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Advanced Research Activities on Biofuels Production at Vietnam Academy of Science and Technology (VAST)

Assoc. Prof. Tran Dang Thuan

Institute of Chemistry – Vietnam Academy of Science and Technology (ICH-VAST)

Ethanol talk, Hanoi - 2024

Motivations

- Vietnam has been a development success story since Economic reforms launch in 1986:
  - Industrialization
  - Social modernization
  - World's poorest nations to a middle-income economy with GDP/capita ~ 3655.46 US (2022)

- Vietnam has been facing with remarkable issues
  1) The effect of global warming
  2) Environmental pollutions (wastewaters, solid wastes and air pollution)

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Motivations

Government' Commitments to Lead Vietnam Further Sustainable Development Beyond

Decision	Year	Vision	Goals
177/2007/QD-TTg	November 20, 2007	Approval for the Scheme on Development of Biofuels up to 2015, with a Vision to 2025	Ethanol and vegetable oil output will reach 1.8 million tons, satisfying some 5% of the whole country's gasoline and oil demand by 2025
1658/QD-TTg	October 01, 2021	Approval for National green growth strategy for 2021 - 2030 period, with a vision by 2050	By 2050, 100% municipal solid wastes and 100% wastewater is expected to be treated to meet technical regulations
896/QD-TTg	July 26, 2022	Approval for the National strategy for climate change until 2050	Reduce greenhouse gas emission following net zero emission target by 2050, **achieving an circular economy**
876/QD-TTg	July 22, 2022	Approval for the action program for transition to green energy and mitigation of carbon dioxide and methane emissions from transportation	Develop green transportation system towards the goal of **net-zero greenhouse gas (GHG) emissions by 2050**

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Major Research Directions at VAST

VAST

38 Institutes, Centers & Universities

1. Information, electronics, automation and space technologies
2. Biotechnology
3. Material sciences
4. Biodiversity and bioactive compounds
5. Earth sciences
6. Marine sciences and technologies
7. **Environment and energy**

Research Activities on Environment and Energy at VAST

Environment

1. Wastewater Treatment Technologies
2. Solid Wastes Treatment & Management Technologies
3. Air Treatment, Control & Monitoring Technologies
4. Soil Treatment and Restoration Technology

Institute of Chemistry

Institute of Environmental and Energy Technology
Institute of Biotechnology
Institute of Material Sciences,
etc.

Energy

1. Renewable/green energy (hydrogen, solar, wind…)
2. Biofuels (ethanol, biodiesel, jet fuels)

Institute of Chemistry

Institute of Environmental and Energy Technology
Institute of Biotechnology
Institute of Material Sciences
Institute of Biotechnology

Biofuels Research at Institute of Chemistry - VAST

Ethanol production

1. Agricultural wastes (rice straw, grass)
2. Seaweed
3. Microalgae (third generation biomass feedstock)

Biodiesel

1. Microalgae oil
2. Waste cooking oil, animal fats

Jet-fuels

1. Microalgae oil

Ethanol Feedstocks in Vietnam

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Rice straw

51 million tons/year

Cassava

10 million tons/year

Sugar cane

11.5 million metric tons

Seaweed

150,000 tons/year

Corn

4.6 million tons/year

Organic waste

8 million tons/year

Ethanol Feedstocks in Vietnam

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Agricultural waste

- Rice husks and straw
- Garbage from corn
- Coffee waste
- Coconut shell
- Waste from sugarcane(bagasse, top, leaves)
- Peanuts byproducts
- Cashew nut shell
- Cassava root
- Other types

Energy crops

- Energy plants (fast growth and high calorific value)
- Elephant grass
- Other types

