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ENHANCE MICROALGAE

Interreg Atlantic Area
European Regional Development Fund
EUROPEAN UNION

Communications about the INTERREG EnhanceMicroalgae project towards stakeholders and general public

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Manchester M13 9PL UK

La Rochelle, 20/10/2022

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01 | OUTLINE

Communications and metrics

EMA website and social media
EMA Newsletter
Microalgal strain catalogue
Microalgal growth video

Research and development

Laboratory-scale, bench- and pilot-scale cultivation
An autotrophic cultivation model
New publications and keynote lectures/seminars

2.1 EMA Website

EMA website management.

www.enhancemicroalgae.eu

- 81 posts throughout the lifetime of the project
- Updated with EnhanceMicroalgae Project Extension
- New list(s) of full and associated partners.
- In total 46,844 views since creation of the site
- Links to microalgae-related workshops, conferences, and webinars
- Publications page updated regularly with EMA partners contributions
- News page updated regularly with project updates
- Links to social media accounts
- Newsletter subscription on homepage

EnhanceMicroAlgae Website Metrics

- Total of 46,844 pageviews, with 34,377 of those being unique pageviews
- 12,835 pageviews on the homepage
- 2,391 pageviews on the Stakeholder Database, with an average time of 2m26s per view
- 1,885 pageviews on the Publications page
- 2,130 pageviews on the Partners page

Top Languages Accessing the Website

1. English – US
2. English – GB
3. Spanish – Spain
4. French – France
5. Portuguese – Portugal
6. French
7. Chinese – China
8. Italian – Italy
9. German – Germany
10. Spanish

2.2 EMA Social Media

Metrics

LinkedIn

- 550 connections
- Averaging around 1000 views per post
- Good level of interaction (likes/shares) with posts

Top 5 Job Titles Reached:

- Postdoctoral Researcher
- Professor
- Project Manager
- Process Engineer
- Lecturer

Top 5 Industries Reached:

- Biotechnology
- Research
- Higher Education
- Chemicals
- Renewables & Environment

facebook

- 246 followers

twitter

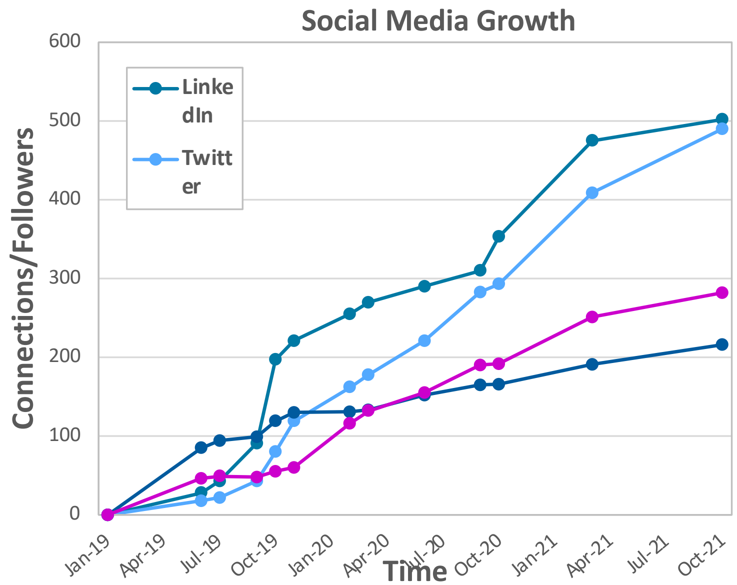
- 573 followers
- 231 tweets

October 2022 Summary as of 19/10:

- 571 Tweet impressions
- 313 profile visits
- 12 new followers

Instagram

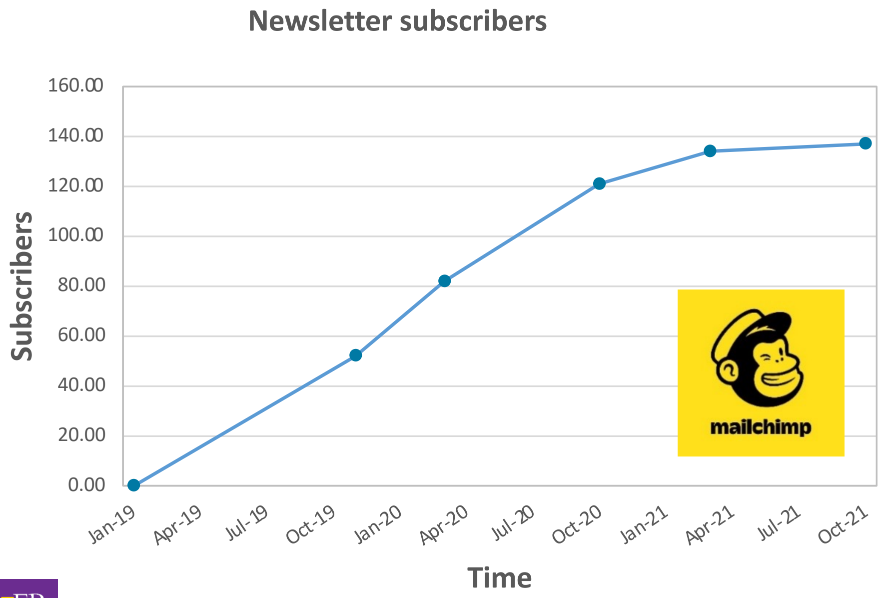
- 277 followers



2.3 EMA Newsletter

EnhanceMicroAlgae Newsletter

- 19 issues in total throughout the project
- 149 active subscribers
- Past issues here.
- Average between 55%-65% of subscribers reading each issue



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2.3 EMA Newsletter

Latest issue

Newsletter - October 2022 Issue

Inside this Issue:

- EnhanceMicroAlgae project successfully extended
- Upcoming workshop in La Rochelle
- Our partners, including new additions
- Press coverage of CNRS and Ifremer's microalgae acne cream
- New publications

EnhanceMicroAlgae project successfully extended

The application for the extension of the project was successful and phase two of the EnhanceMicroAlgae project has begun. The project has been extended until the 30th of June 2023.

EnhanceMicroAlgae Workshop, La Rochelle 20/10/22

The EnhanceMicroAlgae project will be hosting a workshop on the 20th October 2022 in La Rochelle, France. The workshop will focus on the latest developments in microalgae science, start-up creation, industrialisation, and experience sharing to overcome gaps and barriers to innovation and markets.

A full timetable for the day and further information can be found here.

Our Partners

Our Associated Partners

2.4 Microalgal cultivation video

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Chlorella Sorokiniana
Porphyridium Purpureum
Nannochloropsis Gaditana

Lab scale
Bottles (500 ml)

Bench scale
Bubble column (PBR- 15 l)

Pilot scale
Open raceway Ponds (500 l)

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3.2 Laboratory scale experiments

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Conditions	Species Studied		
	C. Sorokiniana	*P. Purpureum*	*N. Gaditana*
Low light Low nitrogen		√	
Low light Central nitrogen			√
Low light High nitrogen	√	√	
High light Low nitrogen		√	
High light Central nitrogen	√	√	
High light High nitrogen	√	√	

