AAR-2023

Advances in Algal Research

International Symposium on

Advances in Algal Research

12-14 June, 2023

Proceedings

Venue: IIT Guwahati

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी · Indian Institute of Technology Guwahati ·

सीएसआईआर - आईआईसीटी
CSIR - IICT

G. B. PANT UNIVERSITY OF AGRICULTURE & TECHNOLOGY, PANTNAGAR 1960

DTU

About The Host Institute

Indian Institute of Technology Guwahati, the sixth member of the IIT fraternity, was established in 1994. The academic programme of IIT Guwahati commenced in 1995. At present the Institute has eleven departments, seven inter-disciplinary academic centres and five schools covering all the major engineering, science, healthcare, management and humanities disciplines, offering B.Tech., B.Des., M.A., M.Des., M.Tech., M.Sc., MBA and Ph.D. programmes. Within a short period of time, IIT Guwahati has been able to build up world class infrastructure for carrying out advanced research and has been equipped with state-of-the-art scientific and engineering instruments. Besides its laurels in teaching and research, IIT Guwahati has been able to fulfil the aspirations of people of the North-East region to a great extent since its inception in 1994.

Indian Institute of Technology Guwahati's campus is on a sprawling 285 hectares plot of land on the north bank of the river Brahmaputra around 20 kms from the heart of the city. With the majestic Brahmaputra on one side, and with hills and vast open spaces on others, the campus provides an ideal setting for learning.

IIT Guwahati is the only academic institution in India that occupied a place among the top 100 world universities – under 50 years of age – ranked by the London-based Times Higher Education (THE) in the year 2014 and continues to maintain its superior position even today in various International Rankings. IIT Guwahati gained rank 41 globally in the 'Research Citations per Faculty' category and overall 395 rank in the QS World University Rankings 2022 released recently. IIT Guwahati has retained the 7th position among the best engineering institutions of the country in the 'India Rankings 2021' declared by the National Institutional Ranking Framework (NIRF) of the Union Ministry of Education. IIT Guwahati has been also ranked 2nd in the 'Swachhata Ranking' conducted by the Govt. of India. Recently, IIT\ Guwahati has been ranked as the top-ranked University in 2019 for IT developers by Hacker Rank in the Asia-Pacific region.

CSIR- Indian Institute of Toxicology Research

Centre for Innovation and Translational Research
Vishvigyan Bhavan, 31 Mahatma Gandhi Marg
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Ashok Pandey
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Distinguished Scientist

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June 11, 2023

Dear Friends, Colleagues & Students,

Greetings from CSIR-IITR Lucknow.

I am happy that IIT Guwahati along with CSIR-IICT, Hyderabad, GBPUAT, Pantnagar and DTU Copenhagen are hosting this prestigious International Symposium on *Advances in Algal Research* from 12th to 14th June 2023. The theme "*Algae* as a tool for wastewater treatment, beyond denitrification, nutrient upcycling and circular bio-economy" of the symposium is very relevant in the present context. Thanks to the scientific committee, I am sure all the participants will have an enriching academic program in the form of invited and contributory talks from leading academic figures as well as budding scientists in the field. The scientific deliberations at the symposium will be highly interesting, informative thought-provoking and will be a memorable event to remember. The event will enhance interactions among the invited delegates and other participating academicians. As of now, I was informed that about 100 speakers and research scholars are taking part. I am sure their abstracts published in the proceedings will inspire and stimulate rich academic discourse and future research ideas. I hope that *International Symposium on Advances in Algal Research* will emerge as a tremendous academic treat for all.

I take this opportunity to thank the Chairs of AAR 2023 Prof. K. Mohanty & Prof. I. Angelidaki for organizing this very important symposium and wish AAR 2023 a great success.

Sincerely,

Ashok Pandey

BRSI Distinguished Fellow
HTBS National Innovation Chair
UPES Distinguished Professor

Formerly- Chief Scientist and Head, Biotechnology Division, CSIR-National Institute for Interdisciplinary Science and Technology, Trivandrum-695 019, India; Eminent Scientist, CIAB, Mohali, Punjab
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International Symposium on
Advances in Algal Research (AAR 2023)

12-14 June 2023, Venue: IIT Guwahati

IIT Guwahati	CSIR-IICT Hyderabad	GPBUAT Pantnagar	DTU Copenhagen
Prof. K. Mohanty	Prof. S. Venkata Mohan	Prof. A. K. Sharma	Prof. I. Angelidaki
Chair	*Co-Chair*	*Co-Chair*	*Chair*

Message from the Chairs, AAR 2023

On behalf of the organising committee, it is our pleasure to extend a warm welcome to all the delegates of the *International Symposium on Advances in Algal Research 2023 (AAR 2023)* taking place during 12-14 June, 2023 at Indian Institute of Technology Guwahati. AAR 2023 is being jointly hosted by DTU, Copenhagen; CSIR-IICT, Hyderabad; GBPUAT, Pantnagar and IIT Guwahati.

AAR 2023 offers researchers from all over the world the opportunity to meet with colleagues, exchange research ideas and share new knowledge related to algal research. This symposium features a strong technical program that includes 10 technical sessions covering various aspects of algal research such as algal cultivation and harvesting techniques, omics/modelling & bioinformatics, advanced algal biorefinery, carbon dioxide sequestration, wastewater/heterotrophic cultivation, wastewater/heterotrophic cultivation and high value products from algal biorefinery.

We have around close to 100 presentations from invited and contributary speakers. We are convinced that this unique gathering of experts will guarantee rich, useful, and effective deliberations. This first edition of AAR Symposium is held at IIT Guwahati, Assam. Guwahati is also known as the City of Temples and the Gateway to North-East India. Pragjyotishpura, which means “east light,” was the city’s previous name. Guwahati, which became one of India’s most developing cities after independence, is also regarded one of the country’s smart cities. We wish that this symposium be held annually at various places under the banner of Algal Research Society of India.

Finally, we would like to take this opportunity to thank all members of the organising committee, the technical program committee, invited speakers, contributary speakers, reviewers and the volunteers for their dedication and contribution to the symposium; without their tireless work, the symposium would not be a success.

(Kaustubha Mohanty) **(Irini Angelidaki)**

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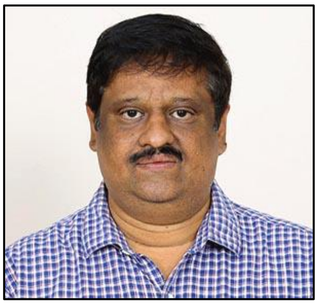
DTU Copenhagen

SYMPOSIUM CHAIR



PROF. S. VENKATA MOHAN
CSIR-IICT, Hyderabad

SYMPOSIUM CO-CHAIR

PROF. ANIL K. SHARMA
GBPUAT, Pantnagar

SYMPOSIUM CO-CHAIR

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Prof. Debasish Das

Dept. of
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AAR-2023 Advances in Algal Research

International Symposium on Advances in Algal Research (AAR-2023)

Indian Institute of Technology Guwahati, Guwahati 781039, India

June 12-14, 2023

PROGRAMME SCHEDULE

12th June 2023			
08:30-10:00	**Registration and Breakfast**		
10:00-10:15	**Opening Session**		
10:15-11:25	**Technical Session I: Algal Cultivation and Harvesting Techniques** **Chairs: Archana Tiwari & Sabeela Beevi**		
10:15-10:30	IL001	Nitin Trivedi, Gujarat Biotechnology University	Marine Macroalgae: A Treasure House of Natural Products
10:30-10:45	IL002	Vandana Vinayak, Dr. Harisingh Gour Vishwavidyalaya, Sagar	Techniques to harvest value-added products from thick-walled microalgae
10:45-11:00	IL003	Vaibhav V. Goud, School of Energy Science and Engineering, IIT Guwahati	*Scenedesmus* sp. and *Limnothrix* sp. consortium as a novel strategy for efficient biomass harvesting with concurrent bioremediation of wastewater and biodiesel production
11:00-11:15	IL004	Ravindra Pal Singh, Gujarat Biotechnology University	Human gut commensal bacterial produce macroalgal glycan digesting enzyme and their industrial exploitation
11:15-11:25	PP001	Ankit Agarwalla, IIT Guwahati	Fabrication and characterization of low-cost kaolin based tubular ceramic membrane for microalgal harvesting
11:25-11:45	**Tea Break**		
11:45- 12:50	**Technical Session II: Omics/modelling & bioinformatics** **Chairs: Pavan Jutur & K Dheeban Chakravarthi**		
11:45-12:00	IL005	Krishna Mohan Poluri, Indian Institute of Technology Roorkee	Molecular Insights into Microalgae based Environment-Energy Paradigm using Integrated Omics Approaches
12:00-12:10	PP002	Riju De, BITS Pilani Goa Campus	Dynamic Optimization Strategies of Batch Hydrothermal Liquefaction of Microalgae for Optimal Biocrude Production
12:10-12:20	PP003	Pravin Ravichandran, St. Joseph's College of Engineering, Chennai	Blending of Algal and Non-edible oil for sustainable production of biodiesel using biochar catalyst – Optimization and Technoeconomic analysis
12:20-12:30	PP004	Chandrani Debnath, NIT Agartala	Evaluation and characterization of indigenous fungal strains from Ethnic drinks for bioethanol production
12:30-12:40	PP005	Daljit Borah, Tezpur University	Optoelectronic sensitivity based investigation on LED inspired microalgae cultivation
12:40-12:50	PP006	Vivek Dalvi, IIT Delhi	Strategies, Innovations and Uncharted Routes for Robust Algal Systems for Energy & Environmental Applications
13:00-14:00	**Lunch**		
14:00-16:15	**Technical Session III: Advanced Algal Biorefinery I** **Chairs: S. Venkata Mohan & Sivasubramanian Velmurugan**		
14:00-14:15	IL06	Sunita Varjani, City University of Hong Kong, Hong Kong (ONLINE mode)	Exploring the Untapped Potential of Photosynthetic Microorganisms: Recent Advances and Future Directions
14:15-14:30	IL007	Yen Wah Tong, National University of Singapore, Singapore (ONLINE mode)	Biorefinery Approach for Integrated Production of Protein and Biomethane from Chlorella vulgaris and Scenedesmus obliquus
14:30-14:45	IL008	Shashi Kant Bhatia, Konkuk University, Seoul (ONLINE mode)	Upcycling of Algal Biomass by Microbial Cell Factories
14:45-15:00	IL009	Sourish Bhattacharya, CSIR-CSMCRI, Bhavnagar, Gujarat	Sustainable process for microalgal based nutraceuticals through biorefinery model

15:00-15:15	IL010	Monika Prakash Rai, Amity University	Photocatalytic nanomaterial GO@g-C_3N_4 stimulated biomass and lipid production in *Chlorosarcinopsis* sp. MAS0_4: A nano-bio hybrid approach
15:15-15:30	IL011	K Dheeban Chakravarthi, TERI-Deakin Nano Biotechnology Centre, TERI	Integrated Production of Algal Biofuels and Biocommodities
15:30-15:45	IL012	Baskar Gurunathan, St. Joseph's College of Engineering	Biofuels Production from Marine Macroalgae – A Biorefinery Approach
15:45-16:00	IL013	Karthik Rajendran, SRM University-AP	Microalgae based nutrient recovery for a sustainable circular economy: A perspective from Energy, Economy, and Environment
16:00-16:15	IL014	Sanjeev Mishra, SSS National Institute of Bio-Energy, Kapurthala	Microalgal biorefinery model for simultaneous wastewater treatment and production of biodiesel, bioethanol, and hydrochar
16:15-16:30	**Tea Break**		
16:30-17:40	**Technical Session IV: Advanced Algal Biorefinery II** **Chairs: Borja Valverde Pérez & Debraj Bhattacharyya**		
16:30-16:40	PP007	J. Santhosh, CSIR-IICT Hyderabad	Acidogenesis of food waste for biohydrogen production integrated with algal biorefinery
16:40-16:50	PP008	Nikhil Kadalag, Institute of Chemical Technology Mumbai	Integrated One-Pot Process for Simultaneous Biomass and High-Value Biochemical Production in *Phaeodactylum tricornutum*
16:50-17:00	PP009	Amit Singh, IIT Roorkee	Waste algae to biomethane for reducing greenhouse emissions from eutrophic lake
17:00-17:10	PP010	Boda Ravi Kiran, CSIR-IICT Hyderabad	Modulating nutrient regimes to augment photosystems and metabolite synthesis in microalgae
17:10-17:20	PP011	Khushal Mehta, SRM University-AP	Exogenous supply of growth modulator to uncouple growth with energy reserve compound accumulation in *Scenedesmus* spp. under various long-term stress conditions and to acquire an integrated biorefinery approach
17:20-17:30	PP012	Priya Bisht, IIT Roorkee	Valorization of aqueous phase derived from hydrothermal liquefaction of algal biomass
17:30-17:40	PP013	Rahul Kumar, IIT Delhi	Indoor air purification using non-activated microalgal biochar with diatom embedment for removal of particulate matter, formaldehydes, and total volatile organic compounds
17:40-18:20	**Technical Session V: Carbon Dioxide Sequestration** **Chairs: Mohan Raj Subramanian & Garlapati Vijay Kumar**		
17:40-17:50	PP014	Satyanarayana Reddy Battula, IIT Kharagpur	Design and operation of a pilot-scale integrated system sparged with flue-gas CO_2 generated in situ for microalgal cultivation in an algal-biorefinery
17:50-18:00	PP015	Maya S Nair, NIT Calicut	Algal Sheets: A Sustainable - Green Technology for Carbon Capture
18:00-18:10	PP016	Gourav Kumar, International Centre for Genetic Engineering and Biotechnology, New Delhi	Enrichment of Tocopherol Yields Employing CO_2 Supplementation and Nitrate Limitation in Microalgae *Monoraphidium* sp.
18:10-18:20	PP017	Deepesh Singh Chauhan, IIT Guwahati	Nutrient and light availability syncretic effects on microalgal CO_2 biomitigation and bioenergy production
19:30-Onwards	**Dinner**		