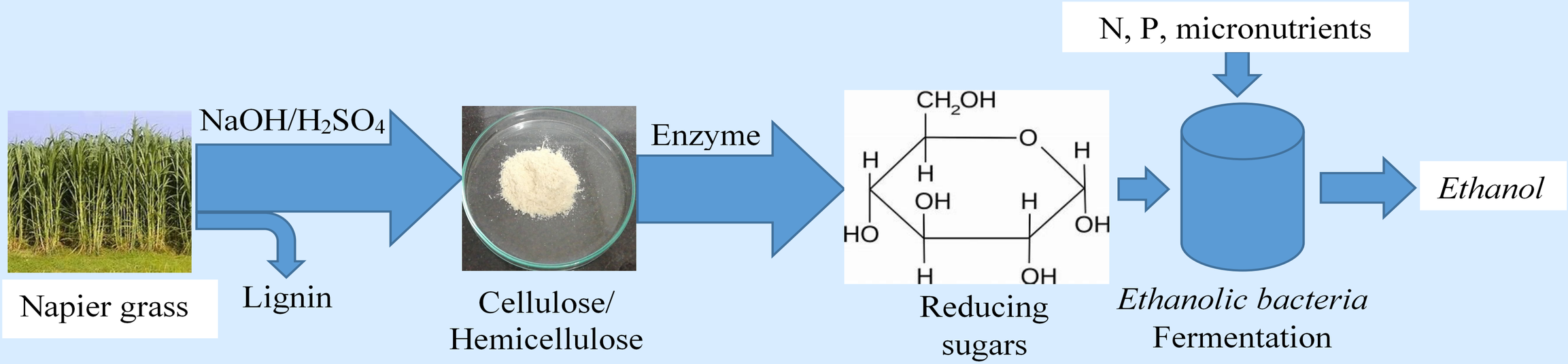
Waste from forests

- Wood fuel and fire wood
- Bamboo
- Others (activated carbon)

Other types

- Garden plants and family plants
- Wood for construction
- Wood waste from processing factories (wood shavings, sawdust)
- Scattering trees, etc.

Conversion of Lignocellulosic Materials to Ethanol



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C.W. Lin, C.H. Wu, **D.T. Tran**, M.C. Shih, W.H. Li, C.F. Wu (2011). Mixed culture fermentation from lignocellulosic materials using thermophilic lignocellulose-degrading anaerobes. Process Biochemistry, 46:489–493 [SCI; IF = 2.529].
A.H. Li, C.W. Lin, **D.T. Tran** (2011). Optimizing the response surface for producing ethanol from avicel by *Brevibacillus* strain AHPC8120. Journal of the Taiwan Institute of Chemical Engineers, 42:787–792 [SCI; IF = 2.848].
D.T. Tran, C.W. Lin, C.Y. Lai, C.H. Wu (2011). Ethanol production from lignocelluloses by native strain *Klebsiella oxytoca* THLC0409. Waste and Biomass Valorization, 2:389–396 [SCI; IF = 0.915].
D.T. Tran, Y.P. I, C.W. Lin (2013). Developing co-culture system of dominant cellulolytic *Bacillus* sp. THLA0409 and dominant ethanolic *Klebsiella oxytoca* THLC0409 for enhancing ethanol production from lignocellulosic materials. Journal of the Taiwan Institute of Chemical Engineers, 4:762–769 [SCI; IF = 2.848].

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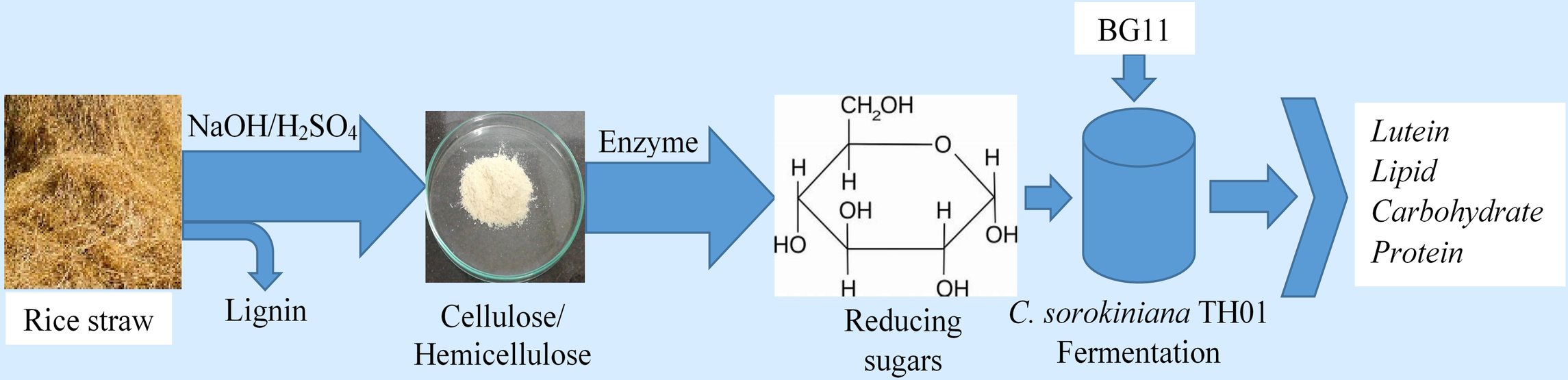
Conversion of Lignocellulosic Materials to Ethanol



Cam Van T. Do, Van Toan Lam, Phuong Dung T. Nguyen, **Dang Thuan Tran***, Quoc Anh Ngo, Truong Giang Le (2023). Recovery of carbon from rice straw for production of high-value products by *Chlorella sorokiniana* TH01 through mixotrophic cultivation. Biochemical Engineering Journal, 197:108966.