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3.2 Lab scale experiments

Chlorella Sorokiniana

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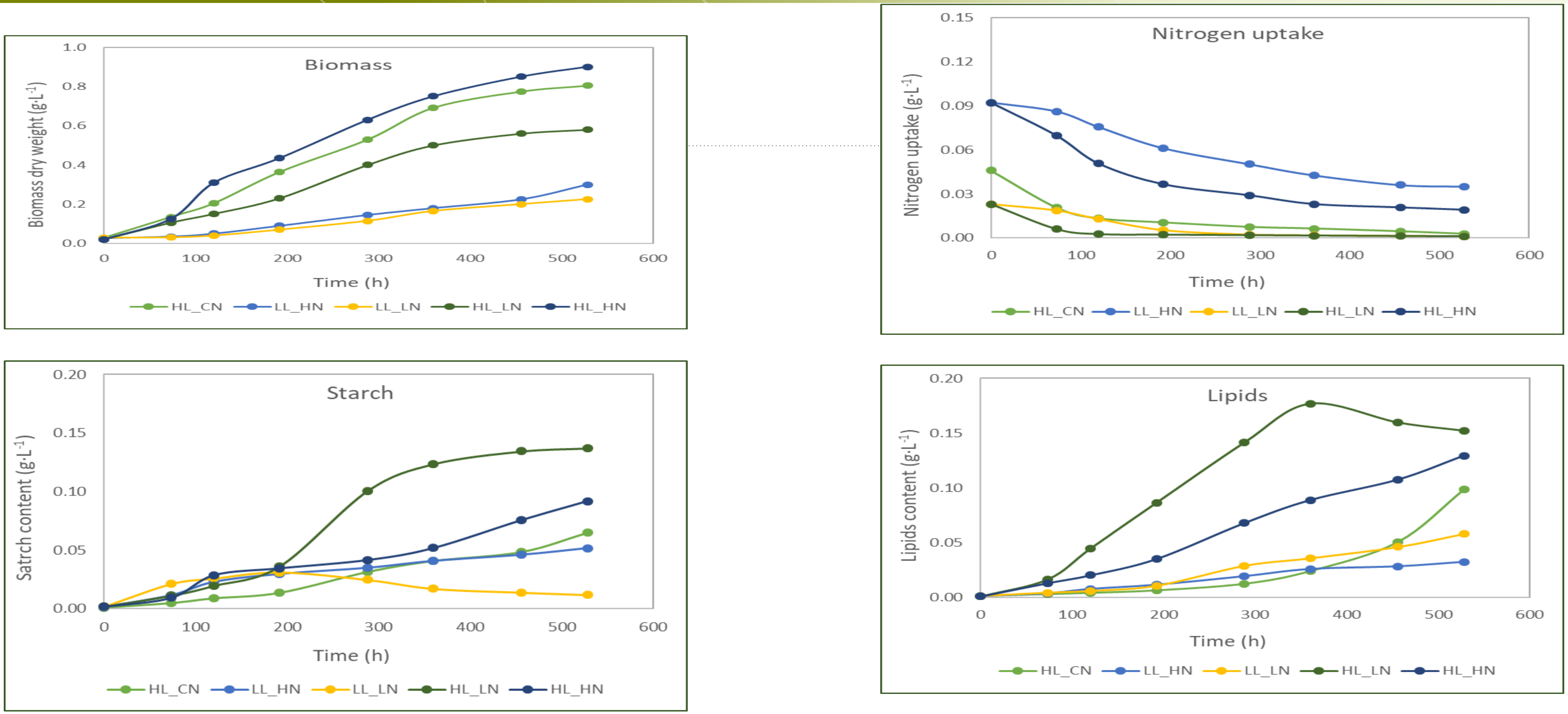

Figure : Comparison of experimental results of Chlorella Sorokiniana in bottles _Low N (1.65mM) _Central N (6.6mM) _High N (3.3mM) and _Low L (20 µmol·m-2·s-1) _High L (110 µmol·m-2·s-1)

3.2 Lab-scale experiments

Porphyridium Purpureum

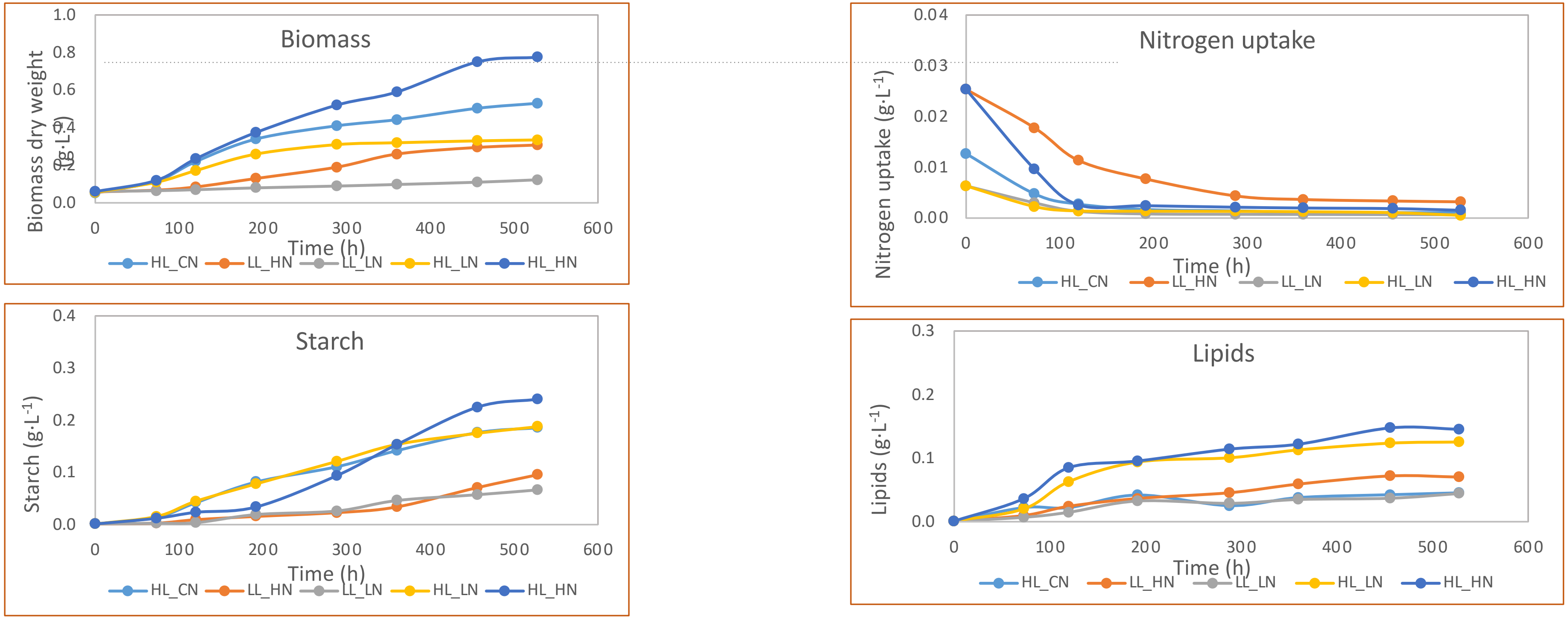

Figure : Comparison of experimental results of Porphyridium purpureum in bottles _Low N (0.45mM) _Central N (0.90mM) _High N (1.80mM) and _Low L (20 µmol·m-2·s-1) _High L (110 µmol·m-2·s-1)

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3.2 Lab-scale experiments

Nannochloropsis Gaditana

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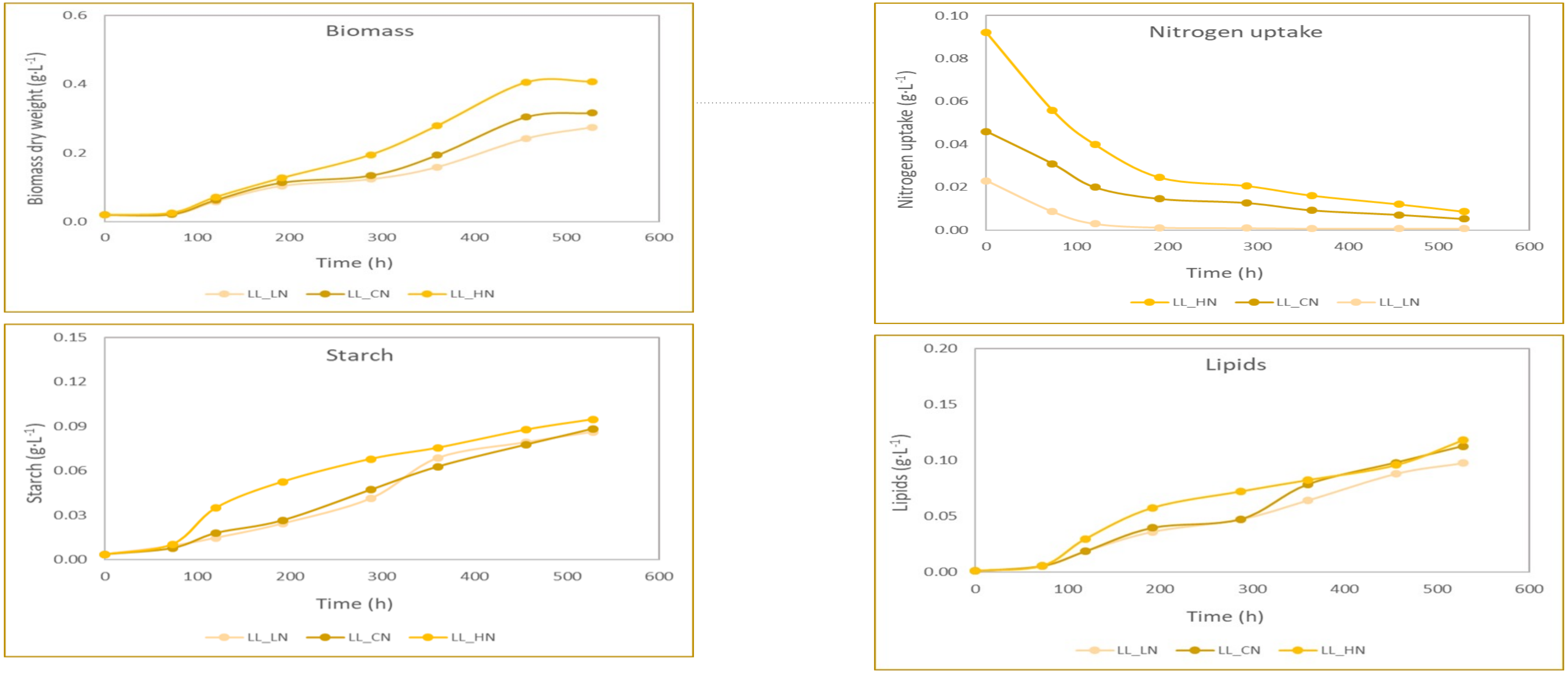