13th June 2023			
08:00-09:00	**Breakfast**		
	Technical Session VI: Wastewater/Heterotrophic cultivation **Chairs: Baskar Gurunathan & Temjensangba Imchen**		
09:00-09:15	IL015	Irini Angelidaki, Denmark Technical University, Copenhagen	Microalgae as tool for wastewater treatment with simultaneous high value production
09:15-09:30	IL016	Nilotpala Pradhan, CSIR-IMMT, Bhubaneswar	Microalgal CO_2 Sequestration and biomass generation using 30,000 L Raceway pond
09:30-09:45	IL017	Pavan Jutur, International Centre for Genetic Engineering and Biotechnology, New Delhi	Valorization of Carbon Dioxide (CO_2) for Producing Biomass, Biofuels, and Biorenewables (B3) in Microalgae: A Circular Bioeconomy Perspective
09:45-10:00	IL018	Gunjan Prakash, Institute of Chemical Technology Mumbai	Genetic and molecular biology interventions as a promising strategy for the production of high-value chemical production from microalgae
10:00-11:00	**Technical Session VII: Wastewater/Heterotrophic cultivation I** **Chairs: Nilotpala Pradhan & Ashokkumar Veeramuthu**		
10:00-10:15	IL019	Debraj Bhattacharyya, IIT Hyderabad	Wastewater Treatment Using Algal-bacterial Hybrid Systems
10:15-10:30	IL020	S Venkata Mohan, CSIR-IICT	Microalgal Biorefinery – Closed Loop Approach for Fuels and Chemicals
10:30-10:40	PP018	Pooja Singh, IIT Guwahati	Hydrothermal liquefaction of *Monoraphidium* sp. KMC4 grown on dairy wastewater for bio-oil production
10:40-10:50	PP019	Raj Kumar Oruganti, IIT Hyderabad	Algal-bacterial trickling photobioreactor for domestic wastewater treatment: organic matter and nutrient removal
10:50-11:00	PP020	Subhasmita Panigrahi, CSIR-IMMT, Bhubaneswar	Application of extracellular polymeric substances in metal extraction produced by cyanobacteria grown in wastewater
11:00-11:20	**Tea Break**		
	Technical Session VIII: Wastewater/Heterotrophic cultivation II **Chairs: Gunjan Prakash & Krishna Mohan Poluri**		
11:20-11:35	IL021	Xuan-Thanh Bui, Ho Chi Minh City University of Technology, Vietnam (ONLINE mode)	Algal biomass production and pollutants removal by a moving bed membrane photobioreactor
11:35-11:50	IL022	Garlapati Vijay Kumar, Jaypee University of Information Technology	Phycoremediation of X-ray developer solution towards silver removal using waste as a nutrient media of *Desmodesmus armatus*
11:50-12:05	IL023	Mona Sharma, Central University of Haryana	Photobiological hydrogen production and bioremediation of contaminants using cyanobacteria: an integrated approach
12:05-12:20	PP021	Satya Sundar Mohanty, IIT Guwahati	Microalgae mediated biodegradation of pharmaceuticals: An insight into removal kinetics, co-metabolism, and transformation products
12:20-12:30	PP022	Lakhan Kumar, Delhi University	Synthesizing biogenic silver nanoparticles from *Graesiella emersonii* and assessing their antibacterial and decolorization of dye-contaminated water efficiency

13:00-14:00	**Lunch**		
14:00-15:30	**Technical Session IX: High Value Products from Algal Biorefinery I** **Chairs: Irini Angelidaki & Vaibhav V Goud**		
14:00-14:15	IL025	Kit Wayne Chew, Nanyang Technological University (ONLINE mode)	Microalgae with artificial intelligence: A perspective on biotechnology for bioproducts
14:15-14:30	IL026	Archana Tiwari, Amity Institute of Biotechnology, Noida	Valorization of agricultural wastewater for generation of high value products from freshwater diatom *Nitzschia* sp.
14:30-14:45	IL027	Ashokkumar Veeramuthu, Saveetha Institute of Medical and Technical Sciences, TN	Astaxanthin from microalgae and residues for solid biofuel production
14:45-15:00	IL028	Borja Valverde Pérez, Technical University of Denmark, Copenhagen	Valorization of industrial wastewater into microalgal biomass – focusing on microbial contamination control and biomass harvesting
15:00-15:15	IL029	Debashish Das, IIT Guwahati	Microalgae, a potential platform for biofuels and value-added products: Process engineering perspective
15:15-15:30	IL030	Sabeela Beevi, Institute of Bioresources and Sustainable Development (IBSD), Imphal	Sustainable microalgal biomass production in biorefinery wastewater for high value bioproducts and circular bioeconomy
15:30-15:45	IL031	Sivasubramanian Velmurugan, NIT Calicut	Algal pigments: A promising alternative in nutraceutical studies and food industry
15:45-16:00	IL032	Temjensangba Imchen, CSIR-National Institute of Oceanography, Goa	Efficiency of nitrate uptake and its impact on microalgae biomass
16:00-16:15	IL033	Pau Loke Show, University of Nottingham, Malaysia (ONLINE mode)	Innovation and Research Trend in Algal Technology
16:15-16:30	IL034	Mohit Singh Rana, E3BIOCLEANTECH PVT. LTD.	Algae-based circular bioeconomy for wastewater treatment and resource recovery
16:30-16:50	**Tea Break**		
	Technical Session IX: High Value Products from Algal Biorefinery II **Chairs: Ravindra Pal Singh & Nitin Trivedi**		
16:50-17:00	PP023	Poonam Kumari, CSIR-IICT Hyderabad	Critical Factors Influence on Photosynthetic Catalysed Polyhydroxyalkanoate Production
17:00-17:10	PP024	Jayshri Khadilkar, Institute of Chemical Technology Mumbai	Towards the sustainable production of vegan Eicosapentaenoic Acid (EPA): year around cultivation of *Nannochloropsis oculata* and scale up under tropical environment.
17:10-17:20	PP025	Abdalah Makaranga, International Centre for Genetic Engineering and Biotechnology	Dynamic metabolic crosstalk between microalgae *Chlorella saccharophila* and its new symbiotic bacteria improves lutein production without compromising growth
17:20-17:30	PP026	Debidatta Barik, CSIR-IMMT, Bhubaneswar	Screening of microalgal strain for enhanced biomass production with simultaneous carbon dioxide sequestration
17:30-17:40	PP027	John Kiran Katari, IIT Guwahati	Extraction, purification, characterization and bioactivity evaluation of high purity C-phycocyanin from *Spirulina* sp. NCIM 5143
17:45-18:15	**Closing Session**		
19:30 Onwards	**Dinner**		

Abstracts of Invited Speakers

IL001
Marine Macroalgae: a Treasure House of Natural Products

Nitin Trivedi

Department of Marine Biotechnology, Gujarat Biotechnology University, Gandhinagar- 382355, Gujarat, India.
(E-mail: nitin.trivedi@gbu.edu.in)

	Dr. Nitin Trivedi is working as an Assistant Professor in the Department of Marine Biotechnology at Gujarat Biotechnology University, Gandhinagar, Gujarat. He obtained his Ph.D. in Biological Science from CSIR-CSMCRI, Bhavnagar, Gujarat, India in 2015. Since 2009, Dr. Trivedi has been working in the area of Marine Biotechnology with a special emphasis on seaweed biotechnology and marine microbial biotechnology. So far, he has published 32 publications in SCI journals and two patents. Dr. Trivedi has received several fellowships/awards like DST INSPIRE Faculty, DSKPDF, CSIR-SRF, ARO PDF in Israel, PDF at Dalhousie University, Canada, Visiting Scientist at the University of Algarve, Portugal, guest researcher at the University of Messina, Italy, etc.

ABSTRACT

Marine macroalgae or seaweeds are emerging as a potential candidate to fulfill the future needs of food, feed, bioenergy, and biomolecules due to their diverse structural and biochemical composition. Seaweeds have a global distribution with high biomass productivity and CO_2 sequestration potential, with no arable land, fertilizer, and freshwater requirements. These properties provide a suitable platform to make them as an attractive source for future seaweed-based industries. Seaweeds contain several bioactive components like soluble fibers, vitamins, minerals antioxidants, proteins, fatty acids, and hydrocolloids like agar, carrageenan, and alginates which have proven food applications. Researchers across the globe have now focused on seaweed growth engineering and cultivation in both sea and land-based systems followed by value addition in a bio-refinery model to achieve increased sustainability and return on investment (ROI). The talk will cover the introduction of seaweeds, their different applications with a major emphasis on food and value-added products, market status, and major challenges associated with seaweed research.

Keywords: Blue Biotechnology; Circular bioeconomy; Phyconomy; Seaweed biorefinery

IL002
Techniques to harvest value-added products from thick-walled microalgae

Vandana Vinayak[1*]

Diatom Nanoengineering and Metabolism Laboratory, School of Applied Sciences, Dr Hari Singh Gour Central University, Sagar. Madhya Pradesh 470003.
(E-mail[1*]: kapilvinayak@gmail.com)

Dr Vandana Vinayak is working as Assistant Professor at Dr Harisingh Gour Central University Sagar, M.P. She has published more than 60 Scopus indexed research papers, about 15 chapters and has about 25 awards in her CV. She has been awarded notable awards like Young Scientist Award, Noel Deer Gold medal award from Ex-President of India Dr A.P.J Abdul Kalam and various other awards. Her research focusses on diatoms and other thick-walled microalgae rich in value added products like lipids and pigments sanctioned from various funding agencies like DST, DBT, UGC, CEFIPRA Indo French Government, INUP and NCPRE, IIT Bombay, DST Nanomission etc. More details about her research work can be found on her website: www.vandanavinayak.com

ABSTRACT

Microalgae like diatoms and *Haematococcus pluvialis* are potential microalgae of interest in the commercial market, since they are rich in lipids and pigments. On the offset, one of the common problems of both these microalgae is their thick cell wall. In order to use these value-added products, the microalgae are generally killed or lysed which involve techniques which are expensive and thus overall increases the cost of the value-added products like biofuel and pigments to the exorbitant end. Thus, in order to make the overall procedure cheap and economical various factors from growing microalgae to harvesting value added products from them need to be analyzed. To start with the growth of microalgae in bubble wraps, using wastewater and employing techniques which would not only be economical but will not lyse the cell would be employed. The earlier reports have shown that plastic bubble wraps not only reduce the plastic waste but lower the cost of cultivating microalgae in wastewater. In return the wastewater gets remediated as it provides essential nitrates and phosphates and other trace metal ions required for the growth of microalgae. The thick cell wall of microalgae often requires expensive techniques like homogenizer which indirectly raises the cost of the high and low value-added products. However, a resonating field or high-pressure microfluidics have some options of fracturing the thick cell wall of microalgae allowing the value-added products to come out and the cells healing on being provided fresh nutrient media.

Keywords: Algae; Biofuel; Pigments; Techniques; Wastewater

IL003

Scenedesmus sp. and *Limnothrix* sp. consortium as a novel strategy for efficient biomass harvesting with concurrent bioremediation of wastewater and biodiesel production

Vaibhav V. Goud[1,2]

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[2] Department of Chemical Engineering, Indian Institute of Technology Guwahati, Guwahati, Assam, India, Pin: 781039
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Dr Goud is currently working as Head, School of Energy Science and Engineering & Professor of Chemical Engineering at IIT Guwahati. He completed his Ph.D from IIT Kharagpur in 2006. His research area includes biomass for production of bio-fuels, bio-lubricants and oleo-chemicals, extraction of natural plant products by using subcritical and supercritical fluids as well as processing of non-edible oil seeds. He has been awarded/filed 3 Indian Patents. He has also been awarded with RGYI, Scheme from Department of Biotechnology with major funding. He has also awarded with Visiting Scientist to visit Federal University of Rio De Janeiro (UFRJ), Brazil during June 6 to July 3, 2018 under DBT sponsored Indo-Brazil project. He is a life member of Indian Institute of Chemical Engineers, Sea buckthorn Association of India, and International Society of Food Engineering.

ABSTRACT

Microalgae is well known as potential feedstock for biodiesel production. However, large-scale cultivation is hindered by requirement of massive amount of expensive nutrients and harvesting techniques. Recently, wastewater has been utilized as an alternative nutrient source. But low strength wastewater could not provide microalgae with enough nitrogen (N) and phosphorus (P). In this study, we developed a unique co-culture cultivation of novel strains, *Scenedesmus* sp. DDVG I and *Limnothrix* sp. DDVG II in low strength domestic wastewater (DWW). The N/P in DWW was balanced by adding external urea resulting in high removal efficiencies of COD (89.5 %), TN (99.9%), and TP (99.1 %). The biomass harvesting efficiency resulted in 99.5 % with biomass productivity of 70.8±1.1 mg/L.d and lipid yield of 46.2 %. The biodiesel produced by the co-culture system met all of the requirements outlined by EN and ASTM. Moreover, we demonstrated the viability of those isolates in feed supplement for monogastric animals using amino acid profile, an in-vitro digestibility and MTT assay assessment. Overall study suggested the prospect for cleaner environment and greener energy production.

Keywords: Biodiesel; Biomass; Cyanobacterium; Easy harvesting; Microalgae

IL004
Human gut commensal bacterial produce macroalgal glycan digesting enzyme and their industrial exploitation

Ravindra Pal Singh

Department of Marine Biotechnology, Gujarat Biotechnology University, Gujarat International Finance Tec- city, Gandhinagar, India
E-mail: ravindra.singh@gbu.edu.in

Current position: Associate Professor at GBU, Gandhinagar, Gujarat.
Area of research: I have been working at the interface between biology and chemistry since several years. I am currently working on characterizing complicated macroalgal glycans and understanding the molecular mechanism of human gut bacteria in digesting that glycan. We also use discovered enzymes from human gut bacteria to create value-added products such as prebiotics and bioethanol.
Post position:

- Ramanujan and Ramalingaswami Re-entry Fellow at NABI, Mohali
- Post Doctoral Research Associate, John Innes Centre, UK
- JSPS Postdoctoral Fellow, Kyushu University, Japan
- Outstanding Postdoctoral Fellow, Tel Aviv University, Israel.

ABSTRACT

Macroalgae are profoundly present in the intertidal regions of oceans and have been consumed as human diet for several decades. Dietary glycans derived from macroalgae have incredible powers to maintain gut microbiome. The human gut bacteria harbor a unique cluster of genes that are dedicated for utilizing a specific type of glycan. Some genes of those clusters consist of endo-acting enzymes that produce a variety of oligosaccharides *in vivo*. Those produced oligosaccharides are often reckoned by immune cell receptors and play outstanding roles in gut homeostasis. Some molecular mechanisms by which human gut bacteria utilize macroalgal glycan have been discovered in the last decade. Several enzymes associated with such locus have tremendous potential for exploitation for food industries and biorefinery. For example, we used glycoside hydrolases, belonging to families 16 and 158 for generation of β– 1,3 linked ologisacchrides from laminarin and curdlan respectively. Furthermore, our recombinant enzymes are being explored for production of bioethanol using macroalgal biomass.

