

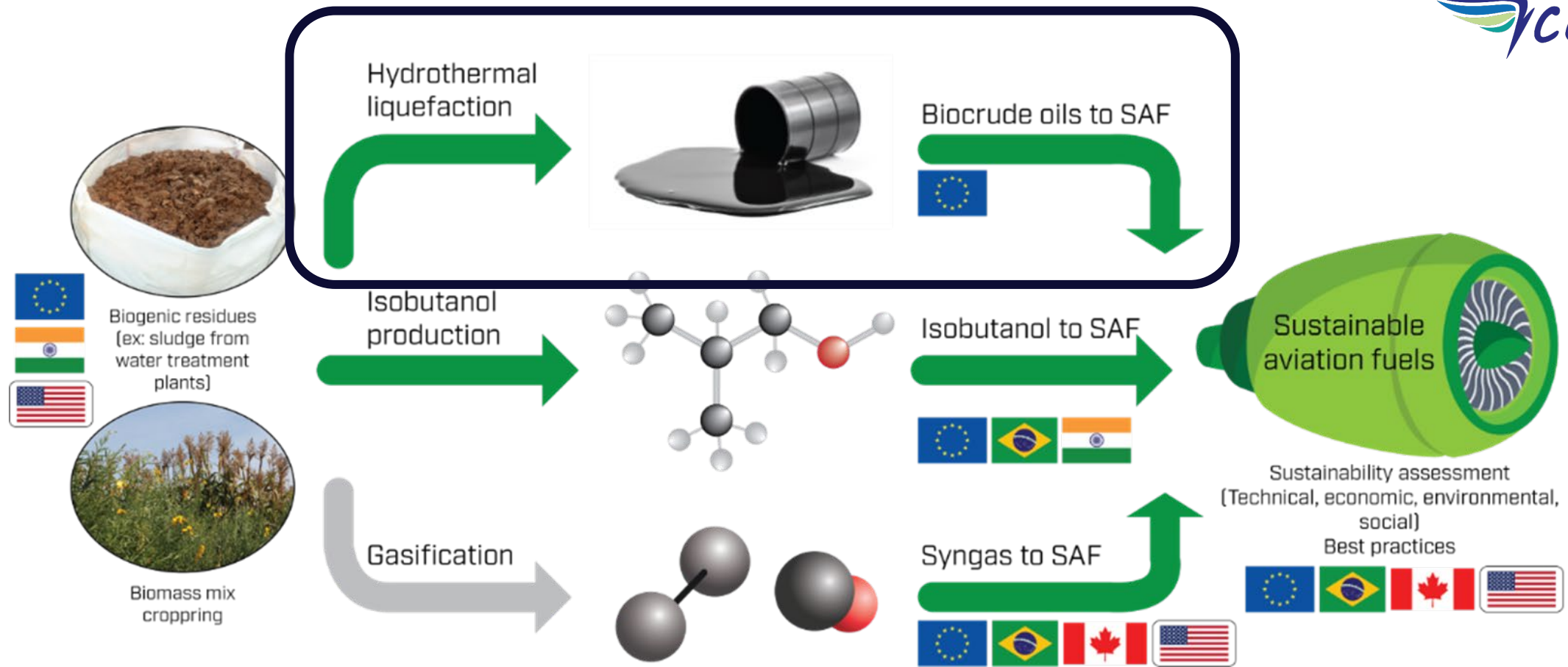


ICARUS Final Webinar

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Value chain Crude to SAF

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Value chain Biocrude oil to SAF

Outline

- Motivation
- Stages of the Biocrude-to-SAF Value Chain
- Bio-oil production via HTL PROCESS
 - Phase Separation
 - Bio-oil properties
- Bio-oil Upgrading via HDO (Hydrodeoxygenation)
- Results
- Technical Challenges
- Main Conclusions

MOTIVATION



Technical Drivers

- Hydrothermal Liquefaction (HTL) enables conversion of wet biomass (e.g., algae, residues) into biocrude without costly drying, improving energy balance and competitiveness.
- Hydrotreatment is the most mature technology for upgrading biocrude into SAF, ensuring removal of nitrogen and oxygen for jet fuel specifications. Modular biocrude upgrading processes allow integration with existing refinery infrastructure, reducing capital costs and accelerating scale-up.