Figure : N.gaditana in bottles. Experimental condition: Low light (20 µmol·m-2·s-1) Central N (0.046 g/L)

Conditions	Species Studied		
	C. Sorokiniana	*P. Purpureum*	*N. Gaditana*
High Light Central Nitrogen Low Air Flow Rate	√	√	
High Light Central Nitrogen High Air Flow Rate	√	√	√

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3.3 Photobioreactor experiments

Chlorella Sorokiniana

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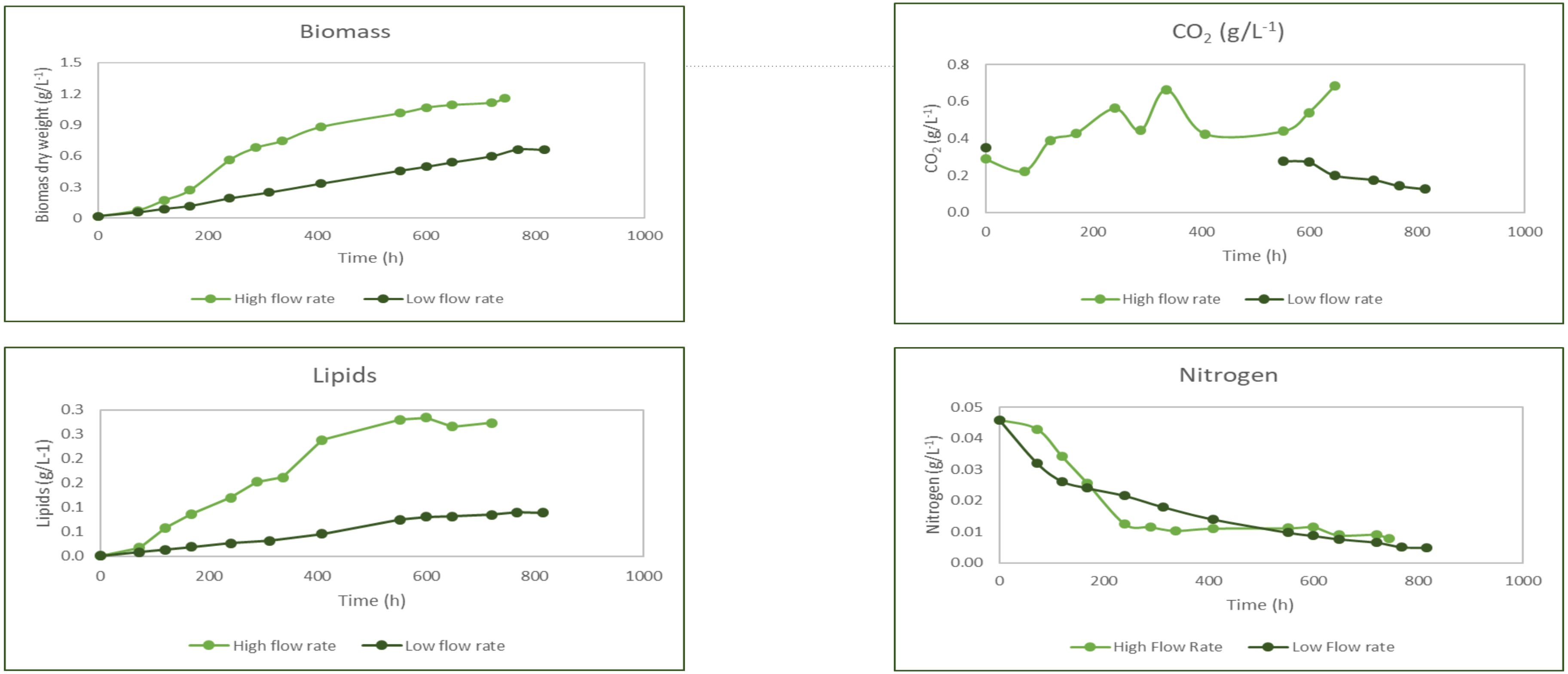

Figure : Comparison of biomass experimental results of C. sorokiniana in bubble column PBR High airflow rate (5L/min) _Central N (0.046 g/L) and Low air flow rate (1.5L/min) _Central N (0.046 g/L)

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3.3 Photobioreactor experiments

Porphyridium Purpureum

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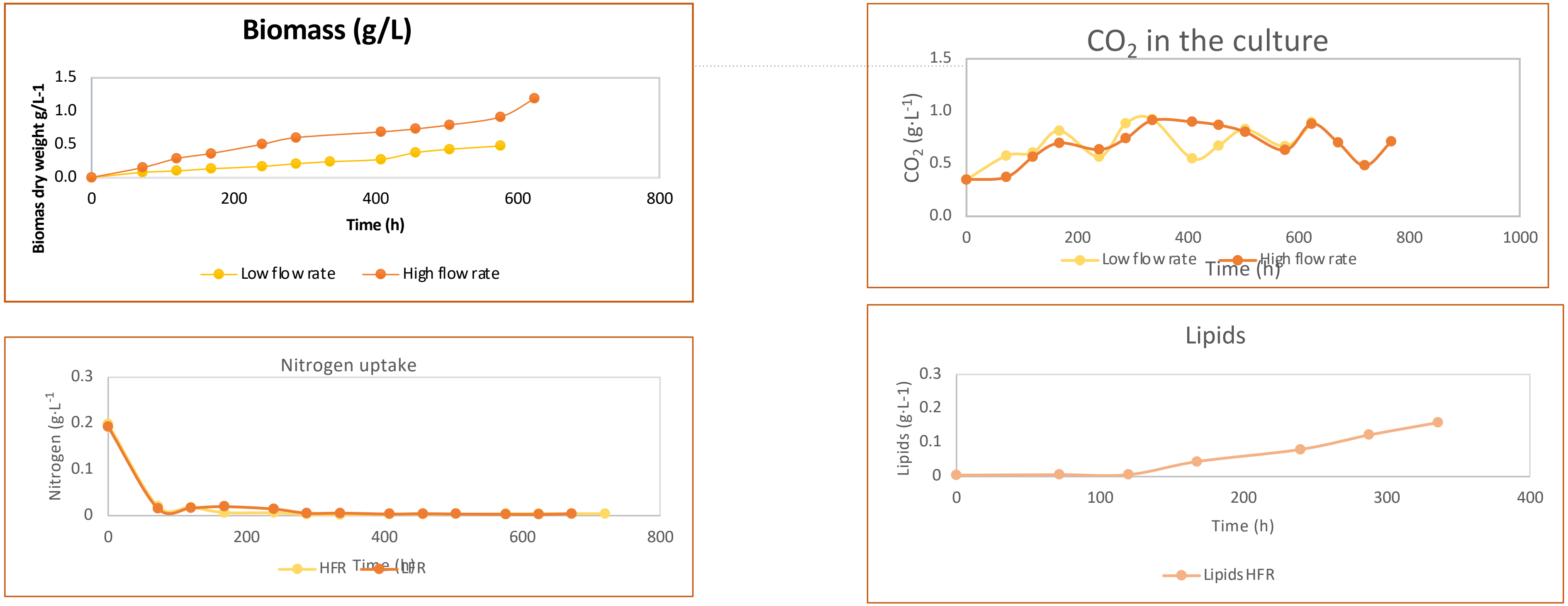

Figure : Comparison of experimental results of Porphyridium purpureum in bubble column PBR High airflow rate (5L/min) _Central N (0.046 g/L) and Low air flow rate (1.5L/min) _Central N (0.046 g/L)

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3.3 Photobioreactor experiments