Biochemical Engineering Journal 197 (2023) 108966

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Contents lists available at ScienceDirect

Biochemical Engineering Journal

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

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Recovery of carbon from rice straw for production of high-value products by *Chlorella sorokiniana* TH01 through mixotrophic cultivation

Cam Van T. Do [a], Van Toan Lam [b], Phuong Dung T. Nguyen [b,c], Dang Thuan Tran [d,*,1], Quoc Anh Ngo [d], Truong Giang Le [d]

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Conversion of Seaweed Materials to Ethanol

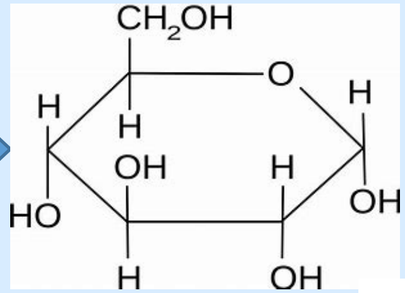
Seaweed

Solvents

Bioactive compounds

Cellulose/ Hemicellulose

Enzyme



Reducing sugars

N, P, micronutrients

Saccharomyces cerevisiae V7028

Ethanol

Do Trung Sy, Ngo Quoc Anh, Do Quang Khang. Study on conversion of seaweed, agricultural wastes containing carbohydrate to ethanol using biocatalysts. Doctoral dissertation, 2015.

Microalgae-Based Biorefinery Platform

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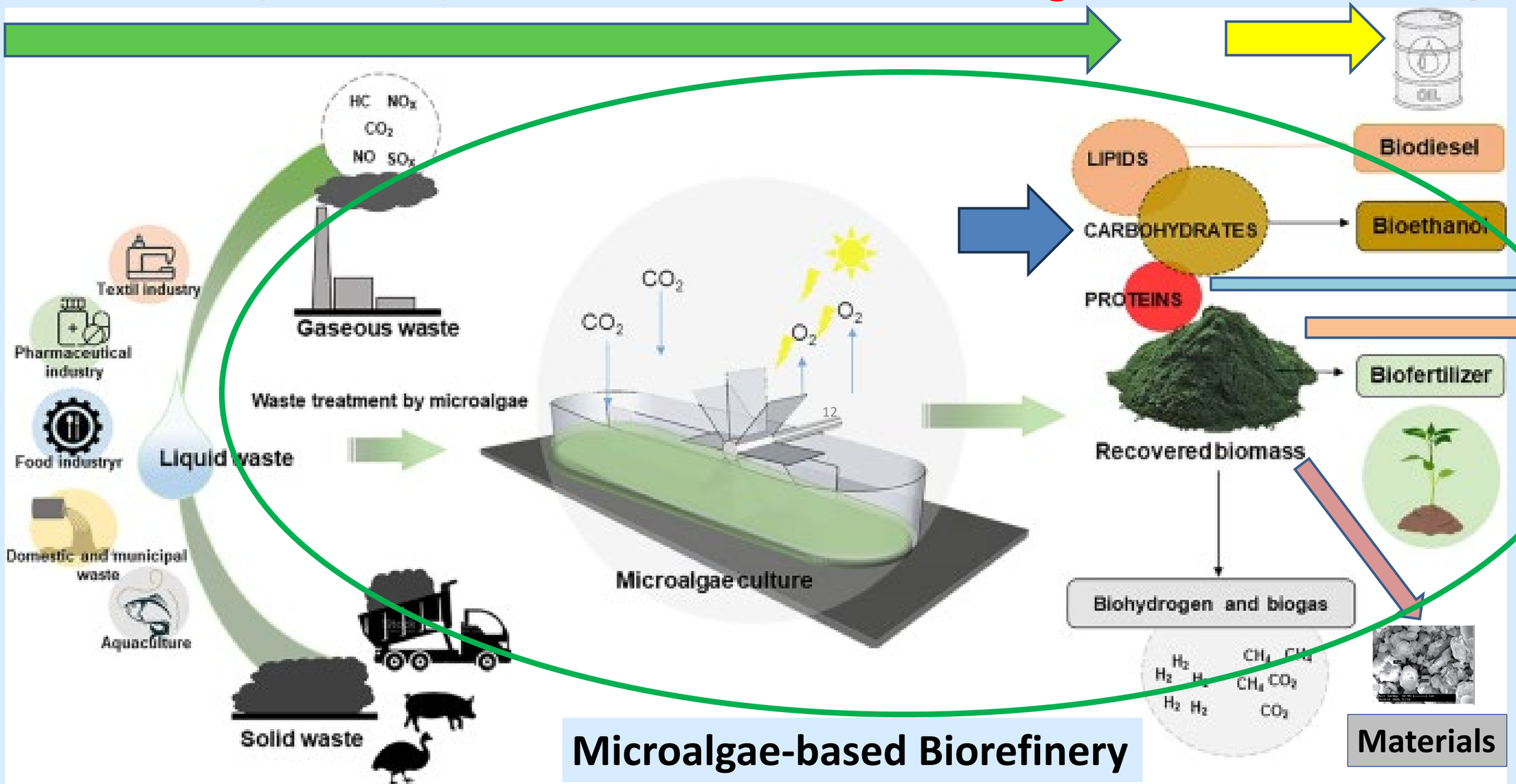
1) Turning liquid and gas wastes into biomass using microalgae