Strategic Benefits

- Feedstock Diversification: Biocrude pathways unlock abundant, non-food biomass sources (agricultural residues, algae), mitigating feedstock scarcity.
- Infrastructure Compatibility: Produces “drop-in” fuels that leverage existing global refining and distribution networks.
- Economic Viability: Lower CAPEX compared to building new SAF plants; potential for regional mini-refineries feeding centralized upgrading hubs.

Stages of the Biocrude-to-SAF Value Chain



Feedstock → Pretreatment → Biocrude → Upgrading → Fractionation

Feedstock Sourcing

Focuses on using non-food biomass.

Biocrude Production via HTL

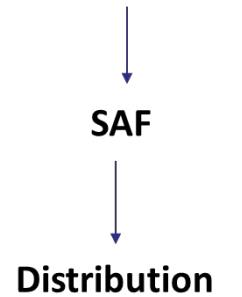
Hydrothermal liquefaction converts wet biomass efficiently into biocrude, avoiding costly drying processes.

Upgrading through Hydrotreatment

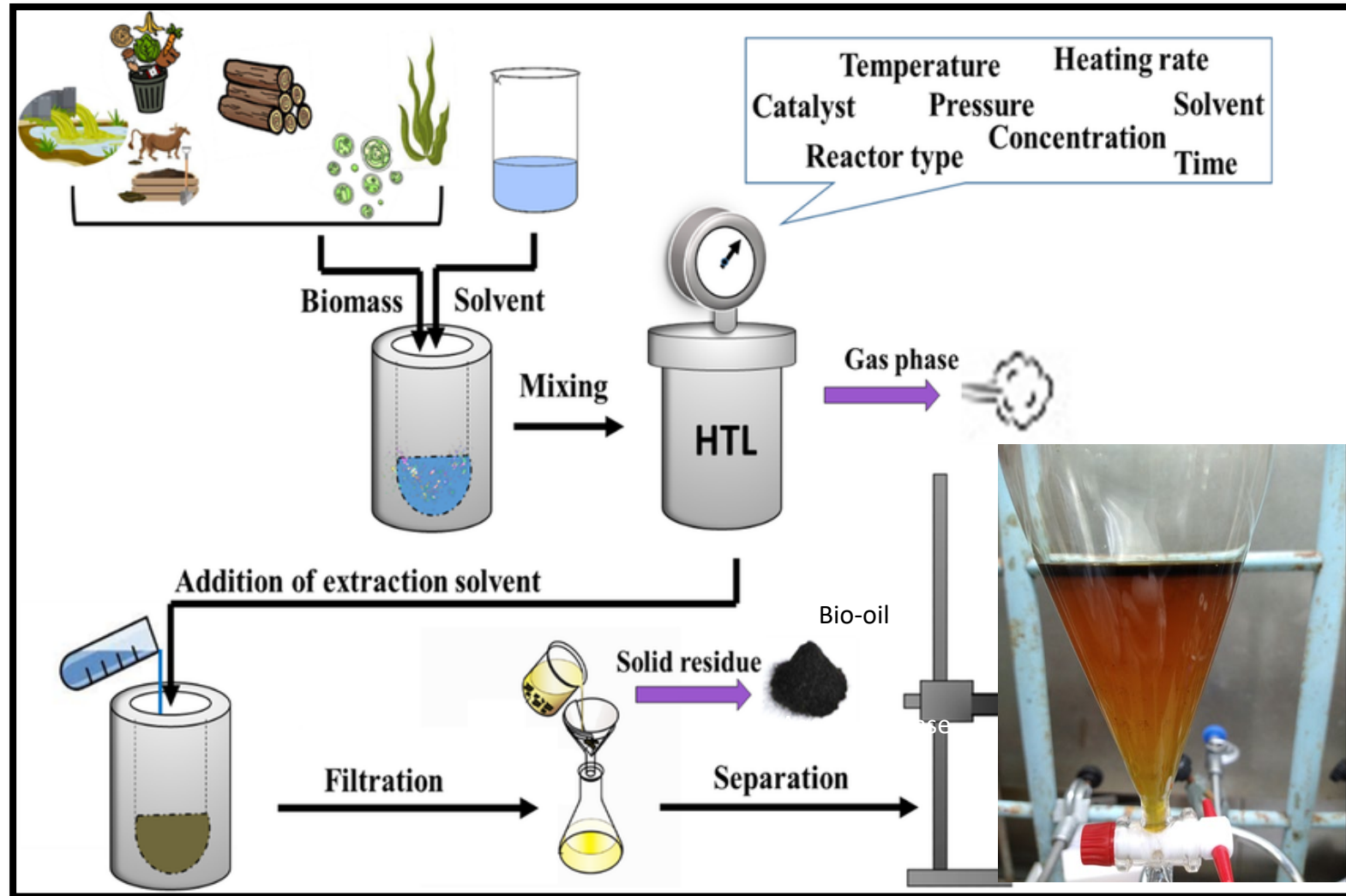
Hydrotreatment upgrades biocrude to meet jet fuel specifications for sustainable aviation fuel.