Nannochloropsis Gaditana

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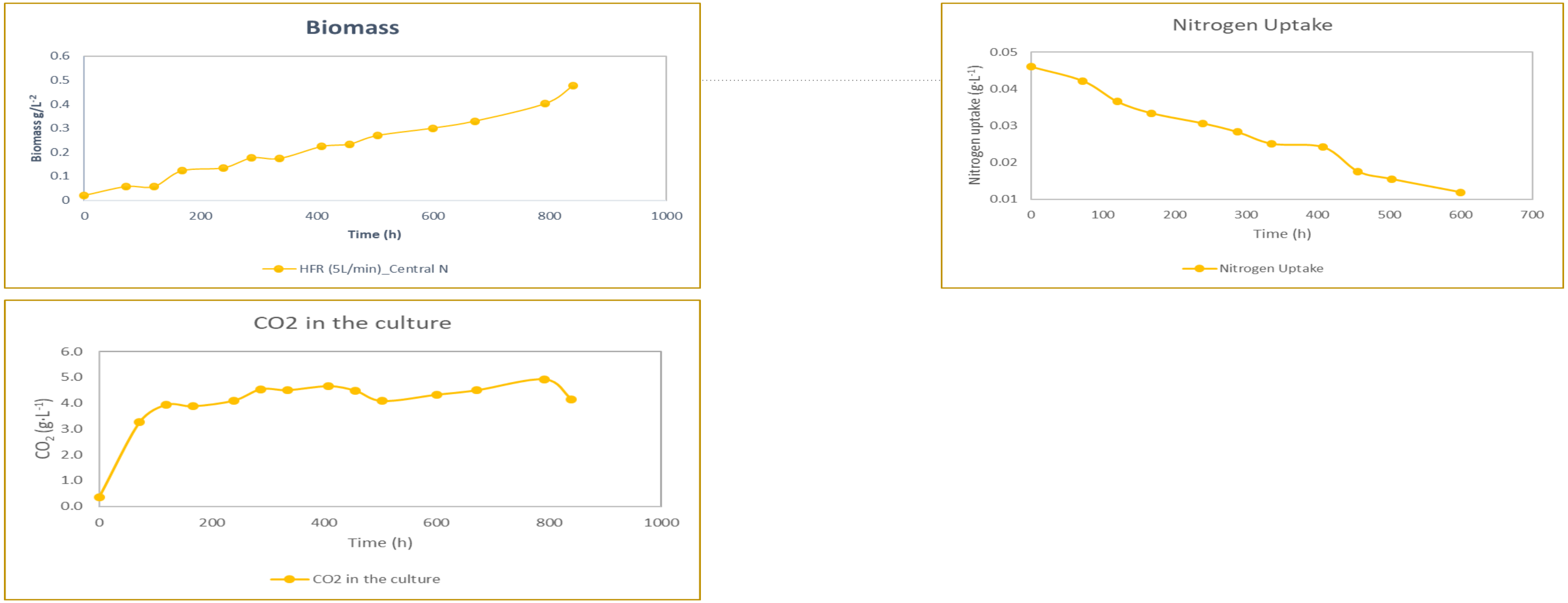

Figure : Experimental results of Nannochloropsis Gaditana in bubble column PBR High airflow rate (5L/min) _Central N (0.046 g/L) Light??

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3.4 Open ponds experiments

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Conditions	Species Studied		
	C. Sorokiniana	*P. Purpureum*	*N. Gaditana*
High Light			
Low Nitrogen		√	
Air Flow Rate			
High Light			
Central Nitrogen	√		√
Air Flow Rate			
High Light			
High Nitrogen		√	√
Air Flow Rate			

3.4 Open ponds experiments

Chlorella Sorokiniana

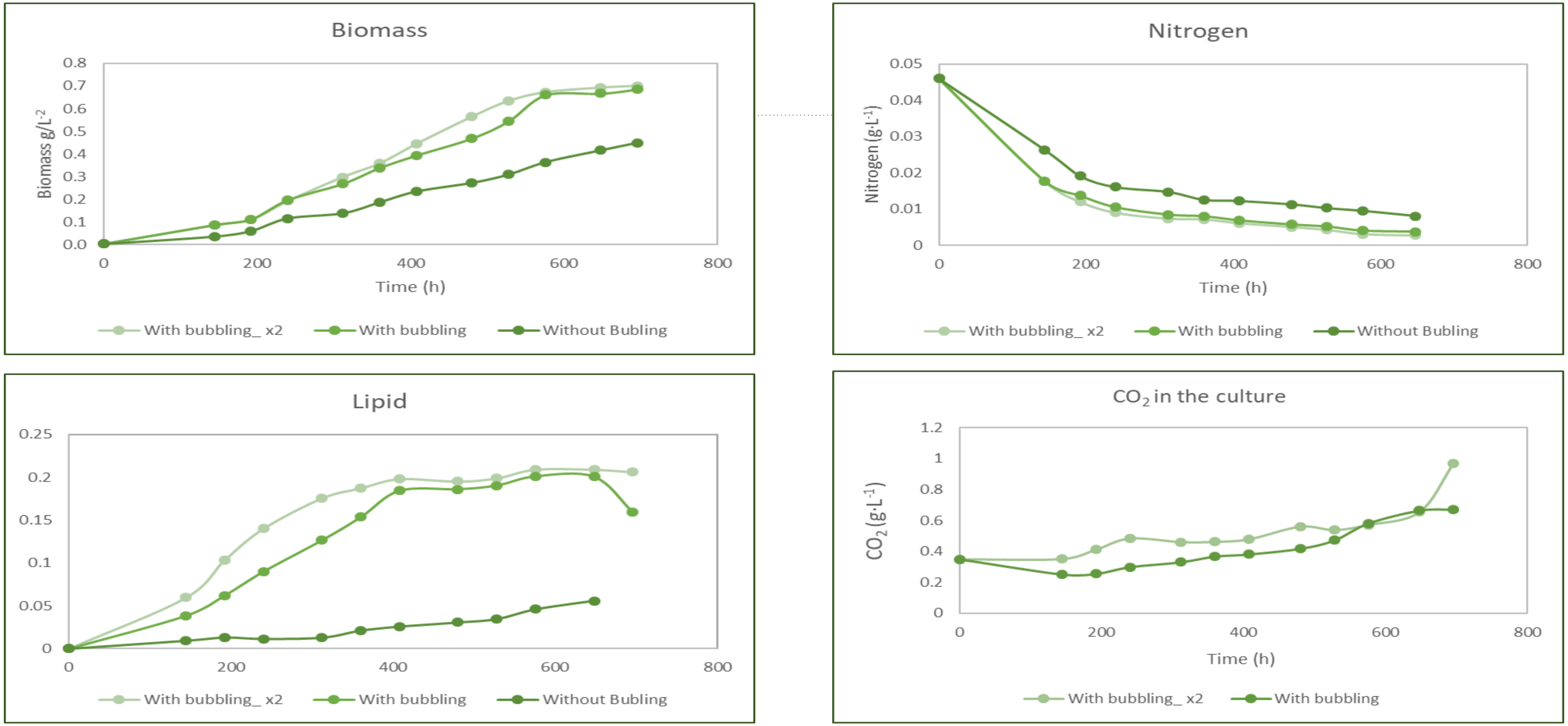


Figure : Comparison of experimental results of Chlorella Sorokiniana in ponds _Central N (0.90mM)