2) Recovery of valuable compounds from microalgae biomass for multiple applications



Turning Liquid and Gas Wastes into Biomass using Microalgae

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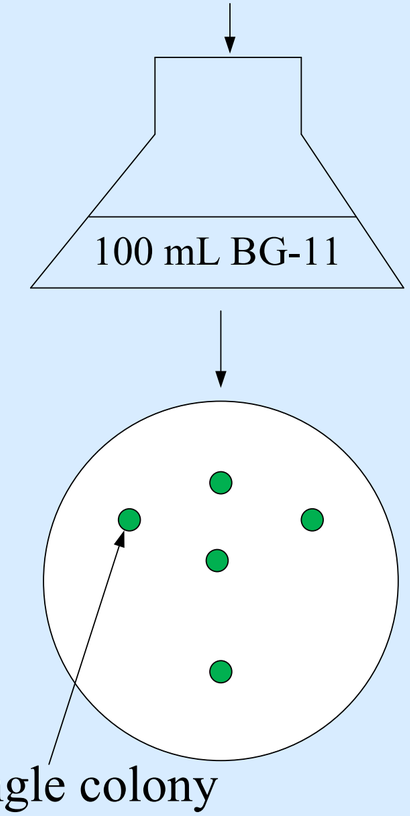
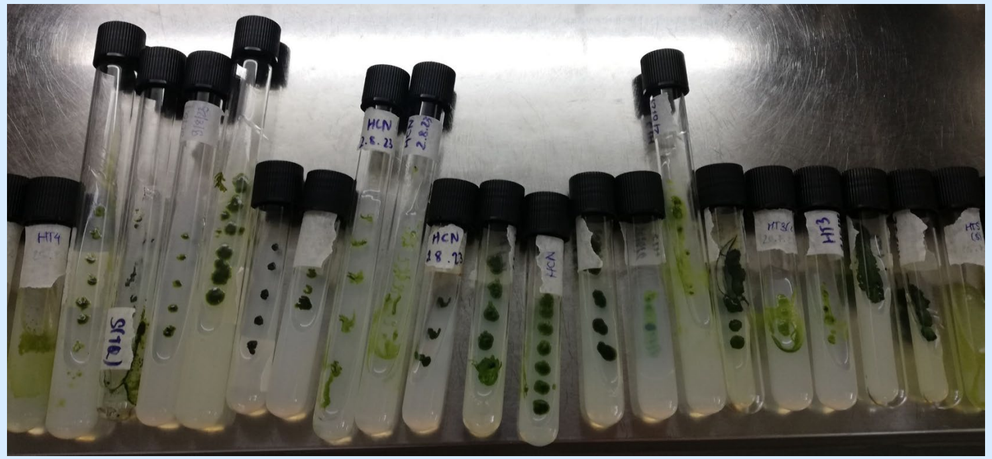
A. Isolation and purification of microalgae to create a library of microalgae & cyanobacteria

Water/wastewater/soil samples



Inoculation:
Shaking: 150 rpm
Temperature: 25 °C
Lighting: 60 µmol/m^2/s
Time: 7 days

Growing on BG-11 agar:
Temperature: 25 °C
Lighting: 60 µmol/m^2/s
Time: 7-12 days



A microalgae & cyanobacteria collection for R & D (> 500 strains)