Distribution and Certification

Distribution includes certification to ensure compliance with international fuel standards like ASTM.



HTL PROCESS



Source : DOI:10.1007/s12155-023-10615-5

HTL PROCESS

Thermochemical process to convert wet biomass (such as agricultural waste, algae, sewage sludge, among others) into high-value products, mainly bio-oil, gas, char, and an aqueous phase.

Objective: To transform organic waste into renewable liquid fuels. To utilize wet biomass without the need for prior drying, making the process more energy efficient.

Operating conditions:

Gas: Absence of O₂ (or air)

Temperature: 200 – 375 °C

High pressure: 100 – 250 bar

Residence time: Short

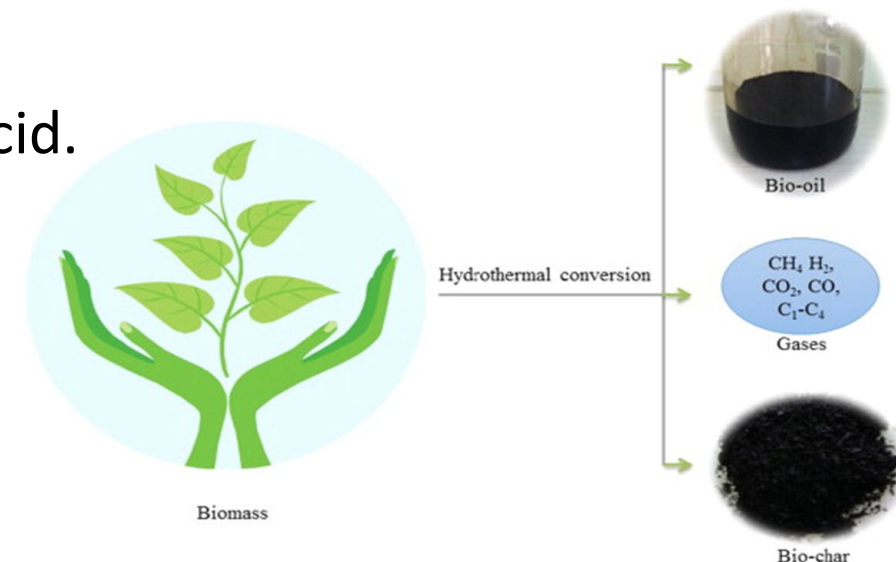


Spiruline

HTL PROCESS

Products

- Bio-liquids - (acids, alcohols, aldehydes, esters, ketones, phenols, and lignin-derived oligomers)
 - Bio-oil (30-35% (w/w)) (mixture of aromatic and oxygenated hydrocarbons, heterocyclic and nitrogenated compounds)
 - Aqueous phase (organic acids) – acetic acid, formic acid.
- Bio-gas (H_2 , CO e CO_2 , $C_1 - C_4$)
- Bio-char



HTL PROCESS – Phases Separation

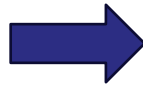
- HTL trials were completed with *Spirulina*, *Chlorella* and *Nannochloropsis* microalgae feedstocks.