3.4 Open ponds experiments

Chlorella Sorokiniana

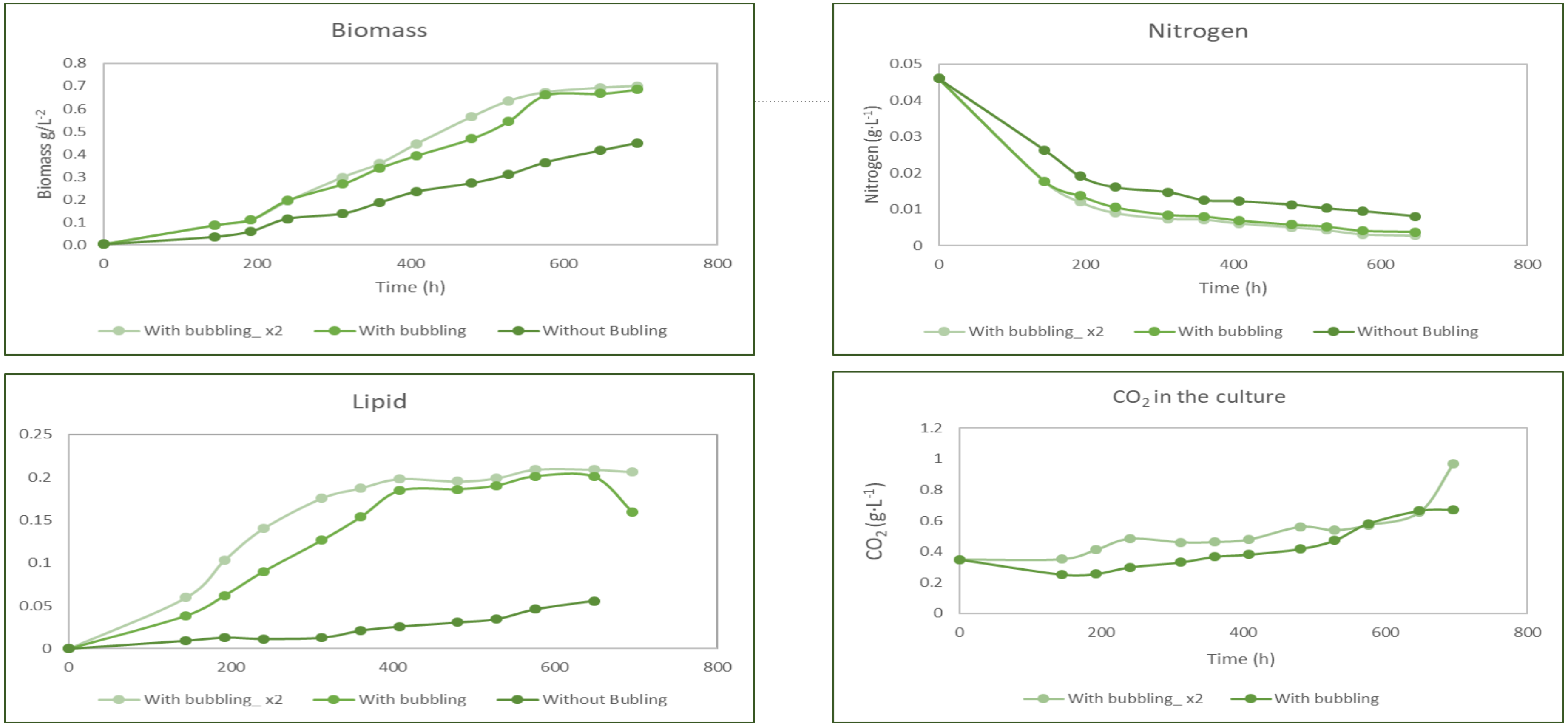


Figure : Comparison of experimental results of Chlorella Sorokiniana in ponds _Central N (0.90mM)

3.4 Open ponds experiments

Chlorella Sorokiniana

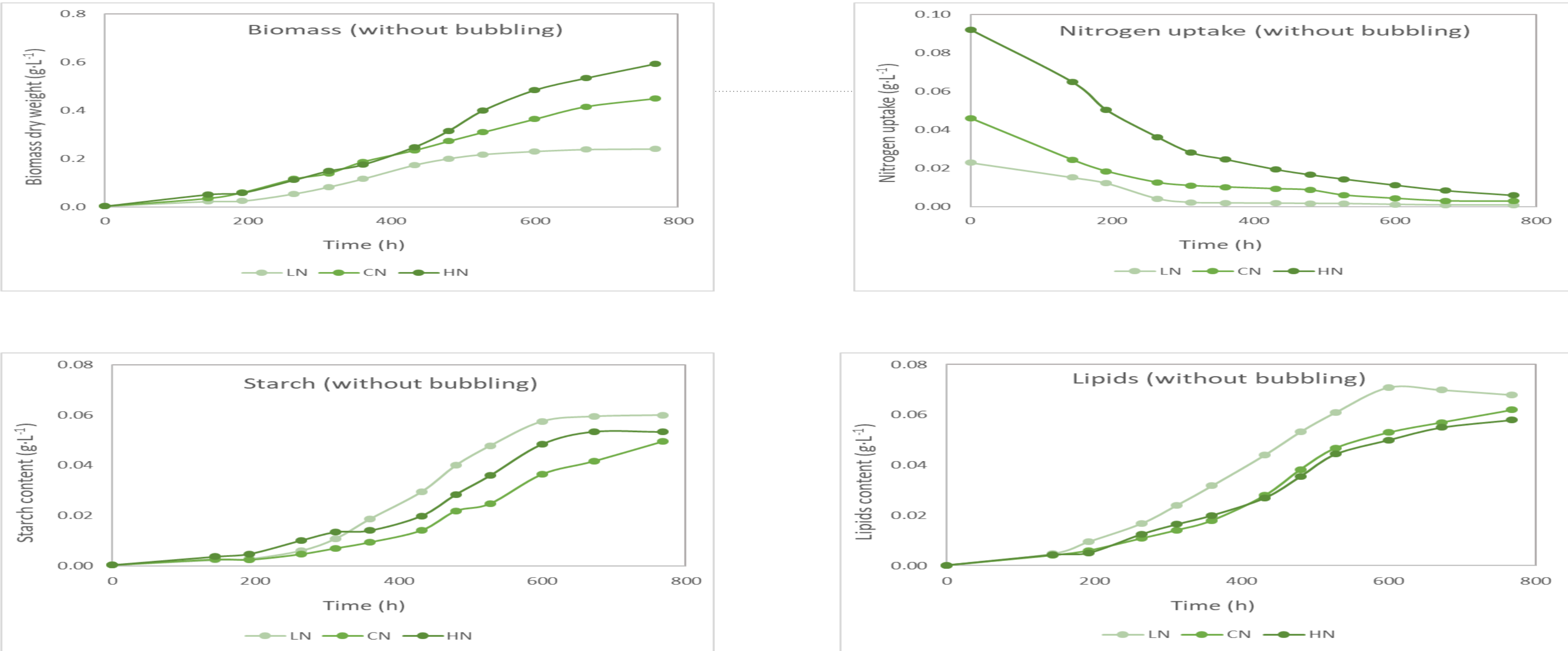


Figure : Comparison of experimental results of Chlorella Sorokiniana in ponds_no bubbling

3.4 Open ponds experiments

Porphyridium Purpureum

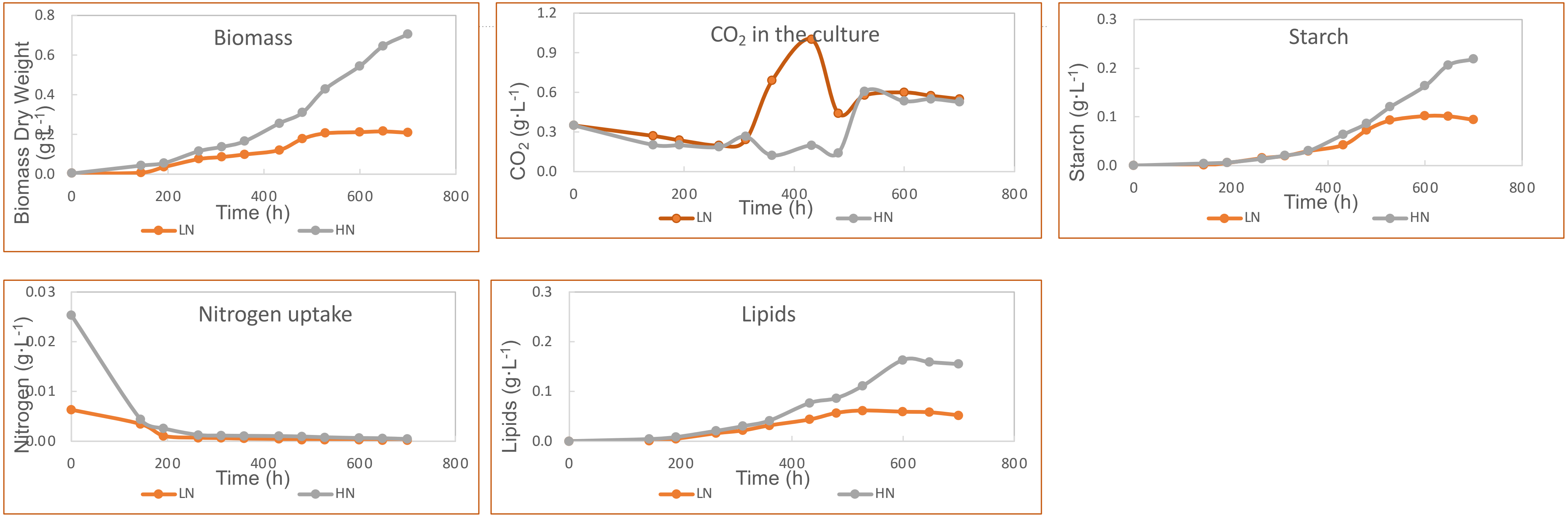
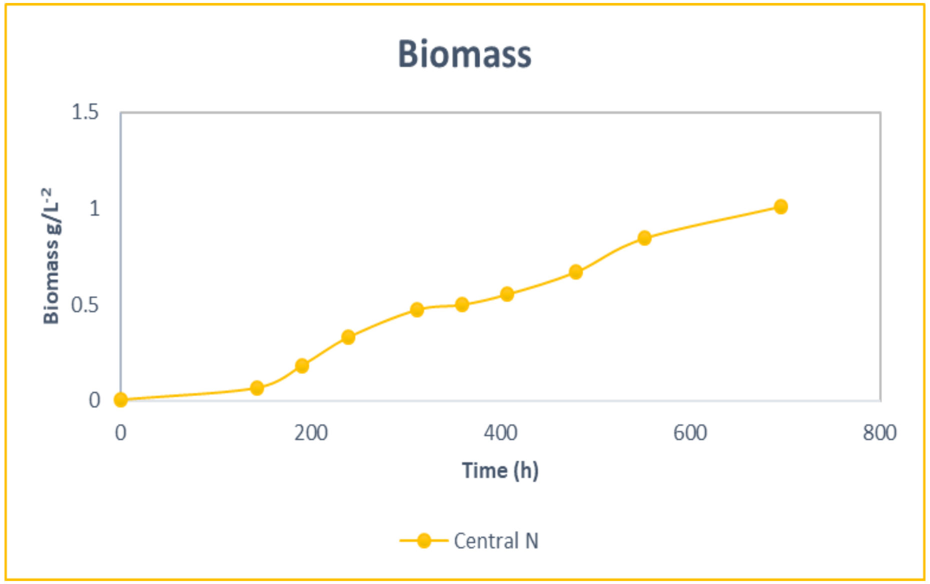