Turning Liquid and Gas Wastes into Biomass using Microalgae

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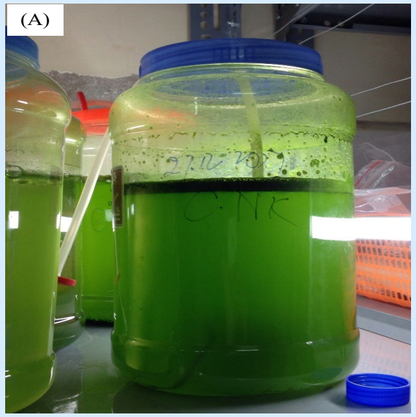
ii) Microalgae production in domestic wastewater using *C. variabilis TH03*



5 L

50 L

RW, 500-1000 L

Nutrients removal:

COD > 74.8%
TN > 85.1%
TP > 99.7%
Turbidity > 95%

Biomass composition:

Lipid > 22.6%
Protein > 33.7%
Carbohydrate > 31.6%
Chlorophyll > 2%

1. **Thi Cam Van Do, Thi Nham Tuat Nguyen, Dang Thuan Tran*, Truong Giang Le, Van Tuyen Nguyen.** *Semi-continuous removal of nutrients and biomass production from domestic wastewater in raceway reactors using Chlorella variabilis TH03-bacteria consortia*. **Environmental Technology & Innovation, 2020; 20:101172**
2. **Dang Thuan Tran, Hai Yen Nguyen, Thi Cam Van Do, Pau Loke Show, Truong Giang Le, Van Tuyen Nguyen (2020).** *Factors Affecting Pollutants Removal and Biomass Production Capability of Chlorella variabilis TH03 in Domestic Wastewater*. **Materials Science for Energy Technologies, 2020, 3:545–558;**
3. **D.T. Tran, T.C.V. Do, Q.T. Nguyen, T.G. Le .** *Simultaneous removal of pollutants and high value biomaterials production by Chlorella variabilis TH03 from domestic wastewater*. **Clean Technol. Environ. Policy., 2021, 23:3–17;**
4. Cam Van T. Do, Mai Huong T. Pham, Thanh Yen T. Pham, Cuc T. Dinh, Thu Uyen T. Bui, **Thuan Dang Tran***, Van Tuyen Nguyen (2022). Microalgae and bioremediation of domestic wastewater. Current Opinion in Green and Sustainable Chemistry, 34:100595.

Harvesting Microalgae

1) Bio-Flocculation with 4 mg chitosan (CTS)/L + 16 mg Xanthan Gum (XG)/L, harvesting efficiency > 95%

Flocculation

Filtration

Carbohydrate
Lipids
Protein
Others

Biomass powder

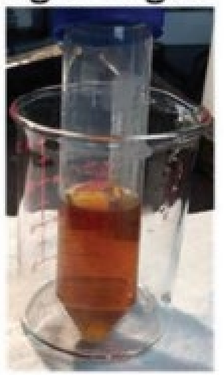
Diluted Acid Treatment for Recovery of Algal Sugar for Ethanol Production