Biocrude oils to SAF Phase separation



Spiruline

Acetone/Ciclohexane
(2:1, vol/vol)



T=325 °C P= 39.30 bar
Reaction time =30 min
Medium flow rate filtration (1 time)

Sequential

- 1) Filtration and decantation to remove the fraction containing water from the reaction product mixture, leaving only cyclohexane and bio-oil .
- 2) The AqP was distilled to recover the products from this phase and then dissolved in ultra-deionized water.
- 3) The reactor was washed with acetone, and the product was filtered and added in the fraction containing cyclohexane + bio-oil.
- 4) The solvents, cyclohexane and acetone, were then evaporated to obtain bio-oil.

MORE EFFICIENT

HTL PROCESS - Bio-oil properties

Proprieties	Light crude oil	Heavy crude oil	Spirulina Bio-oil	Chlorella Bio-oil	Nannochloropsis Bio-oil
HHV (MJ/kg)	47.0	42.5	36.8	35.1	34.5
C (% w/w)	84.0	85.0	73.3	70.7	68.1
H (% w/w)	14.0	11.0	9.2	6.8	8.8
O (% w/w)	1.0	1.0	10.4	14.8	19.0
N (% w/w)	1.0	0.3	7.0	5.9	4.1
Ashes (% w/w)	0.1	0.1	-	-	-

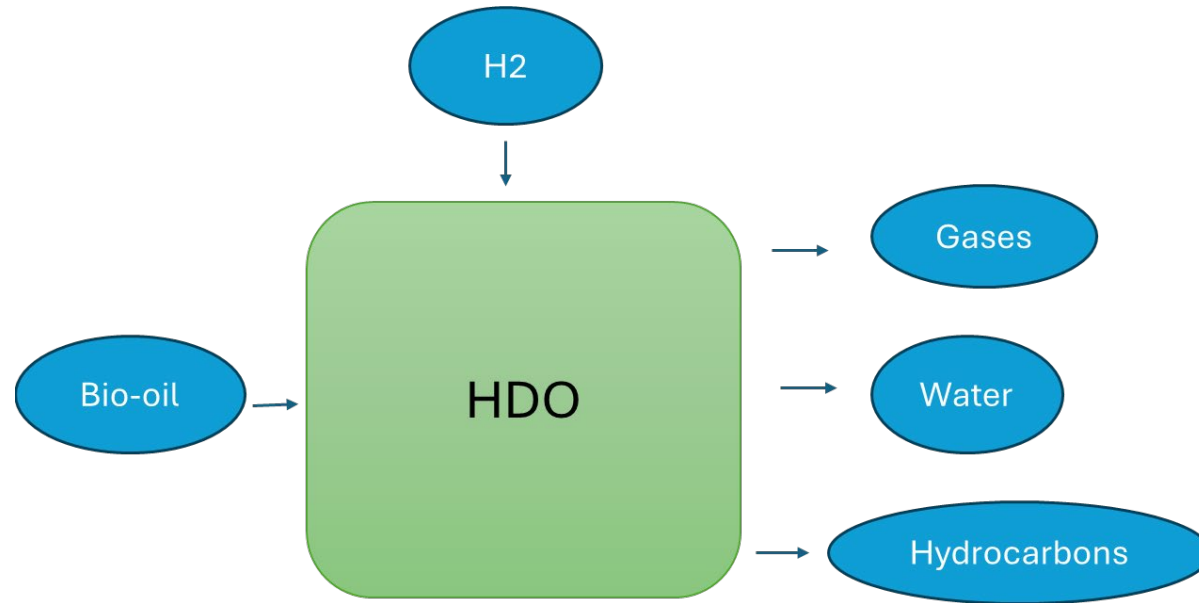
- High oxygen content
- High viscosity
- Chemical instability
- Low energy density
- High acidity and water content



Upgrading via HDO (Hydrodeoxygenation)

Process under high temperature and high hydrogen pressure conditions, using metallic catalysts, to remove oxygen from organic compounds.

