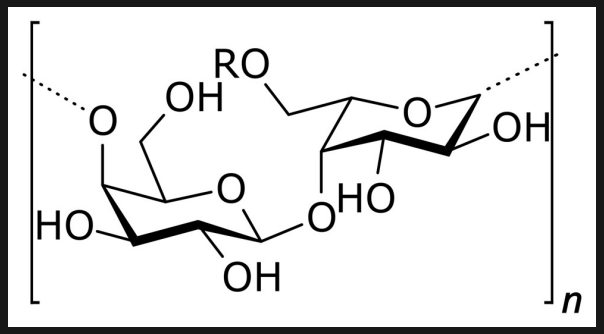
Cellulose

Non-Carbohydrates: ash, protein, lipids

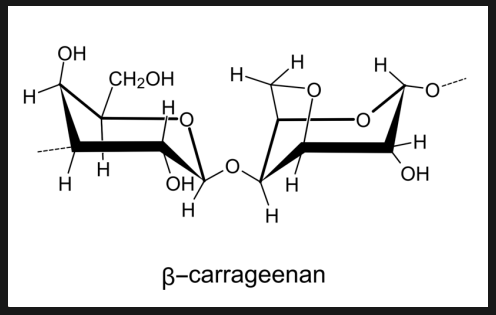
Red Seaweed Chemistry

- Agar, a mix of agarose and agaropectin.





- Carrageenan



- Sulphated mannans
- Cellulose

Chondrus crispus (Irish Moss)

Palmaria palmata (Dulse)

Porphyra species (Nori)

Gracilaria verrucosa

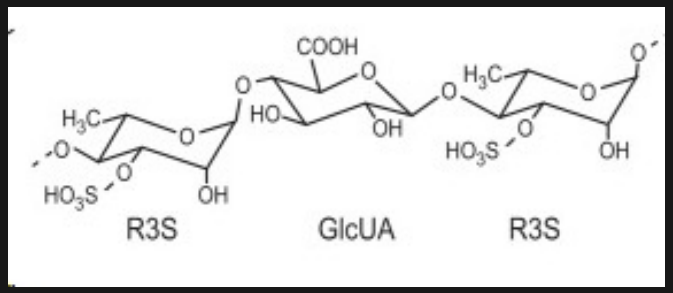
Further details at: www.celignis.com/seaweed-analysis.php

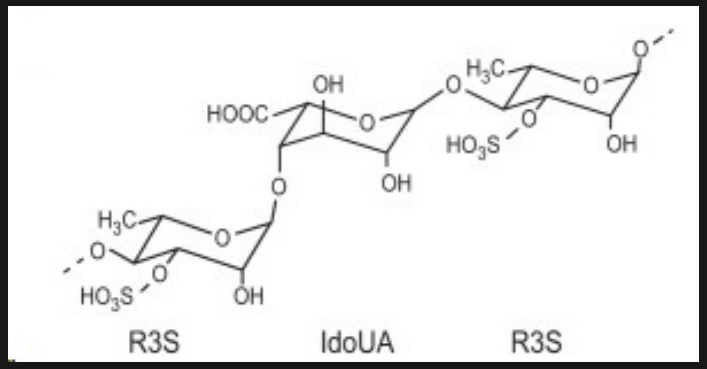
Green Seaweed Chemistry

Ulva (Sea Lettuce): e.g. Ulva lactuca

Cladophora: e.g. Cladophora rupestris

- Ulvan contains glucuronic acid, iduronic acid, rhamnose and xylose.





- Cellulose
- Xylan

Further details at: www.celignis.com/seaweed-analysis.php

SAF from Seaweed: Challenges

- Logistical challenges associated with harvesting and transport.
- Highly heterogeneous chemistry (even within species).
- High ash and moisture contents challenging for some processes.
- Hydrolysis and fermentation processes focused on terrestrial biomass (esp. glucose).

SAF from Seaweed: Advantages

- Abundant resource.
- No land-use conflicts.
- Low (production) cost.
- Can be valorised in a biorefinery approach.

Seaweed Analysis and Bioprocessing at Celignis

- Wide variety of analysis packages

P71: Seaweed Carbohydrates
P72: Seaweed Amino Acids
P73: Seaweed Lipids as Fatty Acids
P74: Pigments in Seaweed
P75: Seaweed Phytohormones
P76: Seaweed Vitamins (Fat-Soluble)
P77: Seaweed Vitamins (Water-Soluble)
P78: Seaweed Total Phenolics
P79: Seaweed Phenolics Profiling
P170: Seaweed Total Tannins
P171: Alginate Molecular Weight Analysis
P172: Total Phlorotannins Estimation
P155: Polyamines Speciation
P160: Polyphenols Speciation

- Processing equipment to TRL6

Selective extraction of polysaccharides & bioactives

Application testing (e.g. plant trials) of extracts

Hydrolysis to sugars

Fermentation to alcohols and other products

Biomaterials formulations

Valorisation (e.g. combustion/biochar) of residues

Further details at: www.celignis.com/seaweed-analysis.php

Thanks!

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www.celignis.com