2% H_2SO_4

PAHS

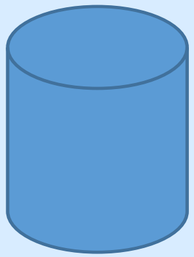
Filtration

Filtered liquor with algal sugars



Flocculated and vacuumed algal solids

N, P, micronutrients



Saccharomyces cerevisiae FAY-1

Ethanol

Lipid extraction

Conversion of Algal Lipids to BIODIESEL

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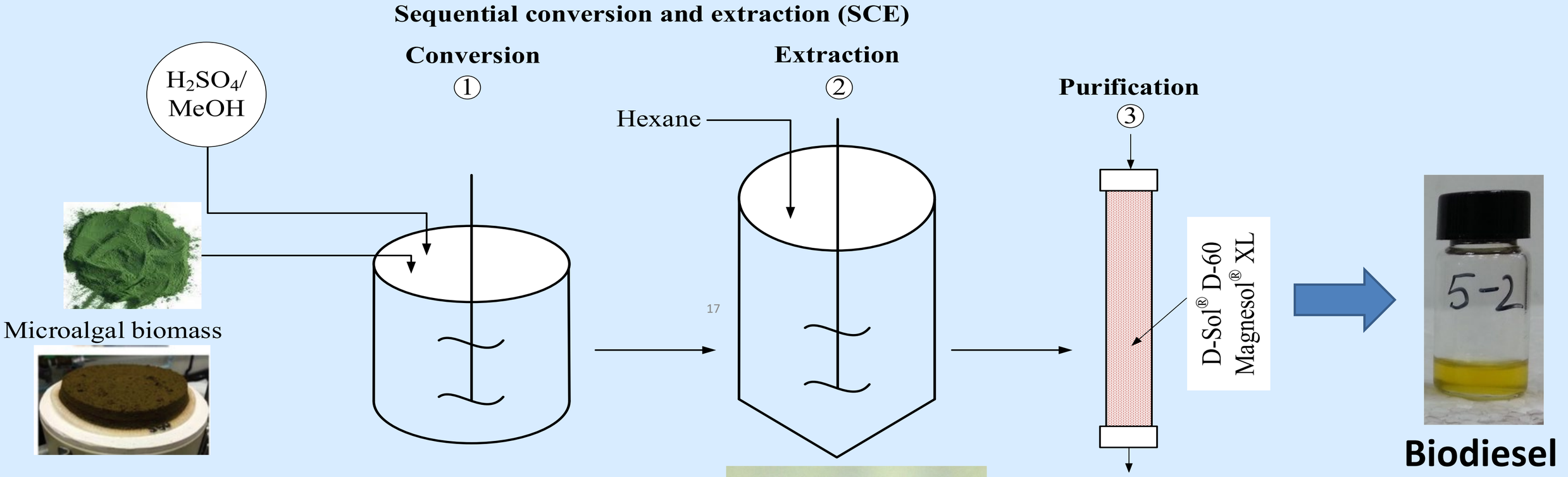
Development of a mini biodiesel production line from lipid-rich *S. acuminatus* TH04 biomass using H_2SO_4/methanol (5%, v/v) as a catalytic solvent



D.T. Tran, T.N. Ta, T.H.N. Do, T.M. Pham, T.B.H. Doan, T.H.T. Mai, T.C.V. Do, T.G. Le, V.T. Nguyen. Developing a mini biodiesel production line via sequential conversion to purification from *Scenedesmus acuminatus* TH04 grown in domestic wastewater. Journal of Chemical Technology and Biotechnology, 2020, 95: 2159–2170

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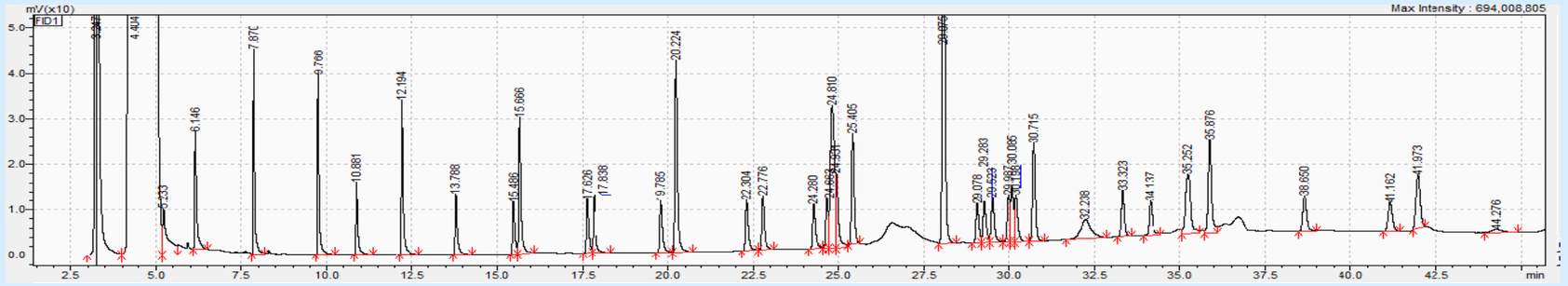
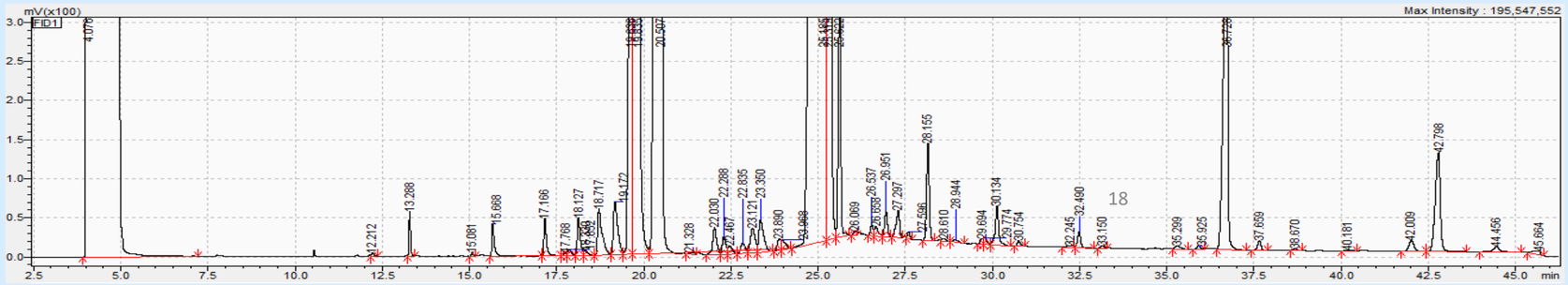
Fatty Acid Composition of Algal BIODIESEL