Objective : Improve the physical and chemical properties of bio-oil.



Operating conditions:

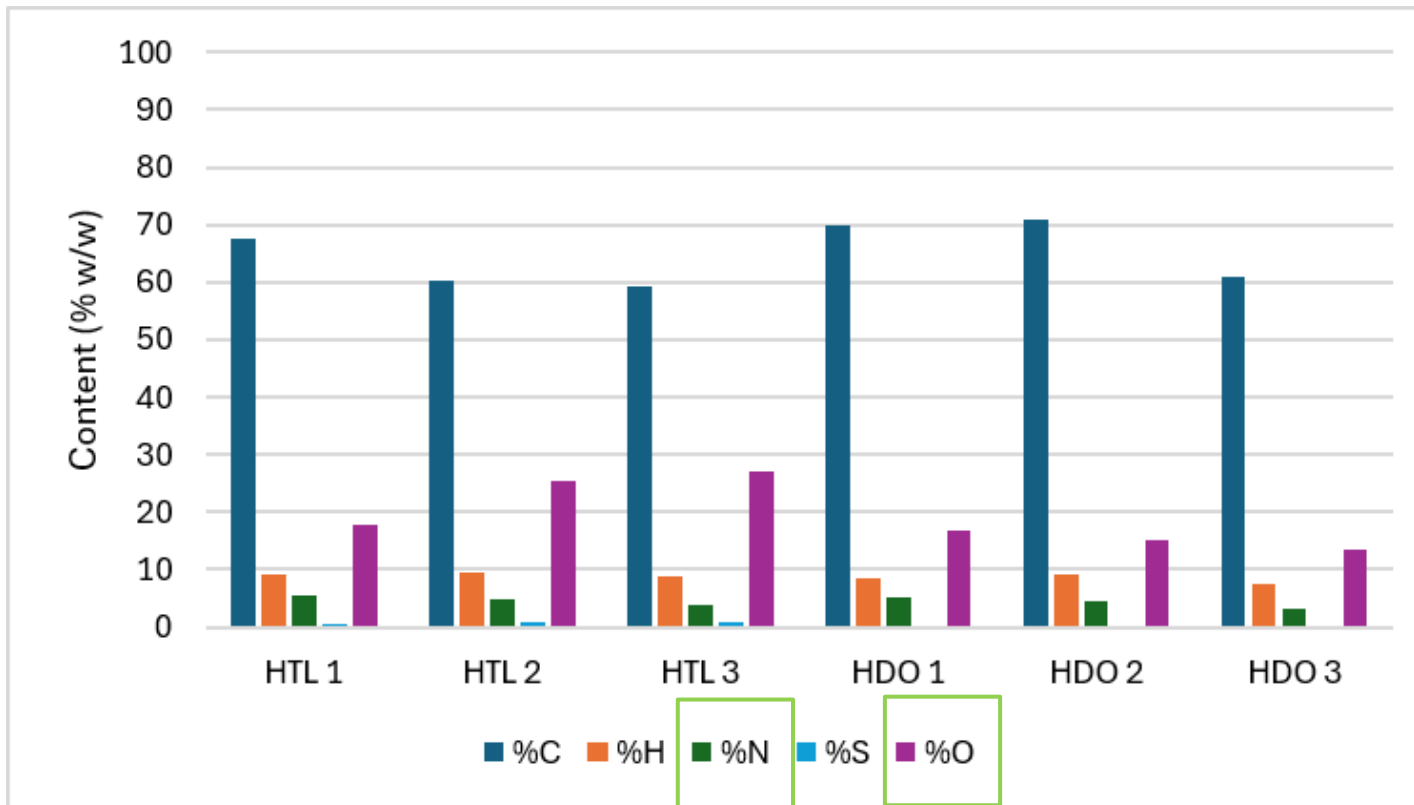
Temperature: 200°C and 400°C.