Keywords: Macroalgae; Agarose; *Bacteroides uniformis*, Gut microbiome,

IL005
Molecular Insights into Microalgae based Environment-Energy Paradigm using Integrated Omics Approaches

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Dr. Krishna Mohan Poluri is currently working as an Associate Professor at Department of Biosciences and Bioengineering IIT-Roorkee. He completed his PhD from TIFR-Mumbai, and Post-doc from Rutgers University & University of Texas Medical Branch (UTMB-Texas). His areas of expertise are NMR Spectroscopy, Structure based design of Therapeutics and Scaffolds, Bio-nanotechnology and Algal Biotechnology etc. He has published ~ 160 publications in various reputed SCI Journals. He won several awards and fellowships for his research work. Most prominent are: Young scientist awards from Indian Science Congress association (ISCA) -2009, National Academy of Sciences India (NASI)-2014, Innovative Young Biotechnologist Award (IYBA)-2013 by DBT and SERB-STAR (2022) Award by SERB

ABSTRACT

Microalgae are diverse group of microorganisms portraying a promising solution to mediate a paradigm shift to green energy, while conserving the carbon footprint. Accounting to the environmental benefits from green energy, direct implication of these green cells for remediation of wastewater with hazardous pollutants cannot be omitted. Thus, establishing a firm chain linking the benefits of environment and economy, our research group is working on the aspect of harnessing the potential of green microalgal cells for heavy metal remediation, desalination to regenerate clean water, and to produce bioenergy, precisely biodiesel under the biorefinery approach. The work conducted in the lab is focused to dissect the intrinsic nexus of molecular pathways in microalgal cells by linking the high throughput information across different platforms such as transcriptomics, proteomics, NMR based metabolomics, and biochemical characterizations. While acquiring the in-depth knowledge of algal stress physiology, the vision of the group is to optimize the downstream processing of the renewable energy compounds /value-added products to establish a cost-effective, green, and sustainable environment/economy.

Keywords: Biofuels; Biorefinery; Bioremediation; Environment-energy paradigm; Heavy metals; Microalgae

IL006
Exploring the Untapped Potential of Photosynthetic Microorganisms: Recent Advances and Future Directions

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ABSTRACT

Photosynthetic microorganisms have emerged as a promising source of biomass, a renewable and sustainable alternative to fossil fuels. Recent advances in the field of biomass research have revealed the untapped potential of these microorganisms, which can be used to produce a range of valuable products, including biofuels, food supplements, and bioplastics etc. Microalgae have been employed globally for these areas of research. In recent years, there have been significant advancements in the technologies for microalgae research, including improvements in cultivation, harvesting, and extraction methods. These advancements have enabled the development of integrated systems that can maximize biomass production while minimizing environmental impact. This talk will provide an overview of the latest technologies for microalgae research and their potential for sustainable biomass production. The importance of life cycle assessment (LCA) in evaluating the environmental impact of microalgae-based biomass production and the need for continued research to optimize the sustainability of these technologies will be covered. Overall, the talk will provide a comprehensive overview of the advances and future directions in biomass research using photosynthetic microorganisms, highlighting the potential of these microorganisms for sustainable development.

Keywords: Biochemicals; Biofuel; Biomass; Life cycle assessment; Microalgae

IL007
Biorefinery Approach for Integrated Production of Protein and Biomethane from *Chlorella vulgaris* and *Scenedesmus obliquus*

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Prof. Yen Wah Tong is an Associate Professor in the Department of Chemical and Biomolecular Engineering at the National University of Singapore, where he leads the Biomimetic Materials and Systems Lab. His research focuses on applying biomimetic principles to various fields, such as tissue engineering, drug delivery, waste valorization, microalgae cultivation, and bioenergy production. Currently, Prof. Tong is serving as the Co-Director for the National Research Foundation, Campus for Research Excellence and Technological Enterprise (NRF CREATE) program in collaboration with Shanghai Jiao Tong University, overseeing the E2S2 (Energy and Environment Sustainability Solutions for Megacities) initiative.

ABSTRACT

Microalgae biomass has gained significant attention as a bioenergy source due to its faster growth rates and the ability to grow on non-arable land using waste resources. However, its high production cost has hindered its widespread application as a bioenergy feedstock. To overcome this challenge, the biorefinery concept can be adopted, involving microalgae biomass conversion into a range of marketable products. This study aimed to integrate protein and biomethane production from two freshwater microalgae species, *Chlorella vulgaris*, and *Scenedesmus obliquus*. Both species were cultivated under mixotrophic conditions (2 g/L glucose and 1 g/L sodium nitrate) to achieve high biomass and protein production of 2.4 g/L and 0.9 g/L, respectively. The harvested biomass was mechanically homogenized and subjected to a pH adjustment to extract and precipitate crude protein. The residual biomass was then subjected to anaerobic digestion for biomethane production. Optimized conditions resulted in 70% protein extraction from microalgae biomass, with an overall protein content of 70-80% in the crude protein extract. The amino acid analysis confirmed the presence of all essential amino acids in the microalgal protein, making it suitable for food and feed applications. Residual microalgae biomass produced 1.4-2.1 times more biomethane than raw biomass. These findings offer an alternative approach to fully exploit microalgae biomass and pave the way for future biorefinery research.

Keywords: Alternative protein; Anaerobic digestion; Bioenergy; Downstream processing; Microalgae

IL008
Upcycling of Algal Biomass by Microbial Cell Factories

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Dr. Shashi Kant Bhatia is working as an Associate Professor in the Department of Biological Engineering, Konkuk University, Seoul, South Korea. His major research areas include environmental biotechnology, resource recovery from waste, valorizations of biowaste into biomaterials, bioenergy, and biochemicals. He has published more than 200 research and review articles, edited 4 books, and holds 12 international patents. His current H-index is 47 with i10- index 146, and citations over 7000. He is serving as associate editor in Microbial Cell Factories, Frontiers in Microbiology, 3 Biotech, PLOS One, Biomass Conversion and Biorefineries, Sustainability, Bioprocess and Biosystems Engineering, and Energies journals.

ABSTRACT

Macroalgal biomass is rich in carbohydrates and low in lignin content and can act as a promising carbon source for microbial fermentation. Algal biomass is renewable, abundant in coastal areas, and requires minimum efforts in cultivation and harvesting with the least environmental impact. Red macroalgae Eucheuma spinosum is a seaweed cultivated commercially in Philippines, China, Indonesia, and Malaysia for carrageenan production used in cosmetics and food processing. Microorganisms are not able to utilize biomass directly due to its complex and recalcitrant nature and therefore, an effective pretreatment is mandatorily required for maximized release of the free sugars. The dilute acid pretreatment also leads to the production of biosugars and various side products i.e., acetic acids furfural, and hydroxymethylfurfural (HMF) which further inhibit microbial growth. Various biomass-derived biochar i.e., cork, soybean, algal, pine, rice husk, lignin, etc. were explored for the detoxification and removal of these inhibitors. Algal biomass-derived biochar showed maximum removal of furfural and HMF without affecting sugar concentration. The isotherm and kinetic models for furfural and HMF were the Langmuir model and pseudo-first-order. The detoxified algal hydrolysate was further explored as a feedstock for polyhydroxyalkanoate and biohydrogen production. The study shows the potential of algal biomass as an economic feedstock for microbial fermentation to produce valuable products.

Keywords: Biochar; biohydrogen; detoxification; macroalgae; polyhydroxyalkanoates

IL009
Sustainable process for microalgal based nutraceuticals through biorefinery model

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ABSTRACT

Microalgal biomass is extensively being produced all over the world for its potential application in the renewable energy, nutraceutical and biopharmaceutical sector. However, the future of the microalgal industry is reliant on expertise that would increase the biomass yield for commercial level at a lower cost. CSIR-CSMCRI has developed sustainable process for microalgal based gamma linolenic acid through biorefinery model.
A sustainable process was developed for production of γ-linolenic acid through biorefinery model wherein ε-polylysine and protein rich powder was produced as by-product using CSIR-CSMCRI's strain CSMCRI's *Coelastrella thermophila*. Microalgal mass cultivation was done in 10 open ponds each having 15m x 5m x 0.5m dimension. The total capacity of each pond will be 37 m^3 wherein two ponds was kept for generating the inoculum and 8 ponds utilized for mass cultivation for generating the biomass with assumed average productivity of 30±5 $g/m^2/d$. Further, in order to reduce the cost of the product, a viable and scalable circular economy model was designed that utilized fishery wastewater for generation of microalgal biomass through biorefinery model wherein astaxanthin along with other co-products such as ε-polylysine and polyhydroxyalkanoates as co-products were produced apart from γ-linolenic acid.

Keywords: Biofuel; Biorefinery; γ-linolenic acid; Biopolymers; Microalgae.

IL010
Photocatalytic nanomaterial GO@g-C_3N_4 stimulated biomass and lipid production in *Chlorosarcinopsis* sp. MAS04: A nano-bio hybrid approach

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ABSTRACT

The accelerated depletion of non-renewable sources of energy, combined with rising population, has resulted in a pressing need for sustainable fuel. One of the most promising candidates is microalgae-based biodiesel, which has the potential to ameliorate the bulk of the associated environmental difficulties. While low biomass yield and lipid production impede the widespread development of microalgae-derived biodiesel feedstock. Recent research suggests that nanoparticles could be utilised to remove the associated barriers. Thus, in the current study, GO@g-C_3N_4 nanocomposite was synthesised and characterised using techniques such as scanning electron microscopy (SEM), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and zeta potential. Further, a 96-h cytotoxicity assay of the microalgae viability against the as-synthesized nanocomposite was performed. Subsequently, the microalgae cultures in this experiment were supplemented with 0-200 mg/L of the nanocomposite for 30 days. The obtained findings suggested that the 50 mg/L of optimal supplement of GO@g-C_3N_4 nanomaterial for microalgae culture results into the highest biomass and lipid production of 3.825 g/L and 38.5 % respectively. The study determined that the addition of GO@g-C_3N_4 nanocomposite might boost the efficiency of photosynthetic activities, hence improving biomass and lipid production. Further, mechanism was discussed with the help of Reactive oxygen species (ROS) estimation for the improvement of lipid content. Furthermore, these findings support the idea that the nano-algal interface for biodiesel synthesis could be a potential method for sustainable development.

Keywords: Biomass; Microalgae; Nanocomposite; Photocatalyst; Reactive oxygen species

IL011
Integrated Production of Algal Biofuels and Biocommodities

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Dr. Dheeban Chakravarthi Kannan is engaged in algal biofuel research. His focus areas are outdoor algal production, growth system design, algal harvest, lipid extraction and techno-economic analysis. He studied B Tech Chemical Engineering in Anna University, Chennai and obtained his PhD from The Pennsylvania State University. He is presently engaged in demonstration of marine algal production from a 100,000 L algal growth system and related downstream processing for development of transport fuels and value addition co-products. He has publications on algal growth system, lipid extraction, algal nutrient uptake, engineering aspects of algal biofuels, biodiesel production and phase equilibrium thermodynamics.

ABSTRACT

Microalgae are a promising feedstock for the production of biofuels and biocommodities. An integrated project of biofuel production from algae along with development of a variety of co-products for value-addition has been initiated to evaluate the economic viability of the overall process. A 100,000 L/220 sq. m marine algal growth system with related downstream process units for harvest and lipid extraction has been set up in Navi Mumbai as part of the DBT-TERI Center of Excellence on Integrated Production of Advanced Biofuels and Biocommodities. The algal growth system is based on a sunlight distribution design that has been found to give improved productivity over raceway pond standard. Algae are harvested by naturally aggregating feature of select algae without the addition of any chemicals. The harvested wet algal biomass is processed for lipid extraction at normal temperature and pressure, without the need for the resource (land/energy)-intensive drying step. The extracted lipids are converted to biodiesel. The deoiled algae are then processed for evaluation of a variety of value-addition biocommodity development streams – aquafeed, cattle feed, biodegradable food packaging plastics, platform chemicals, pyrolytic products. Technoeconomic analysis has been carried out for the various integrated production streams of biofuels and the aforementioned value-addition co-products. Aquafeed, in particular, shows promise for commercially viable co-production with biofuels in near/medium term. Challenges remain in terms of sustained long-term productivity of algae in the form of annual yields, algal harvest and development of more streams of value-addition biocommodities to an advanced stage.

Keywords: Algae; Aquafeed; Biofuel; Extraction; Value-addition

IL012
Biofuels Production from Marine Macroalgae – A Biorefinery Approach

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Dr. Baskar Gurunathan have 21 years of teaching and research experience, published more than 180 research and review articles in reputed Journals, 37 book chapters and edited 6 books in various fields of Biotechnology. Major research areas include biofuels, bioenergy, technoeconomic analysis, environmental impact analysis, nanocatalysis, nanomedicine and Food safety. Visited Swiss Federal Institute of Technology (EFPL), Switzerland as visiting researcher in November and December, 2018. Fellow of the Institution of Engineers (India) and International Society for Energy Environment and Sustainability. Active life member of various national and international professional bodies. Listed in top 2% Scientist in the world consecutively in 2020 and 2021 by Elsevier BV and Stanford University, USA.

ABSTRACT

In the present study two macroalgal species, namely *Ulva lactuca* and *Codium tomentosum* are used to produce biofuels through an integrated approach. The technical and economic feasibility of producing biodiesel and bioethanol from these sources were studied. The oil yield in the *U. lactuca* showed an increase from 7.65 ± 0.4% to 11.68 ± 0.3% (w/w) and in the *C. tomentosum* sample an oil yield of 10.25 ± 0.3% (w/w) was found to be the highest using n-hexane as a solvent and at the optimal conditions of 5% moisture content, 0.15 mm particle size, 6:1 solvent: solid ratio, at 55°C of extraction temperature in 140 min. The novel heterogeneous nanocatalyst Zn-SiO_2 was used for biodiesel production from algal oil. The maximum biodiesel conversion of 97.43% and 79.21% was obtained for *U. lactuca* and *C. tomentosum* oil respectively at optimal conditions of nanocatalyst concentration (8%), methanol-oil ratio (9:1), and reaction temperature 55°C and 50 min. The residual biomass of oil extraction was used to produce bioethanol by pre-treating the biomass with acids and then hydrolyzing the biomass in the presence of cellulase enzyme to convert the cellulose into glucose. The bioethanol conversion was found to be highest as 3.8 ± 0.12 mg/ml in *C. tomentosum* and as 2.8 ± 0.12 mg/ml in *U. lactuca*. The annual revenue generated for biodiesel and bioethanol was found to be 1,135,000 $/yr and 1,115,000 $/yr, revenue generated from other sources was found as 83,220,187 $/yr. The return on investment was found to be 13.8% for biodiesel and 15.9 % for bioethanol production and approximately payback time as 7 years. From the TEA of the biofuels production process, it was observed that the overall process was technically and economically effective for biofuels production from marine macroalage.

Keywords: Biofuels; Biorefinery; Marine Macroalgae; Nanocatalyst, Technoeconomic analysis.