Figure : Comparison of experimental results of Porphyridium purpureum in ponds _Low N (3.3mM) and _High N (6.6mM)

3.4 Open ponds experiments

Nannochloropsis Gaditana



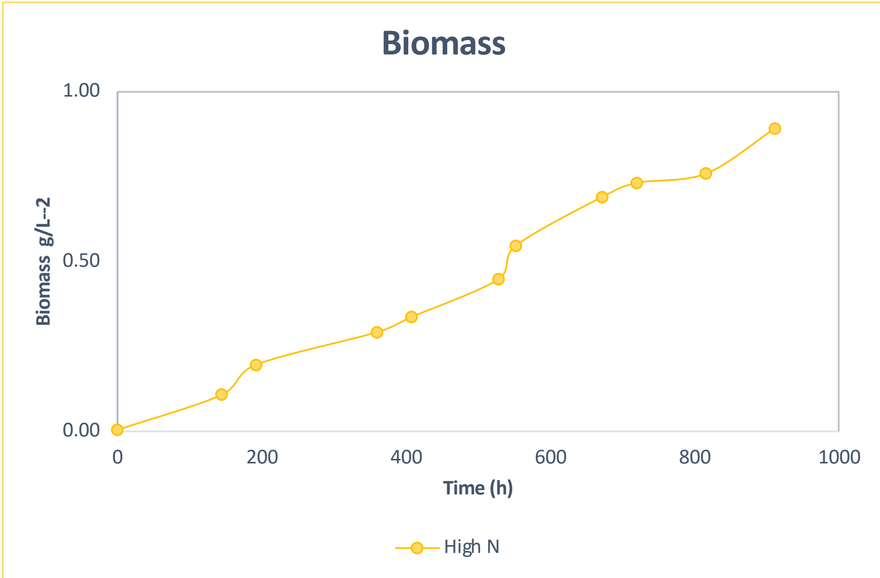


Figure : Comparison of experimental results of Nannochloropsis gaditana in ponds _Central N (3.3mM) _and _Low L (20 µmol·m-2·s-1

Microalgae specific growth rate:

$$\mu = \mu_{M,max}([\mu_I(\bar{I})][\mu_N(q_N)]) \qquad (1)$$

Light contribution

$$\mu_I(\bar{I}) = \frac{\bar{I}}{\bar{I} + K_{S,I} + \frac{\bar{I}^2}{k_{i,I}}} \qquad (1.1)$$

Nitrogen contribution

$$\mu_N(q_N) = 1 - \frac{q_{N,0}}{q_N} \qquad (1.2)$$

q_N , Nitrogen quota

$\bar{I}$, Light intensity

$\mu_{M,max}$, Maximum specific growth rate

$q_{N,0}$, Nitrogen quota to sustain growth

$K_{S,I}$, Saturation constant

$k_{i,I}$, Inhibition constant

Nitrogen uptake rate:

$$\rho_N = \bar{\rho}_{N,max}(N_0, X) \cdot \frac{N}{N + K_{s,N} + \frac{N^2}{k_{i,N}}} \qquad (2)$$

$$\bar{\rho}_{N,max}(N_0, X) = \rho_{N,max} \cdot \frac{N_o}{N_o + K_*} \cdot e^{-\phi_N \cdot X} \qquad (2.1)$$

ρ_N , Nitrogen uptake rate

N , Nitrogen concentration

N_0 , Initial nitrogen concentration

X , Biomass concentration

$\rho_{N,max}$, Maximum nitrogen uptake rate

$K_{s,N}$, Uptake saturation constant

$k_{i,N}$, Uptake inhibition constant

K_* , Saturation constant, N_0

ϕ_N , Uptake regulation coefficient

Rates of formation of cellular compartments:

$$R_1 = r_1 \cdot \frac{N_i^{n_S}}{N_i^{n_S} + K_{s,S}^{n_S} + \left(N_i^2/k_{i,S}\right)^{n_S}} \cdot \frac{k_1}{k_1 + N/N_o} \cdot \left[1 + \frac{1}{\mu} \cdot e^{\phi_S}\right] \cdot \mu \cdot x^* \quad (3)$$

$$R_3 = r_3 \cdot \frac{N_i^{n_L}}{N_i^{n_L} + K_{s,L}^{n_L} + \left(N_i^2/k_{i,L}\right)^{n_L}} \cdot \frac{k_2}{k_2 + N/N_0} \cdot \left[1 + \frac{1}{\mu} \cdot e^{\phi_L}\right] \cdot \mu \cdot x^* \quad (4)$$

$$R_2 = r_2 \cdot \frac{X}{q_N} \cdot \frac{S/X}{S/X + k_{sat,S}} \quad (5)$$

$$R_4 = r_3 \cdot \frac{X}{q_N} \cdot \frac{L/X}{L/X + k_{sat,L}} \quad (6)$$

N , Nitrogen concentration

X , Biomass concentration

S , Starch concentration

L , Lipid concentration

r_1, r_2, r_3, r_4 , Rates of reactions

$K_{s,S}, K_{s,L}$, Saturation constants

$k_{i,S}, k_{i,L}$, Inhibition constants

n_s, n_L , Shape-controlling exponents

$k_{sat,S}, k_{sat,L}$, Saturation constants

Nitrogen uptake rate:

$$\rho_N = \bar{\rho}_{N,max}(N_0, X) \cdot \frac{N}{N + K_{s,N} + \frac{N^2}{k_{i,N}}} \qquad (2)$$

$$\bar{\rho}_{N,max}(N_0, X) = \rho_{N,max} \cdot \frac{N_o}{N_o + K_*} \cdot e^{-\phi_N \cdot X} \qquad (2.1)$$

ρ_N , Nitrogen uptake rate

N , Nitrogen concentration

N_0 , Initial nitrogen concentration

X , Biomass concentration

$\rho_{N,max}$, Maximum nitrogen uptake rate

$K_{s,N}$, Uptake saturation constant

$k_{i,N}$, Uptake inhibition constant

K_* , Saturation constant, N_0

ϕ_N , Uptake regulation coefficient

Time-dependent kinetic expressions:

ODE(1)	*Active biomass (x^*)*	$\frac{dx^*}{dt} = \mu \cdot X + R_2 + R_4 - (R_1 + R_3) \quad (7)$
ODE (2)	*Nitrogen (N)*	$\frac{dN}{dt} = -\rho_N \cdot X \quad (8)$
ODE(3)	*Nitrogen quota (q_N)*	$\frac{dq_N}{dt} = \rho_N - \mu q_N \quad (9)$
ODE(4)	*Starch (S)*	$\frac{dS}{dt} = R_1 - R_2 \quad (10)$
ODE(5)	*Lipid (L)*	$\frac{dL}{dt} = R_3 - R_4 \quad (11)$
ODE(6)	*Total biomass (X)*	$\frac{dX}{dt} = \frac{d(x^* + S + L)}{dt} = \mu X \quad (12)$