Hydrogen pressure: 20 to 100 bar, which may vary depending on the type of catalyst.

Catalysts: Usually metals such as nickel (Ni), molybdenum (Mo), cobalt (Co) supported on alumina (Al₂O₃) or other supports.

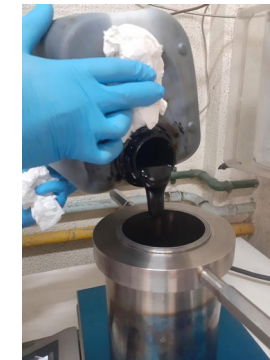
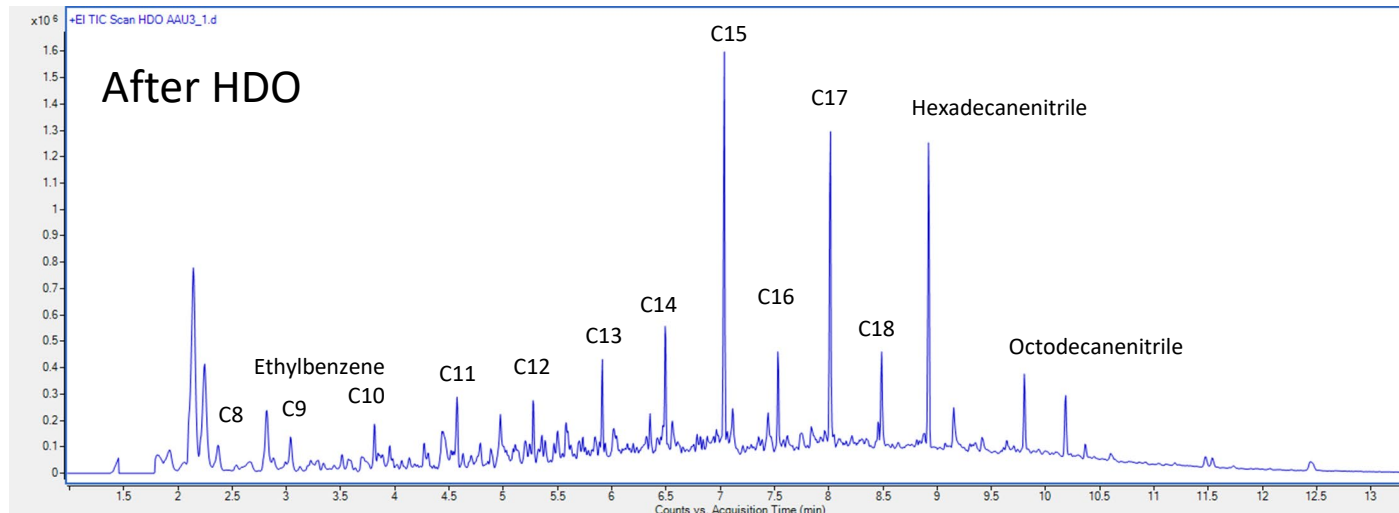
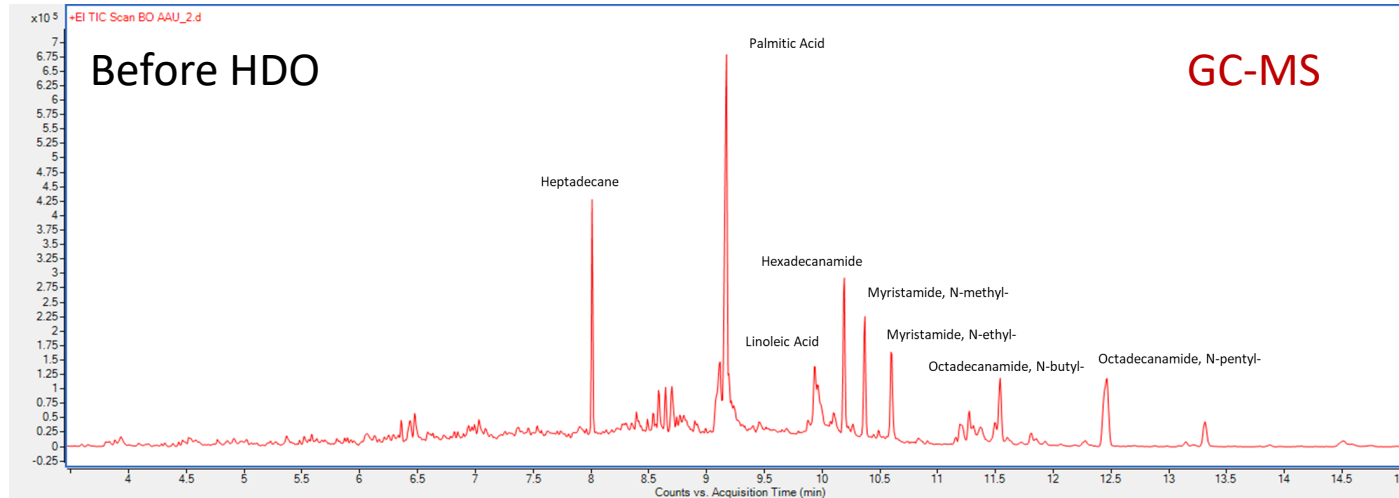
Reaction time: Can vary from minutes to several hours, depending on the system.