IL013
Microalgae based nutrient recovery for a sustainable circular economy: A perspective from Energy, Economy, and Environment

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ABSTRACT

India spends ca. 7 billion USD on fertilizer imports (0.25% GDP), affecting the self-reliance of the country. On the other hand, agriculture and livestock emissions corresponds to 17% of the gross emissions in the country. Both economic and environmental problems could be solved, when the fertilizer could be produced from a waste resource. Wastewater (WW) is one such resource which has the potential to solve these problems. India generates 60 cu.m/p/a of WW, while more than 63% of it is left untreated. In this work, we compared different nutrient recovery methods including microalgae for a sustainable circular economy from three perspectives: Energy, Economy, and Environment. To assess the overall sustainability, nutrient recovery from WW was looked at from multiple dimensions including resource estimation, mass and energy balance, techno-economic feasibility, lifecycle assessment and finally verifying these through experiments. When compared with various nutrient recovery systems, microalgae out projected other systems as a valuable resource (0.5 USD/kg). However, microalgae were also the highest consumer of energy at the rate of 950 kWh/1000 cu.m WW treated. The higher energy consumption was due to the reason that microalgae nutrient recovery was considered after the conventional WW treatment. Since, the value of microalgae was high, the overall savings was highest of various systems compared (80 USD/1000 cu.m). To reduce the energy consumption and improve the environmental performance, instead of post recovery option, a single-pot system was considered for WW treatment and nutrient recovery. Two microalgae species was considered including, *Scenedesmus* and *Chlorella sp.* Sequestered C ranged around 90% for both the species, while the growth rate of algae was 770 and 725 mg/L respectively. From lifecycle assessment perspective, microalgae as a nutrient recovery option yield a negative emission of -155 gCO_2 eq./ cu.m (120-150% lesser than conventional WW treatment).
Keywords: Biofuels; Microalgae; Techno-economic analysis; LCA

IL014
Microalgal biorefinery model for simultaneous wastewater treatment and production of biodiesel, bioethanol, and hydrochar

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ABSTRACT

Ever-escalating global energy demand and global warming due to the burning of fossil fuels encourage the necessity for exploring and implementing alternate clean, green, and sustainable energy resources. In this context, microalgal bioremediation followed by bioenergy production has significant potential that can be valorized under the biorefinery approach. The present study investigated the bioremediation of domestic sewage wastewater using the native microalgal strain *Monoraphidium* sp. KMC4 (MH183246) under fed-batch mode. The study showed a maximum biomass yield of 3.6 gL^{-1} and ~90% removal of ammonia, nitrate, phosphate, and COD. To evaluate the biofuel potential, lipid was extracted from harvested biomass and followed two-step acid (H_2SO_4) and base (NaOH) catalytic transesterification. The fatty acid methyl ester yield of 81 wt% was obtained which had 72% of C16 and C18. Further, to address the biorefinery approach, the lipid-extracted microalgal biomass (LEMB) was hydrolyzed through an acid (H_2SO_4) pretreatment process and bioethanol is produced via yeast fermentation using *Saccharomyces cerevisiae*. Whereas solid residues obtained after hydrolysis was converted to hydrochar via hydrothermal carbonization process, which showed a superior calorific value. Thus, the obtained results validates feasibility of microalgal bioremediation followed by various bioenergy production that carry potential for a self-sustainable microalgal biorefinery model.

Keywords: Biofuels; Biorefinery; Bioremediation; Domestic sewage wastewater; Microalgae

IL015
Microalgae as tool for wastewater treatment with simultaneous high value production

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	Main research field is in biomass conversion technologies to generate bioproducts, biofuels and bioenergy from waste/wastewater treatment systems as well as in CO_2 capturing technologies such as biomethanation of biogas. Research in fermentations and processes such as single cell protein production and biochemicals (eg. biosuccinic acid, lactic acid, PHA, a.o.) and algae production. Focus on microbiology and process technology, process optimization, molecular methods for characterization of bacteria, bioelectrochemistry and biorefineries. Collaboration with industry. She has successfully executed >50 projects both national and EU funded.

ABSTRACT

Industrial wastewaters from food and beverage production processes are often containing nutrients in the form of nitrogen and phosphorus and organic carbon, which need to be removed before discharging the wastewaters into the environment. Meanwhile, these wastewaters constitute an excellent feedstock for cultivation of microalgae. Microalgae have been demonstrated as a sustainable and economical alternative for wastewater treatment with simultaneous resource recovery. Algae can be cultivated mixotrophically, so, they can consume the organic matter in the wastewaters, and at the same time bind nitrogen and phosphorus. Thereby the effluent will be clean water, which can be recycled after harvesting the algae. Besides treating and purifying the wastewaters, microalgae can have a high value as they produce a number of useful biomolecules such as protein, lipids antioxidants, pigments and other interesting compounds that can be used in pharmaceutical, cosmeceutical and food production. Although the concept is very appealing, there are still several challenges to be solved, for consolidating this technology as sustainable and economically feasible. Some of the challenges are microalgae growth yields, productivity, algae harvesting, product induction and not the least control of algal growth for avoiding of bacterial contamination. In this paper, an overview of the concept will be presented.

Keywords: Algae; biomolecules, Industrial wastewaters; sustainable production

IL016
Microalgal CO_2 Sequestration and biomass generation using 30,000 L Raceway pond

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ABSTRACT

Global warming resulting in climate change is caused by the accumulation of greenhouse gases specially CO_2 in the atmosphere. Power plants and other industries generating flue gas (such as iron and steel industries which use coal /coking coal/coke) are the major green house gas (CO_2) contributors. Various possible methods have been proposed for mitigation CO_2 emissions. There is need for ecofriendly, low cost technology to reduce the CO_2 gas emission. Microalgae when grown in large quantity near the source of CO_2 (point source) in presence of water, sunlight and few commercial fertilizers can not only decrease CO_2 emission but also convert the waste CO_2 into valuables like biomass which is renewable source of biodiesel and commercially important bioactive molecules. Microalgae based carbon capture technologies are certainly promising but their successful implementation at industrial scale is still to be realized. Challenges exist to enhance the photosynthetic efficiency of the system so that maximum CO_2 is fixed by algal biomass.

We have studied different techniques to facilitate better dissolution of CO_2 gas into growth media of microalgae thereby increasing their growth which means more fixation of CO_2. To realize the above mentioned goal, we have developed a system which is combination of (i) a shallow raceway pond suitable for microalgal growth and (ii) a vertical column which would be suitable for infusing CO_2 gas into the system and provide sufficient gas mixing. Microalgal strains capable of growth on LCM (low cost medium) composed of commercial fertilizers were identified. These cultures show high growth rate in presence of CO_2 sequestering agents and were able to tolerate them. Our representative data indicate biomass productivity for *Scenedesmus* sp., in range of 8-12 $g/m^2/day$ in open raceway ponds of 30,000 L working volume

Key words: Microalgae; *Scenedesmus* sp.; Raceway pond, CO_2 Sequestration, Biomass

IL017
Valorization of Carbon Dioxide (CO_2) for Producing Biomass, Biofuels, and Biorenewables (B^3) in Microalgae: A Circular Bioeconomy Perspective

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ABSTRACT

Carbon dioxide supplementation regulates the metabolism of photosynthetic organisms, initiating CO_2 fixation through the central carbon metabolism and further partitioning the carbon into various metabolic processes. Understanding the molecular mechanisms of carbon fixation and partitioning is essential to control and regulating biomass and lipid production. In this context, we investigated the metabolic and physiological responses of a freshwater microalga *Chlorella saccharophila* upon supplementation of very-low CO_2 (VLC; 300 ppm, or 0.03%) and high CO_2 (HC; 30,000 ppm, or 3% v/v) for their potential as biorefinery strain. Our results demonstrate that the growth in HC was enhanced 1.4-fold as compared to VLC; moreover, with the help of chlorophyll transients, we predict that the increase in VLC was supported by central electron flow. Similar changes of fold-change were observed within various biochemical constituents, i.e., lipids, proteins and carbohydrates. Upon HC supplementation, the total pigment productivity was also observed to be 1.8-fold higher than cultures supplemented with VLC, further corresponding with the enhanced growth in HC. Furthermore, by application of qualitative metabolomics, we identified nearly 23 essential metabolites, among which there is a significant fold change observed in the accumulation of sugars and antioxidants such as trehalose and α-tocopherol in VLC as compared to HC. In conclusion, our emphasis is understanding the significance of HC supplementation in *C. saccharophila* UTEX247 and providing valuable insights leading to enhanced biomass with simultaneous production of biofuels and high-value biorenewables (B^3) in the context of a circular bioeconomy by the valorization of carbon dioxide (CO_2).

Keywords: Algae; Biomass; Biorefinery; Circular bioeconomy; Metabolomics

IL018
Genetic and molecular biology interventions as a promising strategy for the production of high-value chemical production from microalgae

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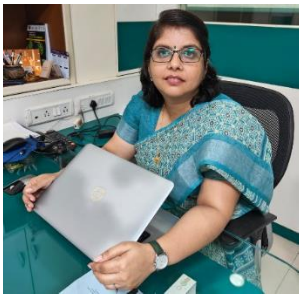

Dr Gunjan Prakash is a Doctorate from India's one of the most prestigious institutes, IIT Delhi. She is currently a faculty at the Department of Biological Sciences and Biotechnology, Institute of Chemical Technology Mumbai. She has expertise in algal biotechnology, fermentation and plant cell culture. She is an expert in developing the genetic toolbox for microalgae and has extended it to a range of species for biofuel development, enhanced abiotic stress resistance, photosynthetic efficiency and bioproducts production. She has executed multiple government and industrial projects at DBT-ICT-Centre for Energy Biosciences, Mumbai and has published several research articles in international peer-reviewed journals. She has also been awarded the Indo-Queensland fellowship.

ABSTRACT

Microalgae have gained significant attention in recent years due to their wide applicability as carbon neutral, sustainable and environmentally friendly alternative to Fossil Fuels and as a source of 4F's i.e. Food, Feed, Fibre and Functional molecules. Fuel and Feed, being low-value commodities, there is a need to develop a microalgal biorefinery concept wherein high-value chemicals can offset the cost of low-value molecules. Carotenoids are one such class of molecules that find their applications in the pharmaceutical, nutraceutical and pigment industries.

Carotenoids are produced via both biological and synthetic means. Microalgae have been hailed as the most promising source of carotenoids for commercial production, owing to their short life cycle and their abilities to grow in brackish water and on non-arable lands. The metabolic engineering of microalgae is a potential alternative to enhance carotenoid production and establish them as a source of natural carotenoids in the market.

The carotenogenic pathway is a tightly regulated pathway in which rate-limiting enzymes and regulatory proteins influence overall production. phytoene synthase (psy) is a rate-limiting enzyme in the carotenoid pathway and has been targeted to increase overall pathway flux. In recent years, Orange (Or)-a novel regulatory protein found in plants and algae—has also been shown to affect carotenoid accumulation by stabilizing psy and affecting the carotenoid pathway in multiple ways. Thus *psy* and *Or* can be important molecular targets for carotenoid pathway engineering. The current talk will focus on the potential of microalgae as the best alternative for carotenoid production and carotenoid pathway engineering targeting *psy* and *Or* for enhanced carotenoid production.

Keywords: Carotenoid; Microalgae; *Orange* gene; *psy* gene

IL019
Wastewater Treatment Using Algal-bacterial Hybrid Systems

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ABSTRACT

The recent GoI regulations on wastewater treatment and reuse have put a lot of emphasis on nutrient removal while simultaneously reducing the limits of BOD, COD, and SS of the treated effluent. Conventional Biological Nutrient Removal (BNR) systems may meet the new criteria; however, they're more complex to operate. Moreover, the cost of treatment, energy use, and carbon footprint also increase which makes the acceptance of such technologies more difficult. Hybrid algal-bacterial systems appear to be a promising technology to satisfy the above criteria. The treatment of wastewater in algal ponds has been in practice in Western countries for several decades. However, an attempt to convert conventional waste-activated sludge systems into hybrid algal-bacterial systems for the simultaneous removal of BOD and nutrients is a relatively new effort. We, at IIT Hyderabad, have developed two pilot-scale prototypes, a biofilm-based system and a suspended-growth system. The biofilm-based system was further taken to the field for full-scale application. In a suspended-growth system, algae and bacteria can coexist. Optimal solids retention time is between 8 and 10 days for the development of a significant proportion of algae in the biomass and for the maximum removal of BOD and nutrients. Several micropollutants, particularly of the PPCP category, were significantly removed. While the biofilm-based system was primarily developed as an intermediate unit, the suspended-growth system was meant to produce an effluent of reusable quality. Both systems achieved their objectives at a much lower energy input since the blower requirement was eliminated/reduced significantly. The sludge generated from the hybrid system can be converted into a very effective adsorbent through physical-chemical-thermal treatment. The adsorbent can be used in tertiary treatment for further removal of micropollutants and recalcitrant organics from wastewater.

Keywords: Algae; nutrient recovery, sludge management, wastewater treatment

IL020
Microalgal Biorefinery – Closed Loop Approach for Fuels and Chemicals

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ABSTRACT

Microalgae have drawn attention in the bioeconomy setting because of their versality in terms of metabolism. Products from microalgae cultivation have a wide range of promising applications in the fields of nutraceuticals, medicines, cosmetics, and renewable energy sources. One of the sustainable options that will be both economically and environmentally viable is the biorefining of microalgal biomass in a circular loop with the goal of maximizing resource recovery. Microalgae based primary products, cultivation strategies, valorization of microalgae biomass for secondary products and integrated biorefinery models for the production of multi-based products will be discussed. In the context of the blue-bioeconomy, the necessity and potential of self-sustainable models in closed loop biorefinery format will be highlighted.

Keywords: Algae; Biofuel; Circular Bioeconomy, Mixotrophic, Wastewater

IL021
Algal biomass production and pollutants removal by a moving bed membrane photobioreactor

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ABSTRACT

Recently, the microalgae-based wastewater treatment process has been considered efficient for nitrogen removal and environmentally friendly. This study used a moving bed-membrane photobioreactor (MB-MPBR) to treat the anaerobic effluent. A 4 L photobioreactor with novel suspended sponges for maximizing the bacteria-microalgae biomass coupled with an external membrane module to keep the permeate reaching the discharged standards limits of Viet Nam. MB-MPBR system was operated under the light transparent of about 3000 lux, a light:dark cycle of 12h:12h, and a mixed activated sludge-microalgae ratio of 3:1, with a suspended biomass retention time of 7 days. The microalgae seed source for this study was Chlorella sp. The total biomass of 20 % and 10 % sponge (v/v) conditions reached 1825 mgMLSS/L and 2240 mgMLSS/L, where biomass productivity were 103.9 mgMLSS/L.d and 90.7 mgMLSS/L.d. At an organic loading rate of 0.2 kg COD/m3.d and nitrogen loading rate of 0.065 kg TN/m3.d, COD removal efficiencies were approximately 98±1.6% for both carrier ratios. Ammonium removal efficiency was approximately 95% and 81% while TP removal efficiencies were 32±6.3% and 83±6.3%. SEM images indicated that microalgae and bacteria attached on both the surface and deep inside of the pores of the sponge carriers. These results showed that MB-MPBR could be an effective algal biomass production method. However, the attached growth biomass was not a major biomass content in the system which should be improved through other carriers.