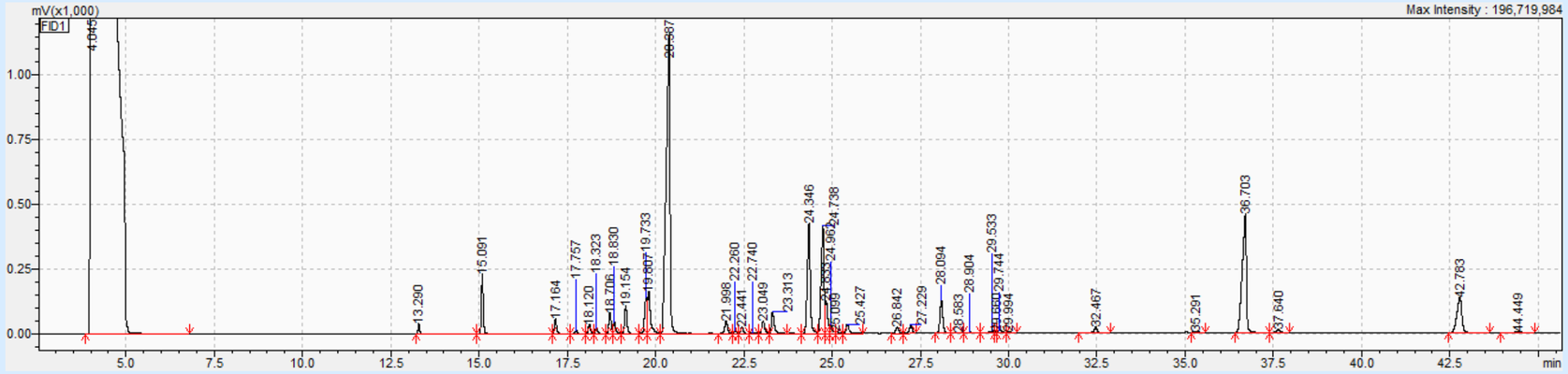
Fatty acid composition of algal oils from *S. acuminatus* TH04 and *C. sorokiniana* TH01



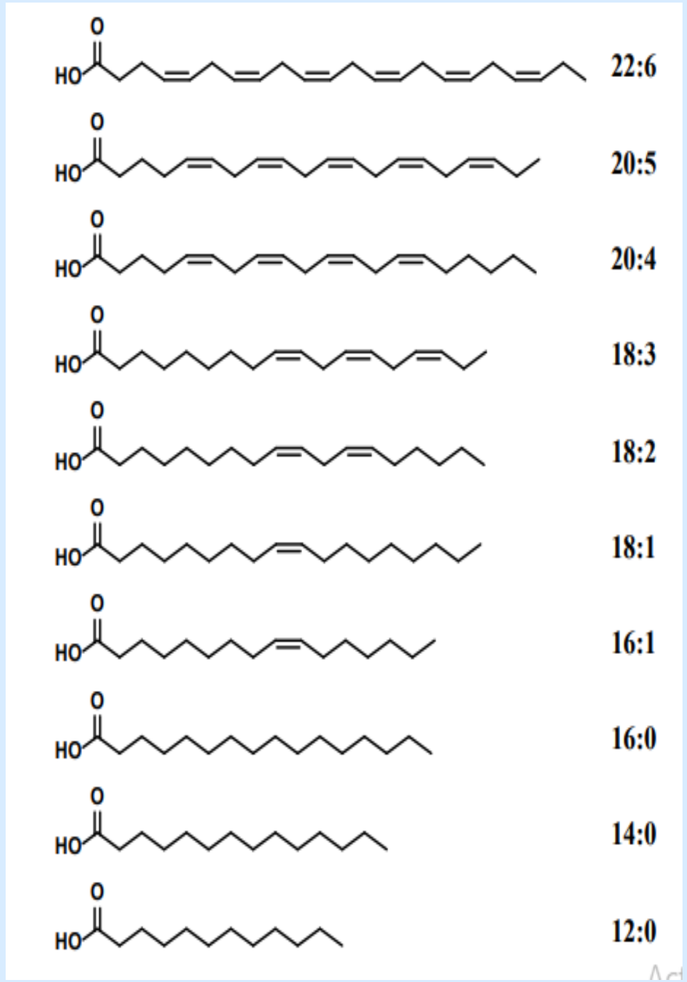
MIX



TH04



TH01



Diesel fuel: C9 to C23
(dominant species is C16)