Results (Evaluation of the pre-treatment efficiency)



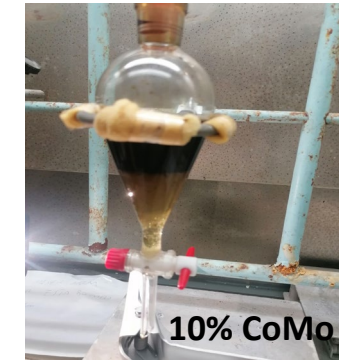
- **Untreated algae** (Exp 1) are rich in carbon and hydrogen but contain a **very high nitrogen fraction**.
- **Thermal and acid pre- treatments** (Exp 3) is the most promising strategy because it achieved high nitrogen removal.
- **HDO 3** (Thermal and acid pre- treatments) shows the best balance: high carbon, lower oxygen, and reduced nitrogen.
- **HDO treatments significantly improve fuel quality by increasing carbon and reducing oxygen.**

Results



Biocrude HTL

After HDO



yield =38%

After distillation



yield=50%

Biocrude HTL from AU	Before HDO	After HDO	unit	Method
Carbon	60.0	81.2	% wt	Elemental analysis CHN by combustion with TCD detection
Hydrogen	9.52	9.88	% wt	
Nitrogen	6.55	5.11	% wt	
Sulphur	0.57	<0.2	% wt	
Oxygen	22.8	3.61	% wt	Calculated *

* By difference: %O=100-(%C+%H+%N+%S+%ash)

Technical Challenges



Biocrude Quality & Upgrading

- ✓ Hydrothermal Liquefaction (HTL) biocrude contains high oxygen, nitrogen, and sulfur, requiring intensive hydrotreatment (HDO) to meet jet fuel specifications.
- ✓ Issues include high hydrogen consumption, catalyst deactivation, and operational complexity.

Process Efficiency

- ✓ Achieving optimal HTL yields (>36–55% dry weight) and refining efficiency (>16–24%) is critical for SAF compliance.
- ✓ Variability in feedstock composition complicates process control.

Integration with Existing Infrastructure

- ✓ While modular upgrading is possible, compatibility with refinery systems and blending limits remain technical hurdles.

Cost

Large-scale production capacity

CONCLUSIONS



The biocrude-to-SAF pathway is promising but faces technical complexity, high costs, fragmented policy frameworks, and sustainability verification challenges.

Overcoming these requires:

Advanced catalytic upgrading solutions.

Strong policy support and harmonized certification.

Investment in large-scale infrastructure and feedstock supply chains.

Critical Success Factors

Success requires coordinated value chains, strong policy backing, and continuous innovation in technology.

Thank you



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