Keywords: biomass production; membrane; microalgae; photobioreactor; sponges

IL022
Phycoremediation of X-ray developer solution towards silver removal using waste as a nutrient media of *Desmodesmus armatus*

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	Doctorate in Bioprocess Engineering / Industrial Biotechnology (IIT Kharagpur) and M.Tech (Biotechnology) as Master's Degree. Grantee of Two Indian Patents, edited one book, published 50 SCI- journal articles, 25 Book chapters, guided 3 Ph.D, 9 Master's & 15 UG dissertations and have communicated/ presented at several conferences either as oral presentations or posters. Taken fellowships of A4U Postdoctoral Fellowship, Spain, 2011-2013; Institute Research Fellowship, IIT Kharagpur, 2006-2010; GATE - MHRD Fellowship, 2002-2003. Listed in "Top 2% World's Scientists, by Stanford University Rankings (2022, 2021 & 2020), USA". Research interests include Bioprocess Engineering / Industrial Biotechnology, Environmental Biotechnology, Microalgal Technology.

ABSTRACT

The present study develops a novel concept of using waste media (food waste, FW, and agri-compost media, ACM) as an algal nutrient resource for the phycoremediation of an X-ray developer (XD) solution. The fabricated growth kinetics and dynamic study showcased that the theoretical maximum biomass concentration (Xp) was found to be more (0.871) with diluted ACM than the usual BBM (0.697). The XLim values were 0.362, 0.323, and 0.209 for BBM, diluted ACM, and diluted FW media, respectively. A 3:1 dilution of FW/ACM with XD was suitable for the phycoremediation study of XD solution towards the % removal of biological oxygen demand (BOD), chemical oxygen demand (COD), and silver. The phycoremediation studies of diluted XD solution in FW demonstrated a 74.50% BOD removal, 81.69% COD removal, and 54.70% removal of silver. The growth of D. armatus in diluted XD solution in food waste was 1.37% lipid content. The phycoremediation of diluted XD solution with ACM resulted in 83.05% BOD removal, 88.88% COD removal, and 56.30% silver removal with the concomitant lipid production of 1.42%. The optimal bioremediation coupled lipid production of *D. armatus* was observed on the 19th day of *D. armatus* cultivation in the developer effluent, along with food waste and agri-compost media, for 31 days. Overall, the study proposes a cleaner approach of utilizing the wastes as growth media through a circular economy approach, eventually reducing the growth media cost with integrated macromolecule production and phycoremediation capabilities.

Keywords: Agri and food waste media, Growth kinetics, Phycoremediation, Silver removal, X-ray developer effluent.

IL023
Photobiological Hydrogen Production and Bioremediation of Contaminants using Cyanobacteria: An Integrated Approach

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Abstract

Energy self-dependent wastewater treatment plant would be important in the coming years considering economic and environmental sustainability aspects. The world must find a way of producing fuel from renewable sources of energy to replace the fossil fuels. Hydrogen can be considered as one of the most promising alternative fuel for a world in which air pollution has been alleviated, global warming has been arrested, and the environment has been protected in an economically sustainable manner. Hydrogen production from solar energy using photosynthetic microorganisms is one of the best biological ways. Biological hydrogen evolution provides a sustainable and environmentally friendly way to produce clean energy from renewable resources. In the present study, hydrogen production by *Nostoc linckia* was studied using alginate immobilized biomass of the cyanobacterium in a lab-scale photobioreactors (PBRs). Hydrogen production rates improved significantly when immobilized cyanobacterial biomass was used in PBR and the production continued up to 25 days by maintaining required anoxic conditions and carbohydrate supplement. Average hydrogen production rate over 25 days was 132 mmolH 2 /h/mg Chl a. The biological waste from the PBRs was utilized for sequestration of carcinogenic crystal violet dye (CV) from aqueous solutions in packed-bed column. Three PBRs containing immobilized cyanobacterial biomass were run for 5, 15 and 25 days, and the biological waste collected at the end of the operation was used for biosorption studies under already optimized conditions. Biosorption efficiency of the waste biomass was found to be influenced by the operation time of the hydrogen photobioreactor.

Keywords: Biohydrogen; Photobioreactor; Spent biomass; textile dyes; Alginate-immobilization.

IL025
Microalgae with artificial intelligence: A perspective on biotechnology for bioproducts

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Dr Kit Wayne Chew is an Assistant Professor at the School of Chemistry, Chemical Engineering and Biotechnology, Nanyang Technological University, Singapore. His research and technological development interests are in sustainable bioprocess engineering for food and pharmaceutical products, focusing on the utilization of algae biotechnology to develop cost-effective and environmentally friendly methods for the synthesis of functional ingredients. He received the Green Talents Award 2022 and was listed as the Top 2% World Top Scientists in The Stanford List 2022/2021. Up to now, he has published more than 180 Journal articles and 15 book chapters.

ABSTRACT

Identification of microalgae species is of great significance due to the discovery of various new species and to detect the occurrence of harmful algae blooms, which can affect both the aquatic habitat and human health. Microalgae are the future green biomass and alternatives due to their promising composition of bioactive compounds that can be utilized in many industrial applications. The potential of incorporating artificial intelligence into the processing of microalgae can give a “domino effect” in further providing optimization leverages to the supply chain, in the operations including cultivation, processing, system design, process integration, and products generation. Currently, microalgae species identification are conducted through DNA analysis and various microscopy techniques which poses several limitations such as costly validation, requiring skilled taxonomists, prolonged analysis, and low accuracy. To overcome these challenges, the potential and innovation of digital microscopy with the incorporation of both hardware and software that could produce a reliable recognition, detection, enumeration, and real-time acquisition of microalgae species, has been developed. From this perspective, the linkage between microalgae genetic information and optimized bioproducts using Artificial Intelligence can be closed further. The acceleration of artificial intelligence research, using large and complex data from microalgae research can be properly analyzed by combining the cutting-edge of both fields. These adaptation of automation in bioprocessing will then create the pathway for a digitalized future for microalgae bioproducts manufacturing and application.

Keywords: Chlorella; extraction; green biomass; machine learning; optimization

IL026
Valorization of agricultural wastewater for generation of high value products from freshwater diatom *Nitzschia* sp.

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ABSTRACT

A significant global concern is how to use agricultural wastewater feasibly. In the study, commercial agriculture fertilisers are emphasised as a source of nutrients for the development and long-term cultivation of freshwater diatoms (*Nitzschia* sp.). The biomass potential of *Nitzschia* sp. for the generation of metabolites, antibacterial activity, and as a biofertilizer was assessed in this study. In agricultural wastewater (0.5 mg ml^{-1}), *Nitzschia sp.* was grown to its highest cell density (12 x 10^5 cells ml^{-1}), protein content (10.0 mg g^{-1}), and lipid content (14.96%). At a concentration of 2 mg per ml, the contents of phenol and carbohydrates rise in a dose-dependent manner, with 8.27 mg g^{-1} and 2.05 mg g-1, respectively. Chrysolaminarin content was maximum in 1mg mL^{-1} (11.57 mg mL^{-1}). Both gram-positive and gram-negative bacteria were susceptible to the biomass antimicrobial effectiveness. The growth of periwinkle plants was also assessed as a diatom biofertilizer, and it revealed maximum leaves, early branching and a notable rise in shoot length. Diatom biorefineries have a huge potential for recovering agricultural wastewater and generation of valuable molecules.

Keywords: Agriculture wastewater; Biorefinery; Diatoms; High value products; *Nitzschia* sp.

IL027
Astaxanthin from microalgae and residues for solid biofuel production

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Prof. Dr. Ashokkumar Veeramuthu has more than 14 years of research experience in the field of Energy and Environment at both the academic and industrial levels. He received his Ph.D. from the University of Madras, Chennai, India. During his Ph.D. period, he was awarded an Indo-Australian fellowship and visited Adelaide University, Australia as a visiting scientist. Currently, he is working as a Professor at Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, India. He is the Visiting Professor at Chulalongkorn University, Thailand, and the National University of Singapore (NUS), Singapore. He was also a visiting scientist under the Marie Skłodowska-Curie Actions Fellowship scheme. Dr. Ashok also worked in Reliance Industries Pvt., Ltd., Mumbai (Biorefinery for biofuels and bioproducts division). His area of expertise is value-added bioproducts, biomass thermochemical techniques, torrefaction, and biochar synthesis, bio-jet fuels, and metallic iron production and CO2 sequestration wastewater treatment using renewable biomass resources.

ABSTRACT

Astaxanthin has gained significant attention in the field of medicine due to its potential health benefits and antioxidant properties. Studies reveal that the astaxanthin produced from algal resource showed a potential benefit towards pharmaceuticals and nutraceuticals industries. It has been reported that the market value of natural astaxanthin is up to 30000 USD/kg. The global astaxanthin market is projected to reach USD 1.6 billion by 2025, at a CAGR of 9.5% from 2020 to 2025. In the present study, the alga Haematococcus was cultivated at a pilot scale for high biomass production. The biomass was harvested on day 30 and analyzed for their bioproducts productivity. The results show that the alga can be able to produce a high amount of natural astaxanthin up to 5.7 wt%. Further, the residue was explored for biochar production through torrefaction techniques. This study will help to develop an algal biorefinery approach to enhance the circular bioeconomy.

Keywords: Astaxanthin; Biochar; Cultivation; Microalgae; Torrefaction

IL028
Valorization of industrial wastewater into microalgal biomass – focusing on microbial contamination control and biomass harvesting

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	Graduated as chemical engineer at the university of Santiago de Compostela, I hold a PhD on process design, modeling and control of biological resource recovery technologies from wastewater. Currently I am appointed as associate professor at the Technical University of Denmark, department of Environmental and Resource Engineering (DTU Sustain). I mainly work on waste/water treatment technologies combining several approaches, including lab and full-scale experimentation, process modeling and control and microbial ecology. My main interest is on developing processes that enable circular bio-economy in the urban, industrial and rural context.

ABSTRACT

Microalgae have been studied because of their potential to solve some of the most pressing challenges that the world is facing today, as microalgal biomass is a good feedstock for bioenergy, fertilizer and feed or food. However, producing microalgae from synthetic resources has a high cost and high impact on the environment. As alternative, algae have been proposed for remediation of wastewaters rich in nutrients, thereby decreasing the environmental footprint of their production. Furthermore, when grown autotrophically, algae can fix CO_2. Despite the great potential, algal technologies have not been successfully implemented at commercial scale for water treatment. Contrary to traditional microalgae production, the use of wastewater presents several challenges, including dynamics in nutrient and organic carbon content, presence of hazardous components (e.g., pathogens, organic micropollutants such as pharmaceuticals and heavy metals) or out-competition by other microorganisms indigenous of the wastewater. Thus, successful application of microalgae-based technologies for resource valorization into bio-products with high market value require, among others, advanced control strategies, cultivation approaches that prevent from invasion and out-competition by other microorganisms and alignment between the type and composition of wastewater and the intended use of microalgae biomass (Maurya et al., 2022). Furthermore, most biomass valorization strategies require cost intensive harvesting and downstream process (Molina Grima et al., 2003), which often also compromise the overall sustainability of the value chain (Fang et al., 2016). Alternatives such as bio-harvesting or fertigation can lower the costs, while providing effective valorization strategies. In this presentation we will revise recent advances on microalgae cultivation in wastewater in view of upcycling residual resources into higher value products, thereby enabling new circular exploitation models.

Keywords: Biofertilizers; Circular bioeconomy; Microalgae; Microbial feed and food

IL029
Microalgae, a potential platform for biofuels and value-added products-Process engineering perspective

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ABSTRACT

As an alternative to the classical chemical process, synthesis of various value-added products and bulk chemicals through heterotrophic microbial fermentation has been successfully implemented at the commercial scale. However, for many commodity products bacterial fermentation process may not be economically competitive owing to in particular high cost of carbon substrates. Over the past decades, microalgae or cyanobacteria have gained increased attention as an alternative and economical source of various value-added products and bulk chemicals, which can offer environmental sustainability. At Bioprocess Development Lab of IIT Guwahati, we have been focusing towards sustainable process development for various value-added products using microalgae/cyanobacteria as cell factories. I will talk about three case scenarios where, in two cases these photosynthetic microbes were used as potential platform for synthesis of bulk chemicals (*e.g.*, hydrocarbon oil) and high-value compounds (*e.g.*, pigment), the third one deals with application of whole cell protein rich biomass as aqua feed. A two-stage integrated process was demonstrated towards production of hydrocarbon oil designated as ALGLIQOL, with potential to be utilized as liquid transportation fuel. Stage-I involves in-situ catalytic hydrothermal liquefaction (HTL) of microalgae biomass to produce biocrude oil and stage-II involves distillation of biocrude to hydrocarbon oil. Significant similarity in physiochemical properties of ALGLIQOL and gasoline or diesel fuel, indicates its suitability as transportation fuel. We also demonstrated an end-to-end downstream process for extraction and purification of C-phycocyanin from *Spirulina* sp. NCIM 5143. Analytical grade C-phycocyanin purity levels was achieved within two steps of purification with similarity in spectral properties compared to commercially available analytical standard. Finally, a study demonstrates cleaner production process for CO_2 tolerant microalga *Desmodesmus pannonicus* CT01 and its potential as aquafeed for freshwater fish silver carp (*Hypophthalmichthys molitrix*), which would offer scope of CO_2 sequestration at higher concentration.

Keywords: Cyanobacteria; Fish feed; Hydrocarbon oil; Microalgae; Phycocyanin

IL030
Sustainable microalgal biomass production in biorefinery wastewater for high value bioproducts and circular bioeconomy

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ABSTRACT

Microalgal biomass is used as a raw material by many industries, such as cosmetics, food, feed, therapeutics, nutraceuticals, and biofuels. However, the production of microalgae-derived bioproducts is unprofitable due to the costs associated with biomass production and its harvesting process. Integration of microalgal biomass production in biorefinery wastewater is profitable for the generation of multiproducts in a biorefinery approach and will address the circular bioeconomy. Acid pretreatment liquor (APL) is the waste stream generated during the pretreatment process of lignocellulosic biomass for bioethanol. This process generates approximately 3–4 tons of APL per ton of biomass processed. The study describes the growth and biomass production of the freshwater microalga *Chlorococcum sp.* R-AP13 in APL medium obtained from the pretreatment of rice straw and sorghum stover. The microalgal potential of consumption of sugars (C5 and C6) and the removal of degradation products such as HMF and furfural are analyzed. Fatty acid profiling of oils was performed by GCMS, and biodiesel properties of oils were assessed by *in-silico* analyses by the Biodiesel Analyzer®. Results showed that alga can utilize C5 and C6 sugars from APL as carbon sources and survive in the presence of furan-derived inhibitors. *Chlorococcum sp.ARP-13* can able to remove inhibitors from APL during its growth. The maximum yield of biomass and lipid was 1.8 g/l and 0.56 g/l, respectively. FAME profile of fatty acids shows that high oleic acid production is elevated. Physico-chemical properties of oils for biodiesel indicated its compliance to EN 14214 and ASTM D6751. The cultivation of microalgae in biorefinery byproducts (APL) would be immensely beneficial since it would address both wastewater treatment and the value addition of the resource in the context of circular bioeconomy.