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4.1 Model development

Parameter estimation for lab-scale experiments

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μ_{max}	0.0805	h^{-1}
$K_{s,I}$	56.612	$\mu_{mol} m^{-2} s^{-1}$
$k_{i,I}$	6.816	$\mu_{mol} m^{-2} s^{-1}$
$q_{N,0}$	0.0581	$gN\ gC^{-1}$
σ	758.513	$L\ gC^{-1}\ m^{-1}$
$\rho_{N,max}$	60.866	$gN\ gC^{-1}\ h^{-1}$
K_{*}	1.0306	
Φ_N	8.903	
$K_{s,N}$	70.623	$gN\ L^{-1}$
$k_{i,N}$	0.0003	$gN\ L^{-1}$

$K_{s,S}$	0.00906	$gN\ L^{-1}$
$k_{i,S}$	0.00631	$gN\ L^{-1}$
$K_{s,L}$	0.0106	$gN\ L^{-1}$
$k_{i,L}$	0.00800	$gN\ L^{-1}$
n_S	2.852	
n_L	1.4636	
Φ_S	20.333	$L\ gC^{-1}$
Φ_L	10.791	$L\ gC^{-1}$
$k_{sat,S}$	45.940	
$k_{sat,L}$	5.6108	

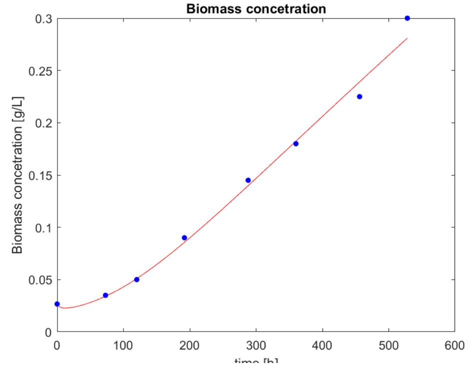
r_1	0.0000136	$gC\ gC^{-1}$
r_2	0.0000299	$gN\ gC^{-1} h^{-1}$
r_3	0.0000010	$gC\ gC^{-1}$
r_4	0.0101	$gN\ gC^{-1} h^{-1}$
k_1	0.0000073	
k_2	0.633	

4.2 Model fitting

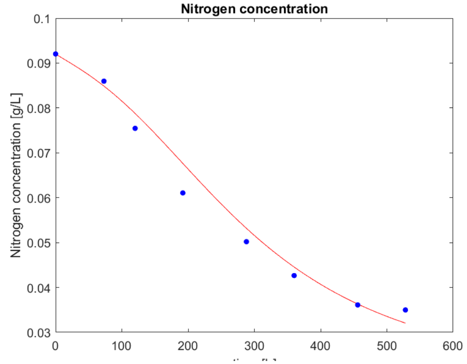
Chlorella Sorokiniana

Lab-scale, low light, high nitrogen conditions

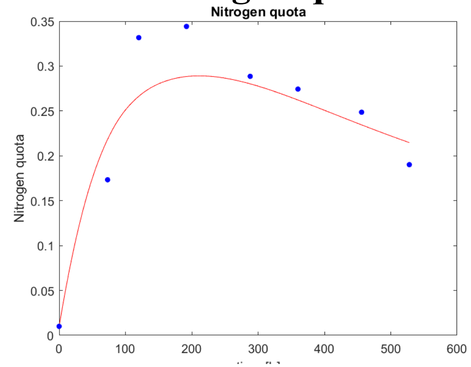
Biomass



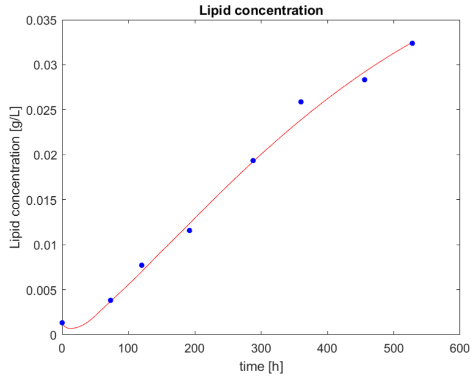
Nitrogen



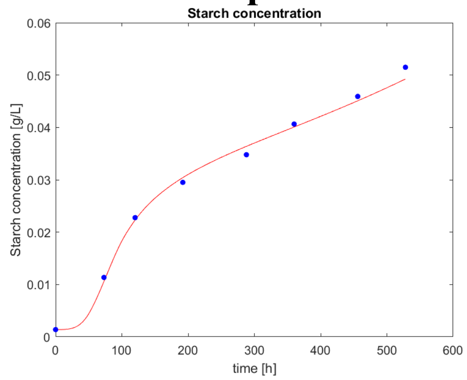
Nitrogen quota



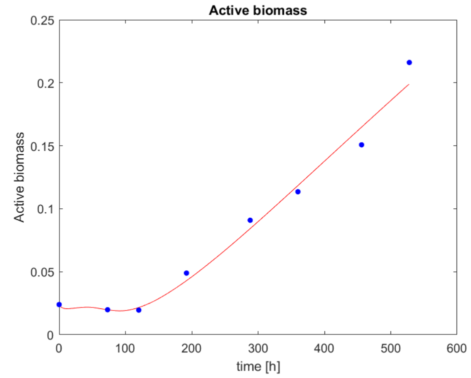
Starch



Lipid



Active biomass



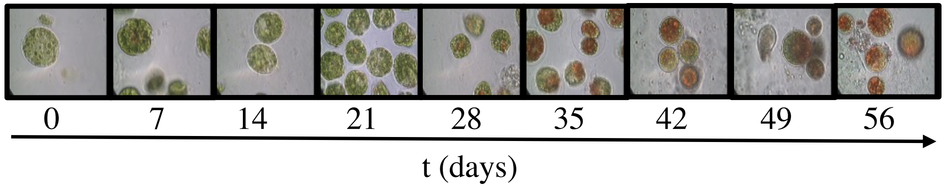
Sargent Centre Seminar Series – Imperial College (12/5/21)
Integrated Systems Approach for Optimizing the Sustainable Bioproduction of Biofuels and Added-Value Chemicals: The Microalgal Biorefinery Paradigm

NUI Galway Ireland Workshop:
Microalgae biotechnology for biofuel
production and environmental application (20/5/2022)
Microalgal biomass as a biorefinery platform for biobutanol and biodiesel production

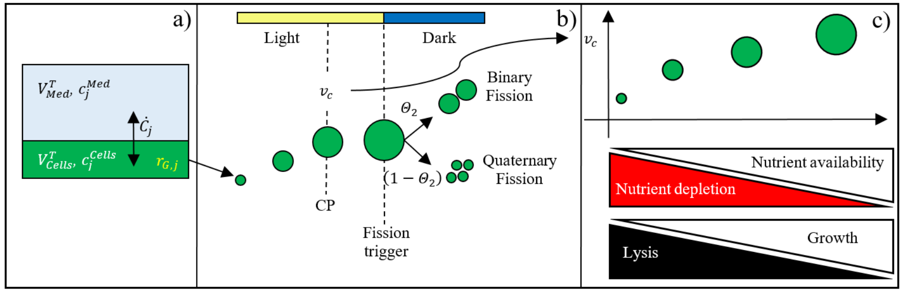
Also, a number of presentations at International conferences:

A multiscale modelling approach for Haematococcus pluvialis cultivation under different environmental conditions

Biotechnology reports (IF= 4.401) in print
https://doi.org/10.1016/j.btre.2022.e00771
EnhanceMicroAlgae project is acknowledged.