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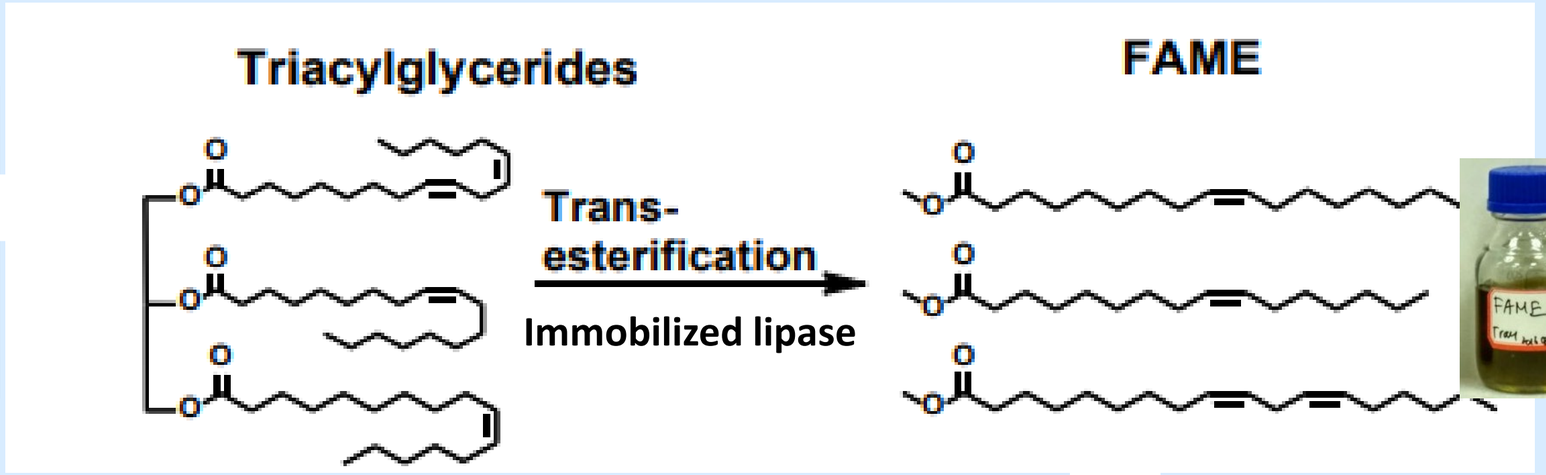
Upgrading Algal Oil to Jet Fuel via Catalytic Processes

Oil extraction

Algal oil



Catalytic process

Hydrocarbons (C8-C16)
Jet fuel (SAF)

Hydrocarbons (C8-C16)
Jet fuel (SAF)

SUMMARY

- Vietnam has high volume of ethanol feedstocks both in the second and third generations;
- Sugar-based ethanol production technology is mature and commercialized elsewhere;
- Application of advanced technologies e.g., system biology, synthetic biology and metabolic engineering for consolidated bioprocessing of ethanol from lignocelluloses is the key to further cutdown production cost and diversify ethanol supply;
- National policies and investments, co-operation of research institutes (e.g., ICH-VAST) and producers are the keys for commercialization of ethanol production and use as a transportation fuel in Vietnam.

Acknowledgements

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VIỆN HÀN LÂM KHOA HỌC VÀ CÔNG NGHỆ VIỆT NAM
VIETNAM ACADEMY OF SCIENCE AND TECHNOLOGY

(03 Projects, 2019-2023)

NAFOSTED
Quỹ Phát triển khoa học & công nghệ Quốc gia

(01 Project, 2018-2022)

VIETNAM ACADEMY OF SCIENCE AND TECHNOLOGY
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(02 Projects, 2019 & 2020)

HỌC VIỆN KHOA HỌC VÀ CÔNG NGHỆ
GRADUATE UNIVERSITY OF SCIENCE AND TECHNOLOGY

(01 Project, 2017-2021)

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THANK YOU VERY MUCH!