Keywords: Acid pretreatment liquor; biorefineries; *Chlorococcum;* fatty acids: microalgae

IL031
ALGAL PIGMENTS: A PROMISING ALTERNATIVE IN NEUTRACEUTICAL STUDIES AND FOOD INDUSTRY

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ABSTRACT

Cyanobacteria are gram-negative photosynthetic prokaryotes that are found in freshwater, marine and terrestrial habitats. They produce various bioactive secondary metabolites like apratoxins, borophycin, lynbyabellin, etc and are rich in lipids which are sources for biofuel production. These cyanobacteria require adequate nutrition, aeration and sunlight for its proper growth. Other than chlorophyll, cyanobacteria is also a source of several carotenoid pigments and accessory pigments like phycocyanin, allophycocyanin and phycoerythrin. Phycocyanin is a major photosynthetic accessory pigment that is widely used as a dye in the food industry. The antioxidant, anti-cancerous and anti-inflammatory properties made them significant in the field of therapeutic studies. Lutein, another carotenoid pigment found in the photosynthetic antenna complexes has several applications in the treatment and prevention of atherosclerosis, age-related blindness and cataracts as well as some other cancers. Hence these products are of high commercial value and is capable of contributing to the nutraceutical and food industry.

Keywords: Algae; Cyanobacteria; Lutein; Phycocyanin.

IL032
Efficiency of nitrate uptake and its impact on microalgae biomass

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Dr. Temjensangba Imchen has more than 14 years of research experience in various aspects of botany, plant tissue culture, biological oceanography and marine biology mainly with algae. Over the years, he has worked on the intertidal rocky shore ecology of algae, taxonomy, bioinvasive aquatic macrophytes, and port biological baseline survey (PBBS) in major ports of India. Currently, he is working on macroalgal diversity of Konkan coast, and assessment of nutraceutical potential of seaweeds. At present, he is working as a Senior Scientist, Biological Oceanography Division, CSIR-National Institute of Oceanography, Goa.

ABSTRACT

Microalgae are grown for their abundance of bioactive compounds, pigments, antioxidants, and other beneficial components like biofuel. In this work, *Coscinodiscus radiatus* and *Trieres mobiliensis*, two heterokont microalgae, were grown in a laboratory environment to examine nitrate uptake and its impact on growth. The results showed that algal biomass increased as nitrate concentrations increased, and for both algae, the highest growth was observed in media with a nitrate content of 1 ml. L^{-1}. *Trieres mobiliensis* had an estimated biomass (chl *a*) of ~795 µg. g^{-1} dw, followed by 705 µg. g^{-1} dw. The half-saturation constant (K_s) of *C. radiatus* was ~1 µM and a maximum uptake rate (V_{max}) was 13 d^{-1}. In contrast, *T. mobiliensis* had a maximum uptake rate (V_{max}) of 16.67 d^{-1} and a K_s value of 1.17 µM with a coefficient correlation of 0.953.

Keywords: *Coscinodiscus radiatus*; half-saturation constant; Nutrient, *Trieres mobiliensis*; uptake rate

IL033
Innovation and Research Trend in Algal Technology

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Professor Ir. Ts. Dr. Pau-Loke Show is currently a Full Professor of Biochemical Engineering at Khalifa University, Abu Dhabi, United Arab Emirates. He also serves as a Professor in the Department of Chemical and Environmental Engineering, University of Nottingham Malaysia, where he is the Director of the Sustainable Food Processing Research Centre and Co-Director of Future Food Malaysia, Beacon of Excellence, at the University of Nottingham Malaysia. He is also the former President and Founder of International Bioprocessing Society based in Malaysia. He has successfully obtained his PhD in two years' time after obtaining his bachelor's degree from Universiti Putra Malaysia. In the year of 2022, he was elected as a Fellow of the Institution of Chemical Engineers IChemE (FIChemE). He is currently a Professional Engineer (PEng) registered with the Board of Engineers Malaysia (BEM), Chartered Engineer of the Engineering Council UK (CEng), Corporate Member of The Institution of Engineers, Malaysia (MIEM), and Professional Technologist (PTech) registered with the Malaysia Board of Technologists (MBOT). Prof Ir. Ts. Dr. Show obtained the Post Graduate Certificate of Higher Education (PGCHE) in 2014 and is now a Fellow of the Higher Education Academy (FHEA) UK.

ABSTRACT

In recent year, Liquid Biphasic System (LBS) has become a proven tool used in separation and purification technology for circular bioeconomy in microalgae biorefinery. The application of Internet of Things (IoT) in LBSs in clarification, partitioning and partial purification of biomolecules and bioproducts had showed the rapid development. This method is able to give high recovery yield and high purity in a single step. The LBS shows characteristics of high selectivity and is easily to scale up. Therefore, LBS offers an attractive alternative that meets the requirements of the high demand in industry processes and it is also beneficial in terms of economic and environmental protection. This presentation aims to share on the recent literature works in the development of different type of LBSs and their applications in novel separations and purifications of biomaterials. Hopefully this presentation will able to build solid research collaborations among industry players and researchers.

Keywords: Algal; Circular Bioeconomy; Liquid Biphasic System; Internet of Things; Microalgae; Biorefinery

IL034
Algae-based circular bioeconomy for wastewater treatment and resource recovery

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	Mohit Singh Rana has completed his Ph.D. IIT Roorkee. He is a co-founder and CEO of E3BioCleantech Pvt. Ltd. It (E3BioCleantech Pvt. Ltd.) is a spin off from IIT Roorkee, India, founded in 2022 by the experts of water, energy and environment. We are a deep-tech, research-based team providing novel, sustainable clean technologies and turnkey solutions in the area of wastewater treatment, clean energy and carbon capture. We extend our services in environmental impact assessment.

ABSTRACT

The need for sustainable energy and wastewater treatment has become increasingly important with the growing population. Microalgae have emerged as a promising option to address the challenges and improve the sustainability of various wastewater business models. In recent times, the use of algae as a potential candidate for water recycling and resource recovery from a range of different wastewater has gained significant attention in the scientific community. In our study, we have explored the potential of selected algae for biomass production using wastewater such as RO reject, municipal sewage, and hydroponics effluent. Specifically, *Chlorella sp.* was able to convert 77.59% of nitrate and 82.71% of phosphate from RO reject into lipid and protein-enriched algal biomass, which holds potential for biodiesel and high-value metabolites production. Similarly, *Chlorella* sp. grown in municipal wastewater was noted to recover 96.35% phosphate and 80 % nitrate into algal biomass, which met the quality standards for biodiesel and bioethanol production. Additionally, our research indicates that algae may also have the potential for removing pathogenic bacteria and viruses from wastewater. Our observations revealed that *C. pyrenoidosa* was able to remove 98% of *Enterobacteriaceae* and 96% of *Salmonella sp.* from sewage, indicating its efficacy as a disinfectant. Overall, recycling of wastewater as growth media may reduce the dependency of mass-scale algae cultivation on freshwater resources. In addition, the wastewater-grown algal biomass can be utilized as a valuable resource for a range of commercial products including biochemicals and biofuel.

Keywords: Algae; Wastewater; Resource Recovery; Circular bioeconomy; Water recycling

Abstracts of Contributory Presentations

PP001 - Fabrication and characterization of low-cost kaolin based tubular ceramic membrane for microalgal harvesting

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ABSTRACT

Tubular membranes with natural kaolin as key precursor were fabricated in this study. Membranes with five different compositions were produced and the optimized membrane (77% kaolin, 2% boric acid, 2% sodium metasilicate, 4% sodium carbonate and 15% calcium carbonate) was used in the harvesting of microalgal culture. The porosity, pore size, water permeability, chemical strength as well as mechanical strength of the membranes were investigated. The fabricated membranes had porosity in the range of (26% - 47%), pore diameter of 0.123-0.182 µm,water permeability of 4.2×10^{-8} – 17.1×10^{-8} m^3/m^2 s kPa, along with good chemical and mechanical strength. The optimized membrane was tested for microfiltration of microalgae *Monoraphidium* sp. KMC4 with an initial concentration of 1.5 g L^{-1} at a constant cross flow rate (1.11×10^{-5} m^3/s) and various transmembrane pressures (69-345 kPa). The separation results yielded an average permeate flux of 1.85×10^{-5} m^3/m^2 s at 276 kPa transmembrane pressure. Complete algal cell recovery and high nutrient passage (>88%) was observed for pressures in the range of (69-345 kPa). Four pore blocking models were fitted to the experimental results in order to explain the fouling mechanism in the microfiltration. The cake filtration model fitted the best as compared to the complete, intermediate and standard pore blocking models. Additionally, the presence of total organic carbon in the range of 31.6-63.2 mg/L gave an idea of the source of pore blocking.

Keywords: *Ceramic microfiltration, Harvesting, Kaolin, Microalgae, Tubular membrane*

Background:

Due to the diluted nature of algae culture, many of the commercially available harvesting techniques-including centrifugation and flocculation, require either excessive energy expenditures or the addition of harmful chemicals[1]. Although centrifugation is the most efficient method, its high energy consumption and risk of cell rupture at high speed limit its use. Also, the microalgal quality and purity are both influenced by the relatively high dosage and toxicity of certain flocculants [2]. Meanwhile, membrane technology has become the most popular way to remove water from industrial algae because of its many benefits, such as high energy efficiency (because there is no phase change), scalability, small footprint, easy operation, and low maintenance.
The present study aims to find a low-cost alternative for the harvesting of microalgal culture. In this regard, naturally available kaolin in the Deopani area of Karbi Anglong District in Assam, India was used to fabricate tubular microfiltration membranes. Five membranes with different compositions were prepared and the optimized membrane was used for testing the harvesting efficiency of *Monoraphidium* sp. KMC4. In addition, the porosity, pore size, water permeability, chemical strength as well as mechanical strength of the membranes were investigated.

Materials and Methods:

- Tubular membranes were prepared using extrusion technique.
- XRD, TGA, FESEM, Porosity analysis was done
- Membrane water permeability was tested using the microfiltration setup

Results and Discussions:

Naturally found kaolin yielded a good quality tubular microfiltration membrane. Average flux of 1.85×10^{-5} m^3/m^2 s at 276 kPa was obtained with 100% cell recovery.NO_3^- passage in the permeate ranged from ~88-97% for the optimized membrane. Higher TOC value of permeate was observed at higher transmembrane pressures. Cake filtration model proved to be the best fit for microfiltration of microalgae.

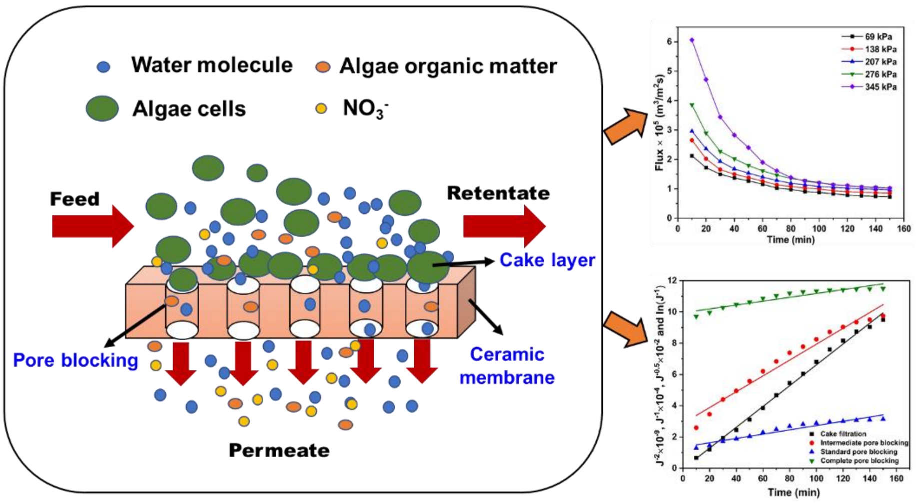

Fig. 1. Overall performance of membrane in terms of flux decline and model fitting

Conclusion:

- Naturally found kaolin yielded a good quality tubular microfiltration membrane.
- Average flux of 1.85×10^{-5} m^3/m^2 s at 276 kPa was obtained with 100% cell recovery.
- NO_3^- passage in the permeate ranged from ~88-97% for the optimized membrane.
- Higher TOC value of permeate was observed at higher transmembrane pressures.
- Cake filtration model proved to be the best fit for microfiltration of microalgae.

Acknowledgement:

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PP002 - Dynamic Optimization Strategies of Batch Hydrothermal Liquefaction of Microalgae for Optimal Biocrude Production

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ABSTRACT

This work demonstrates optimal operating strategies of batch hydrothermal liquefaction (HTL) of two microalgal species, namely, *Nannochloropsis sp.* and *Aurantiochytrium sp.* KRS101 to enhance the reactor performance. Two dynamic optimization problems (DOPS) were formulated and solved with objectives: maximization of the endpoint biocrude yield and minimization of final time to identify the optimal time-varying reactor temperature profiles. We adopted two first-order kinetic models describing the batch HTL of the considered microalgae from literature to represent the dynamic rate constraints of the proposed DOPS [1], [2]. The DOPS were transformed into non-linear programming problems by employing a direct collocation-based approach and subsequently solved in MATLAB® using the *fmincon* solver. For *Nannochloropsis sp.*, the DOP-1 produced a marginal increase in the optimal biocrude yield by 4% in a chosen batch time of 60 mins with a reduction in the reactor thermal energy requirement by 14.4% compared to the selected base case. For *Aurantiochytrium sp.* KRS101, the same had resulted in an 8.57% increase in the biocrude yield and the reactor thermal energy was dropped by 25.8% in contrast to the base case, where fixed temperature profiles were employed. The DOP-2 solutions revealed that batch times were reduced by 54.5% and 66.5% for *Nannochloropsis sp.* and *Aurantiochytrium sp.* KRS101, respectively, to obtain the targeted optimal biocrude yields compared to the base cases. Therefore, the transient optimal temperature trajectories outperform the conventional fixed temperature profiles during the batch HTL operation by generating optimal biocrude yields in minimum time with lesser reactor thermal energy requirements.

Keywords: Biocrude, Batch Reactor, Dynamic Optimization, Hydrothermal Liquefaction, Microalgae.

Background:

HTL is a thermochemical method using which the microalgae can be converted into biocrude, which are CO_2-neutral compared to the fossil-based diesel fuel and therefore, aid in mitigating global warming. In a batch HTL, microalgae are compressed with hot water or a solvent at high pressure of about 5-25 MPa and a moderate temperature range of 473-673 K to produce biocrude along with the generation of biochar, gas, and aqueous phase products [1]. The batch HTL of microalgae encounters several challenges viz. transient behaviour and highly non-linear dynamics. Also, the effect of reaction temperature and residence time play a vital role in affecting the endpoint biocrude yield. Therefore, process optimization becomes essential to enhance the biocrude yield by evaluating the optimal values of the aforementioned parameters, which will lead to achieving energy efficiency and improving the process economics of algal biomass conversion.