Summary: **In this work, we develop a novel multiscale segregated-structured model based on Population Balance Equations (PBEs) to describe the photoautotrophic growth of H.pluvialis, in particular cell growth, and lysis, making possible the description of the relationship between cell volume/transition, cell loss, and metabolic product availability. Cell volume is the internal coordinate of the population balance model, and its link with intrinsic concentrations is also presented. The model parameters are fitted against experimental data, extensive sensitivity analysis is performed and the model predictive capabilities are tested in terms of cell density distributions, as well as 0th and 1st order moments.**

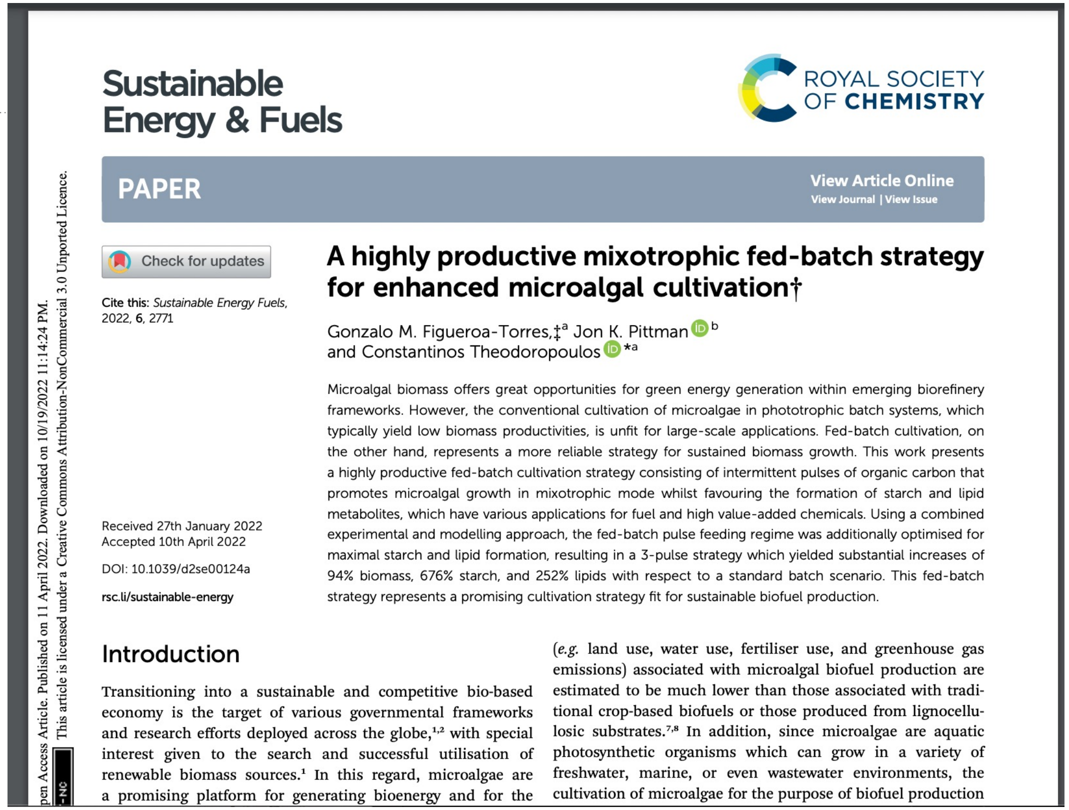


A highly productive mixotrophic fed-batch strategy for enhanced microalgal cultivation

Sustainable Energy Fuels (IF=6.367), 2022, 6, 2771-2782
DOI: 10.1039/D2SE00124A
EnhanceMicroAlgae project is acknowledged.

Summary:

- This work presents a fed-batch cultivation strategy consisting of intermittent acetic acid (carbon substrate) pulses. The fed-batch strategy was evaluated in bench-scale mixotrophic cultures of *Chlamydomonas reinhardtii*, resulting in significantly increased biomass densities, and starch and lipid formation.


Sustainable Energy & Fuels
ROYAL SOCIETY OF CHEMISTRY
PAPER
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Check for updates

Cite this: *Sustainable Energy Fuels*, 2022, **6**, 2771

A highly productive mixotrophic fed-batch strategy for enhanced microalgal cultivation†

Gonzalo M. Figueroa-Torres,‡[a] Jon K. Pittman[b] and Constantinos Theodoropoulos*[a]

Microalgal biomass offers great opportunities for green energy generation within emerging biorefinery frameworks. However, the conventional cultivation of microalgae in phototrophic batch systems, which typically yield low biomass productivities, is unfit for large-scale applications. Fed-batch cultivation, on the other hand, represents a more reliable strategy for sustained biomass growth. This work presents a highly productive fed-batch cultivation strategy consisting of intermittent pulses of organic carbon that promotes microalgal growth in mixotrophic mode whilst favouring the formation of starch and lipid metabolites, which have various applications for fuel and high value-added chemicals. Using a combined experimental and modelling approach, the fed-batch pulse feeding regime was additionally optimised for maximal starch and lipid formation, resulting in a 3-pulse strategy which yielded substantial increases of 94% biomass, 676% starch, and 252% lipids with respect to a standard batch scenario. This fed-batch strategy represents a promising cultivation strategy fit for sustainable biofuel production.

Received 27th January 2022
Accepted 10th April 2022
DOI: 10.1039/d2se00124a
rsc.li/sustainable-energy

Introduction

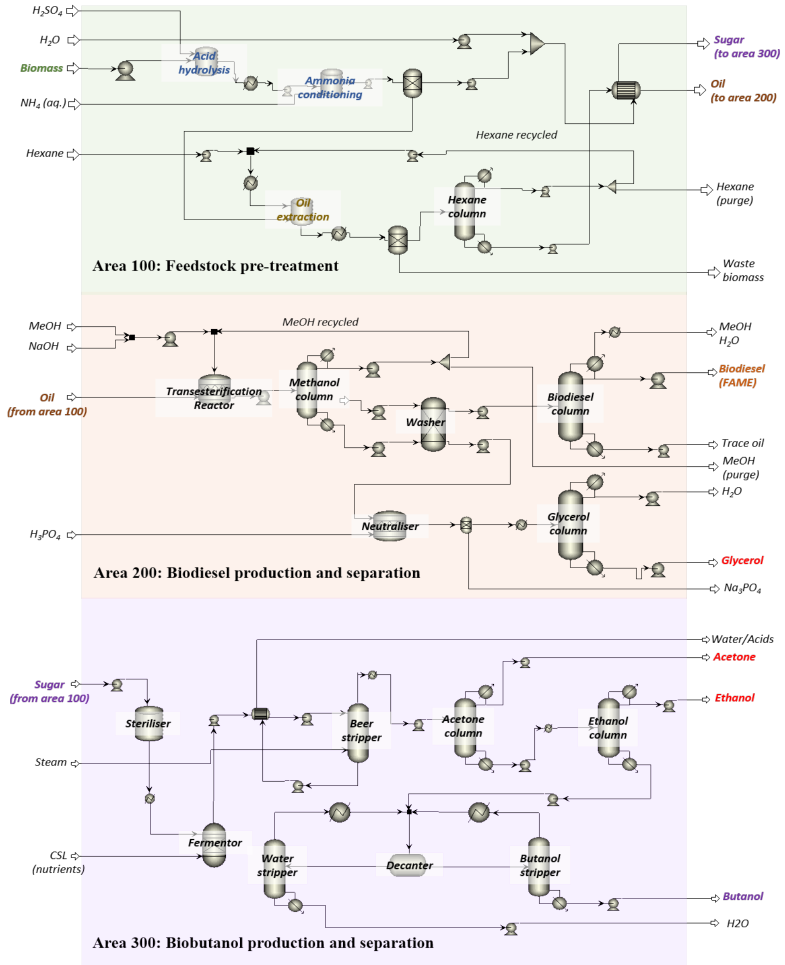
Transitioning into a sustainable and competitive bio-based economy is the target of various governmental frameworks and research efforts deployed across the globe,[1,2] with special interest given to the search and successful utilisation of renewable biomass sources.[1] In this regard, microalgae are a promising platform for generating bioenergy and for the (*e.g.* land use, water use, fertiliser use, and greenhouse gas emissions) associated with microalgal biofuel production are estimated to be much lower than those associated with traditional crop-based biofuels or those produced from lignocellulosic substrates.[7,8] In addition, since microalgae are aquatic photosynthetic organisms which can grow in a variety of freshwater, marine, or even wastewater environments, the cultivation of microalgae for the purpose of biofuel production

Techno-economic analysis of a microalgae-based biorefinery network for biofuels and value-added products

Algal Research (IF= 4.401) (under review)
EnhanceMicroAlgae project is acknowledged.

Summary:

- This work presents a technoeconomic analysis (TEA) of a microalgae-based biorefinery for the production of fuels (biodiesel and biobutanol) and co-products (acetone, ethanol, and glycerol).
- The biorefinery network is comprised of three key areas:
  - *Area 100:* feedstock pre-treatment (acid hydrolysis, AH; solvent extraction, SX).
  - *Area 200:* biodiesel production and separation.
  - *Area 300:* biobutanol production and separation.
- The TEA was conducted to determine the biofuel production capacity and evaluate the investment potential as well as the Minimum Fuel Selling Price (MFSP).



Microalgae Strain Catalogue – A strain selection guide for microalgae users

Microalgae Strain Catalogue were circulated:

- ***1st Edition (September 2019):*** *17 species + 12 medium recipes*
- ***2nd Edition (May 2020):*** *27 species + 14 medium recipes*
- ***3rd Edition (June 2021):*** *37 species + 14 medium recipes + algae-specific stakeholder information*


Thank you!
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