Materials and Methods:

The DOPS were solved by applying the orthogonal collocation on finite elements method. Here, the state (x) and temperature (T) profiles were approximated simultaneously using the Lagrange interpolating polynomials over the batch time, which was discretized into finite elements (FE) of equal lengths [3]. The collocation points (NC) reside inside each FE and were computed by evaluating the roots of the shifted Legendre polynomial of degree NC. This parameterization transformed the DOP into an NLP problem, which was solved using *fmincon* in MATLAB®.

Results and Discussions:

The DOP-1 was formulated considering the HTL of microalgae *Aurantiochytrium* sp. KRS101 for the maximization of the biocrude yield at a fixed batch time of 60 min subject to the model equations. These model equations are mainly the rate constraints, which follow first-order kinetics of dissociation of the individual components of microalgae such as proteins, lipids, and carbohydrates into biocrude, biochar, aqueous phase, and gas. Temperature was chosen as the control variable, which was constrained between 473 to 673 K. The DOP-1 was solved considering 6 FE and 14 NC. A base case was selected as a flat temperature profile maintained at 623 K for the entire batch time, which resulted in the final biocrude yield of 45.5%. For the determined optimal temperature profile, the final biocrude yield was increased to 49.4% as shown in Figure 1. Therefore, the DOP-1 produced a significant enhancement of 8.57% in the biocrude yield compared to the base case. Moreover, the batch HTL reactor operated at the base case required a thermal energy input of 186.9 kJ, whereas for the optimal temperature profile, it was reduced to 148.47 kJ as evident from the comparison of areas evaluated under the temperature versus batch time profiles in Figure 1.

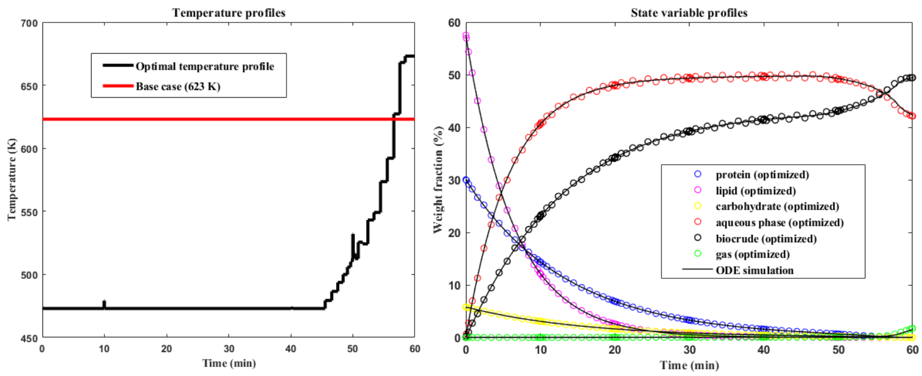

Figure 1. Comparison of the DOP-1 results with the base case for the batch HTL of *Aurantiochytrium* sp. KRS101.

Conclusion:

The DOP-1 solved for microalgae, *Aurantiochytrium* sp. KRS101, predicted an optimal biocrude yield of 49.4% in final time with a 25.8% lesser thermal energy requirement compared to the base case. The DOP-1 produced noticeable benefit from an economic perspective by producing maximum biocrude yield in final time while achieving significant thermal energy savings of the reactor compared to the base case study. Therefore, the DOP-1 is energy-efficient and the existing microalgae based biorefineries would generate higher profits by operating the HTL reactor along the optimal temperature profile.

PP003 - Blending of Algal and Non-edible oil for sustainable production of biodiesel using biochar catalyst – Optimization and Technoeconomic analysis

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ABSTRACT

The utilization of the marine macroalgae has gained lot of attention towards the production of biofuels and bioenergy due to their low cost of cultivation and presence of biological compounds. However, due to their low content of lipids than carbohydrates in macroalgae they have been much lower studied for biodiesel production than microalgae. To efficiently use the macroalgal lipids, blending them with non-edible oil was studied in this research work. Also, the biochar catalyst has been synthesized from the waste biomass for the transesterification reaction. The parameters for the reaction such as the blending ratio (A/N), Methanol to oil (M/O) molar ratio, catalyst concentration, temperature and time for the reaction was optimized using classical and statistical methods using response surface methodology (RSM). The kinetic study of the transesterification reaction was also done. Using the optimized conditions, the technoeconomic analysis was analyzed for industrial scale production of biodiesel. The process flow was simulated using the software and their economic factors such as NPV, IRR, payback period and ROI was evaluated. The sensitivity analysis to assess the uncertainty of the process was also studied.

Keywords: Blended oils, biochar catalyst, biodiesel, optimization, technoeconomic analysis, sensitivity analysis.

Background:

The research study mainly focusses on the biodiesel production from the blended algal and non-edible oils. The biochar catalyst used for the transesterification reaction was synthesized from waste coconut husk biomass. The reaction parameters were optimized using classical and statistical methods. The optimized parameters were used to simulate the process flow using the software and evaluate the economic factors using the model.

Materials and methods:

The marine macroalgal oil from *Ulva intestinalis* and non-edible oil from *Mimusops elengi* was blended with different ratios for biodiesel production using transesterification reaction. The waste cotton husk was pyrolyzed to biochar using muffle furnace. The biochar was further treated to doped with zinc and sulfonated to activate the catalyst. The parameters were optimized using response surface methodology. The process model was also simulated using the software.

Results and discussions:

The activated biochar catalyst was subjected to characterization using FT-IR, SEM-EDAX, XRD, TGA-DSC and BET analysis. The produced biodiesel was characterized to determine the presence of methyl esters using GC-MS analysis. The economic factors like NPV, IRR, ROI and payback period was also evaluated.

Conclusion:

The synthesized biochar catalyst shows better catalytic property in the transesterification reaction to produce biodiesel. The blending of algal and non-edible oil for biodiesel production will also helps to lower the cost of overall production and feedstock availability. The technoeconomic analysis results provide the positive results for scaling up the production to industrial level scale.

PP004 - Evaluation and characterization of indigenous fungal strains from Ethnic drinks for bioethanol production

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ABSTRACT

The global search for alternative, renewable, and sustainable fuels have increased due to industrialization, demographic expansion, and global warming. Biofuels, particularly ethanol, have gained attention due to their sustainable and low-polluting nature. The Indian government has implemented a mandatory 20% ethanol blend with gasoline as a part of a five-year plan. However, novel cultures with ethanol production are yet to be identified for a sustainable process. Therefore, the present study aimed to identify ethanol-producing strains from the local brewing cultures of Tripura's ethnic drink, which is prepared by a consortium of microbes obtained from different plant sources. The study involved isolation, screening, and molecular identification of the strains from the ethnic drink for ethanol production. The isolated strains were characterized for pH, temperature, and carbon sources and evaluated for bioethanol production under aerobic and anaerobic conditions. The study identified two strains of *Candida sojae* TEDI1 (Genbank accession no.: OQ788295.1) and *Candida parapsilosis* TEDI2 (Genbank accession no.: OQ788296.1) from the ethnic drink which contributed for ethanol production. The strains depicted optimal growth at pH 6, 30°C, with an ethanol yield of 0.31 g/g and 0.43 g/g, respectively in the presence of starch as carbon source under anaerobic conditions. The strains were also evaluated for ethanol production using complex carbohydrates obtained from microalgae. Screening for ethanol production in hydrolyzed biomass of *Chlorella sorokiniana* FWC1 with and without pigments produced 0.26% and 0.31% ethanol respectively by TEDI1, 0.32% and 0.38% by TEDI2. Thus, the study proposes these indigenous strains as potential sources for bioethanol production.

Background & Motivation

The search for renewable and sustainable fuels, such as biofuels, has increased due to industrialization, demographic expansion and global warming. The study aims to identify novel cultures for ethanol production by exploiting strains from a local ethnic drink used by the Tribal population of Tripura, India. The study involves isolation, identification, and evaluation of the strains for ethanol production.

Methodology

The study involved the following steps: isolating cultures from an ethnic drink, screening the cultures for their ability to produce ethanol under both aerobic and anaerobic conditions, molecularly identifying and characterizing the isolated cultures, and evaluating the growth of the identified cultures in media containing complex carbohydrates to assess their potential for ethanol production.

Novelty of the work

The novelty of this work lies in the identification of two Candida strains (Candida sojae TEDI1 and Candida parapsilosis TEDI2) from a local ethnic drink in Tripura that can potentially be used for bioethanol production. These strains were isolated, screened, and molecularly identified for their ethanol-producing capabilities from microalgae (Chlorella sorokiniana FWC1), and their growth conditions and carbon sources were characterized. The findings of this study suggest that these indigenous strains have the potential to be used for sustainable bioethanol production and can provide an alternative to traditional fossil fuels. Therefore, this work has significant implications for the search for alternative, renewable, and sustainable fuels.

PP005 - Optoelectronic sensitivity based investigation on LED inspired microalgae cultivation

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ABSTRACT

Microalgae use only the Photosynthetiacally Active Radiation (PAR) or the visible wavelength for photosynthesis. The remaining spectrum consisting of IR and UV present in sunlight is not utilized. Moreover, IR and UV radiations adversely affect the microalgae culture. As a result, although free and abundant, sunlight is not the best illumination option for microalgal cultivation. LED-based illumination for microalgae culture is gaining much research interest due to high microalgal biomass and lipid productivity. The narrow spectral band of LED is advantageous for the researchers to optimize microalgae culture conditions based on light wavelength, intensity and photoperiod. However, using conventional light meters to measure the LEDs intensity may cause major issues as Lux sensors are calibrated only to use for measuring ambient light. In the present study, three different light sensors with different spectral responses were used to measure the intensities of four different LED sources simultaneously.

Keywords: Biomass; LED; Light spectrum; Microalgae; Sensors.

Background

Recent advances in semiconductor technology have led researchers to focus on LED illuminated microalgal cultures, as LEDs have a narrow spectrum, and the microalgae can be grown using a specific wavelength. Light intensity plays a significant role in microalgae's growth and lipid accumulation. In LED based microalgae culture experimentations, researchers use different light sensors to measure and report the light intensity of the LEDs[2-4]. Conventional light intensity measuring devices like Lux/Fc meters are calibrated for ambient light using the CIE Photopic-curve, V(λ), thus having spectral sensitivity in the range of 520-600 nm with highest sensitivity at 555nm [5]. Using CIE optimized light meters to measure certain LEDs, like blue (400-450nm) or red (640-700 nm) could result in inaccurate readings as the instruments does not cover the wavelength spectrum of those LEDs. In this research, a novel approach of using three different light sensors having different spectral sensitivity are used to measure the light intensity of four different LEDs', cool-white (447-557 nm), pink (445-612 nm), blue (443 nm), and red (630 nm), simultaneously. This is done to reveal the difference in the sensor readings given by different sensors for the same light source and thus enlightening the importance of the spectral response of light sensors. In the experimentations, LEDs of different wavelengths were powered using different electrical input power and corresponding LED intensities at different power levels were measured by the three different sensors.

Materials and Methods

LED-based microalgae culture test setups were developed, for the experiments. The detailed construction and working of the setup were reported by Doljit et al.[6]. Four such setups were developed, fitted with four different commercially available LEDs (Crimson LED Strips, Goldmedal Electricals, India), namely, cool-white, pink, blue, and red. The culture setups are equipped with BH1750 light sensor (ROHM Semiconductor, Japan) interfaced with microcontroller to measure and record the light intensity autonomously. To validate the illuminance readings of the BH1750 at different power levels two light sensors namely, 1332 Lux/Fc Light Meter (Metravi, Taiwan), and MQ-510 full-spectrum Quantum sensor light meter (Apogee Instruments, USA) were used. The spectral response of the three sensors and the resulting illuminance readings were investigated.

Results and Discussions

Fig. 1(a-c) shows the light intensities of LEDs measured using different light sensors. The graphs showing intensities measured in Lux are obtained using the BH1750 and the 1332 Lux meter. As shown in Fig. 1a, both the sensors, BH1750 and 1332 Lux meter, give identical readings for the cool-white LED illumination; however, Fig. 1b, 1c, and 1d show that the Lux values for the same LED illumination are different when measured using the two sensors. The possible explanation causing this difference in reading is the spectral response of the two sensors. Light spectrum of the white LED lies within the spectral response of both the sensors, whereas, for the other colors, the LED spectrum falls out of the spectral range of the two light sensors. For instance, BH1750 is slightly more sensitive in the range of 450-500nm and 600-650 nm compared to 1332 Lux meter, thus producing higher values for pink, blue and red LEDs as shown in Fig 1 (b-d). In the same context, the blue LED has a very narrow spectrum with peak intensity in the 443 nm wavelength, which is way out of the 1332 Lux meter's spectral response (510-615 nm), resulting in a very low reading for the blue LED illumination, as shown in Fig. 1c.

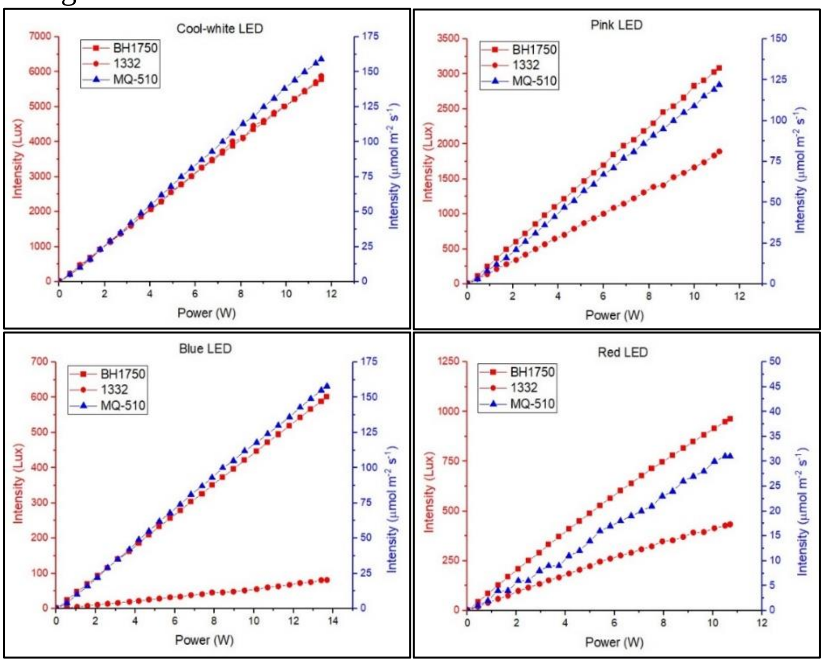

Fig. 1 Intensity measured using three sensors for **a)** cool-white LED, **b)** pink LED, **c)** blue LED, and **d)** red LED. The graphs with square (■) and circle (●) symbols are intensities measured in Lux, whereas the graphs with triangle (▲) symbols is measured in $\mu mol m^{-2} s^{-1}$.

Contrary to the BH1750 and the 1332 Lux meter, the MQ-510 has a wider spectral response (400-700 nm) covering the entire visible radiation. This makes the MQ-510 more suitable for measuring the intensity of a wide range of LEDs. As a result, it is evident that the spectral response of a light sensor creates a significant difference in LED intensity measurements, as different sensors behave differently for different LEDs. Consequently, when using conventional light sensors in LED-based culture experiments, the light sensors must be calibrated with Quantum sensors for each type of LED being investigated separately.

Conclusion

The spectral response of the light sensor plays a significant role in the accuracy of measuring LED light intensities. In the case of using conventional light meters to measure LED intensity for experimentation and to output the results in terms of photon flux ($\mu molm^{-2}s^{-1}$), it is crucial to establish an empirical relationship between conventional light sensors with Quantum sensors for each and every target LEDs.

PP006 - Strategies, Innovations and Uncharted Routes for Robust Algal Systems for Energy & Environmental Applications

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ABSTRACT

The potential of algae is highly radical that people have been working over the years to develop technologies for economically viable algae production for food, feed, polymers, fuel and for the concurrent treatment of (waste)waters. To get algae into mass production and product-based approach applied microbiology laboratory (AML) at Indian Institute of technology (IIT) Delhi has created a whole technological suite that makes algae production economically viable by developing a plethora of new innovations to take on the challenges head-on. In this talk, the state-of-the-art research methodologies and technologies developed by AML researchers over the last decade will be presented.

AML developed suitable strategies and designs to overcome conventional challenges such as low productivity, large footprint, energy intensive harvesting and processing, low product recovery etc. With right selection of the algal-bacterial consortia and cultivation system design, significant biomass yields, treatment capacities and safe partitioning of hazardous contaminants can be obtained (Naaz et al., 2021). Meticulous photobioreactor designs can offer inbuilt resilience against extreme environmental conditions and prevent system crash (Dalvi et al., 2021). Apart from wastewater treatment and energy production, AML has trodden into the territory of algal food, rapid harvesting systems, algal based air purification systems and applications of algal consortia with diatoms for the treatment of industrial thermal power plants. A unique biomolecule driven algal-fungal interaction can (Bhattacharya et al., 2019) helped address the twin problem of algal harvesting and cell wall degradation for easier bioenergy production (Prajapati et al., 2016). This rapid bio-harvesting technology utilizing algal-yeast interaction is transformed as nutritional food source which are consumer friendly foods such as cookies and breads. AML has also successfully demonstrated the use of algal biochar obtained from biomass cultivated in biogas waste slurry for elimination of high concentration of TVOC’s, HCHO and particulate matter with high reusability and high efficiency. Such interventions can address constraints in establishing an environmentally preferable circular biobased economy with a great potential to recover resources and diversify livelihood options.

PP007 - Acidogenesis of food waste for biohydrogen production integrated with algal biorefinery

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ABSTRACT

The study aims to the maximal valorisation of food waste employing acidogenesis and photosynthesis in the biorefinery framework. Food waste was thermo-chemically pretreated for converting soluble reducing sugars from food waste which was utilized for the bioH_2 and volatile fatty acid (VFA) production employing acidogenic bio-system. A total of 220 L day^{-1} bio-H_2 was obtained along with 14 g L^{-1} of VFA composed of acetic acid, propionic acid and butyric acid. The obtained acidogenic outlet with VFA was further valorized utilizing micro algae for simultaneous production of biomass rich in carbohydrates, protein and lipids utilizing mixotrophic mode of cultivation. The algal-treated water was further used to irrigate the plants and biomass can be utilized for fertilizer purpose or animal feed.

Keywords: *Dark fermentation; Pretreatment; Biofuels; Low Carbon, Waste bio-processing*

Materials and Methods

Inoculum

The Anaerobic sludge utilized in this study was obtained from the Amberpet sewage treatment plant in Hyderabad. Prior to its application, the sludge underwent a physical screening process, involving filtration using a stainless steel mesh. This step aimed to eliminate grit, wood pellets, and hair present in the sludge. To promote the growth of active bacterial populations, the filtered sludge was then subjected to incubation at room temperature. During this incubation, a synthetic media containing glucose was introduced to the sludge. Every fourth day, the fermented media was replaced with freshly prepared media to ensure optimal conditions for bacterial activity. A portion of the sludge (1L) underwent heat-shock pre-treatment to inhibit the growth of methanogenic microorganisms. This pre-treatment involved subjecting the sludge to temperatures ranging from 80 to 90 degrees Celsius for a duration of 2 hours. The heat-shock pre-treated sludge was labeled as PT (Venkata Mohan et al., 2008).

Foodwaste

The substrate employed in this study was food waste (FW) obtained from the institute CSIR-IICT in Hyderabad. The institute generates approximately 40-50 kg of FW per day, consisting mainly of cooked rice, boiled vegetables, vegetable peels, spoiled fruits and vegetables, as well as egg and meat waste. Before being used as a substrate, the FW underwent a process of homogenization using a wet-mixer and was subsequently filtered through a stainless steel sieve. The homogenized FW was then characterized to determine its organic content, which measured at 160 g COD/L. Additionally, other compounds were identified, including trace amounts of lactic acid (0.08 g/L), acetic acid (0.25 g/L), propionic acid (0.04 g/L), and butyric acid (0.09 g/L). To establish the desired organic load, the COD concentration of the FW was diluted using tap water. This diluted FW was then utilized as the substrate for the production of H_2.

Experimental Procedure

The experiments were conducted using 50 L glass reactors, with a working volume of 36 L and a headspace of 14 L. The headspace of the reactors was connected to gas bags. The reactor were inoculated with PT culture, with an inoculum loading of 10% (v/v). The reactor receiving PT culture was designated as PT (50 g COD/L), dosed with the quantity of FW as specified for the reactor. The PT reactor were operated for a specific duration for the same period of time. All reactors were maintained at a temperature of 35°C in a suspended growth configuration. Temperature control was achieved using a water bath, and all reactors were equipped with top stirrers to facilitate mixing. The initial pH of the reactors was adjusted to 7 using 0.1 M HCl/NaOH solutions. To maintain anaerobic conditions, N_2 gas was sparged into the reactors for a duration of 20 minutes.

Results and Discussion

Bio-hydrogen ($BioH_2$)

The production of $BioH_2$ from FW at different organic loads (OL: 50 g COD/L) was examined. Acidogenic reactors were operated for a duration of end of days until a steady production rate was attained. The $BioH_2$ production showed a gradual increase over time and varied depending on the specific OL used. $BioH_2$ production commenced as early as 4 hours, and by the 12-hour mark, the cumulative hydrogen production (CBHP) reached 220 L. As the fermentation cycle progressed, the production continued to rise in the reactor, ultimately reaching a maximum at the end of the cycle.

VFA Production

During the acidogenic fermentation process, volatile fatty acids (VFAs) were co-generated alongside $bioH_2$. The total production of VFAs increased gradually as the fermentation time progressed. At the end of the cycle, the highest VFA concentration observed was 14 g/L. The higher VFA production in the PT reactor can be attributed to the presence of enriched acidogens and the availability of substrate for their growth and metabolism. In contrast, the lowest VFA concentration recorded, which was 8 g/L, may be due to suppressed microbial metabolism. The composition of the total VFA mainly consisted of acetic acid (C_2), propionic acid (C_3), butyric acid (C_4), and valeric acid (C_5). The PT reactor exhibited the highest production of C_2-C_4 VFAs among the reactors, indicating a favorable environment for the production of these specific acids.

Substrate conversion

The calculation of Hydrogen conversion efficiencies (HCE) was conducted, taking into account the substrate utilized for $bioH_2$ production, as described in the study by Sarkar et al., 2021a. The PT reactor exhibited a higher substrate (COD) utilization efficiency of 60%. A strong correlation between substrate utilization and $bioH_2$ formation was observed in the UT reactors (R^2 = 0.99), indicating a close relationship between the two variables. In comparison, the correlation in the PT reactors was slightly lower (R^2 = 0.91), indicating a slightly weaker association between substrate utilization and $bioH_2$ production.

Conclusion

The study aimed to evaluate the production of bio-H_2 derived from FW. Various combinations of bioH_2 from PT (0.021 g H_2/g COD) was examined. The results demonstrated that the optimal combination led to the highest production of bio-H_2 reaching 220 L. An energy content of 8.1 kJ/g COD. These findings indicate that the FW has the potential to replace fossil-based, offering a renewable and environmentally friendly alternative.

PP008 - Integrated One-Pot Process for Simultaneous Biomass and High-Value Biochemical Production in *Phaeodactylum tricornutum*

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ABSTRACT

Phaeodactylum tricornutum is a single-celled pennate diatom exhibiting a unique silicated cell wall with characteristic golden-brown color. These intricate glass cells exhibit an innate ability to synthesize commercially significant bioactive compounds, viz. lipids, PUFAs, and pigments. Thus, there has been increasing interest in employing the diatom *P. tricornutum* at an industrial scale for feed, food, and functional molecule application. Although *P. tricornutum* is recommended as a promising biofactory due to its high nutritional value and potential sustainable feed source, some obstacles exist towards achieving their maximum yields. The current study entailed developing a one-pot media recipe towards augmenting *P. tricornutum* ability to synthesize and accumulate desired functional biomolecules. Plackett–Burman's design screening identified $NaNO_3$, NaH_2PO_4, and glycerol as positively impacting nutrients influencing the biomass, lipid, EPA, and fucoxanthin content in *P. tricornutum* biomass. The optimum concentration of identified nutrients was achieved by Central Composite Design for maximum biomass with significant lipid, PUFA, and pigment content. A maximum of 2.42 g/L biomass, 532.48 mg/L lipids, 141.13 mg/L EPA, and 1.23 mg/L fucoxanthin was produced using optimum nutrient concentrations representing >100% validity of the model prediction concerning biomass, lipid, PUFA, and pigment, respectively. The present study established a one-pot media design to deliver *P. tricornutum* as a versatile diatomic species with enhanced lipid, PUFA, and pigment content for functional molecule applications.

Key Words: Biomass, Eicosapentaenoic acid (EPA), Fucoxanthin, Lipid, *Phaeodactylum tricornutum*

Background:

P. tricornutum provides an emerging source of functional ingredients, such as omega-3 fatty acids, pigments, and other nutraceuticals. *P. tricornutum*, thus, has a wide range of applications as a dietary supplement due to its high functional nutritional value. However, there is a pressing need to maximize *P. tricornutum* biomass yield and productivity while enhancing its lipid and pigment contents to substantiate its influential role as a food and functional molecule resource. Thus, the current work focused on developing a one-pot media recipe to augment lipids, PUFA, and pigment synthesis and enrichment in *Phaeodactylum tricornutum* biomass as a potential functional molecule resource.

Materials and Methods:

Based on preliminary experiments, nutrients; $NaNO_3$ (A), NaH_2PO_4 (B), Trace metal salts (C), Vitamins (D), and Glycerol (E) were selected for Plackett–Burman design at two concentrations (high and low). Fourteen experiments were formulated using five nutrients, and responses were measured regarding Biomass, Lipid, EPA, and fucoxanthin content. Once the effective nutrients were identified from the Placket–Burman design, the combined effect of selected media components ($NaNO_3$, NaH_2PO_4, and Glycerol) was elucidated by the Response Surface Methodology to establish the interaction of these media components on Biomass, Lipids, EPA, and Fucoxanthin production. Cells were harvested on the 8th day of cultivation and analyzed for DCW, Lipids [1], EPA [2], and Fucoxanthin [3].

Results and discussion:

Enhancing *P. tricornutum* biomass production with significant lipid, PUFA, and pigment content by employing growth and media engineering strategies is crucial in developing functional foods. Herein, Plackett–Burman's design was adopted to select the essential nutrients influencing the lipid, PUFA, and pigment content in *P. tricornutum* biomass. Further application of Central Composite Design (CCD) to the design matrix established mathematical model equations by studying responses and demonstrated the optimum concentrations of the critical nutrients for higher biomass with significant lipid, PUFA, and pigment contents. Cultivation of *P. tricornutum* in this optimized media (Opti-f/2) enhanced its biomass, lipid, EPA, and fucoxanthin content by 67, 48, 87, and 84%, respectively, to its original media (f/2) composition.

Conclusion:

Adopting a one-pot media engineering approach towards lipid, PUFA, and pigments enriched *P. tricornutum* biomass necessitated screening and optimizing the essential nutrients influencing the lipid, PUFA, and pigment content in *P. tricornutum.* Development of optimized f/2 media design ($NaNO_3$- 660 mg/L, NaH_2PO_4- 52 mg/L, TMS- 5X, Vitamins-5X and Glycerol- 0.05 M) by employing statistical media optimization for *P. tricornutum* cultivation yielded a lipid, PUFA's and pigments enriched *P. tricornutum* biomass.

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PP009 - Waste algae to biomethane for reducing greenhouse emissions from eutrophic lake

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ABSTRACT

Algal blooms in lakes is well-known ecological problem, due to nutrient pollution. This can result in ecological, economic, and health consequences, including decreased water quality, oxygen depletion, and toxin release that can harm aquatic life and humans. Algal blooms also contribute to greenhouse gas (GHG) emissions and climate change. Biomass in lakes is increasing rapidly every year. Due to its high lipid and carbohydrate content, rapid growth rate, and ability to grow in various environments it has been identified as a promising feedstock for biomethane production [1][2]. Study conducted year-round on Hauz Khas Lake, India. During study period, the average recorded biomass concertation was in the range of 2.0 - 4.5 gL^{-1}. In the summer, the volumetric and specific biogas yields have been reported to be, 0.45 to 0.65 m^3 day^{-1} and 0.72 to 1.04 m^3 kg^{-1} VS_{fed} day^{-1} respectively. The average methane yield was found to be around 56% [3]. In lab scale cultivated algal biomass, theoretical methane output potential was reported 504 mL g^{-1} VS, indicating a digestibility of 58.5%[4]. Theoretical carbon dioxide (CO_2) sequestration from algae is around 1.2 Kg CO_2/Kg of biomass. Furthermore, after taking sequestration and production both into consideration GHG potential of algal biomass found to be 5.856 Kg CO_2-equivalent, which makes it very serious environmental problem. Study shows algae has great potential to reduce GHG from lake and replace fossil fuels to meet energy requirements with lesser carbon footprint. Comprehensive investigations are suggested to evaluate GHG potential and mitigation.

Keywords: Anaerobic digestion, Biomethanation, Eutrophication, greenhouse gas potential nutrient pollution, Waste Algae

Background:

Eutrophication, a process caused by excessive nutrient pollution in water bodies, can lead to an overgrowth of algae and aquatic plants. When these plants decompose, it can lead to low oxygen levels and the production of greenhouse gases such as methane and carbon dioxide. Waste algae from eutrophicated lakes is a potential source of renewable energy in the form of biomethane, which can be produced through anaerobic digestion. The greenhouse gas potential of waste algae from eutrophicated lakes is an area of active research, as it offers a potential solution to the environmental problems caused by eutrophication while also providing a renewable energy source. Understanding the greenhouse gas potential of waste algae from eutrophicated lakes can help identify its potential as a sustainable energy source and inform efforts to mitigate the negative impacts of eutrophication on the environment and global climate.

Material and Methods:

The GHG potential of microalgae was calculated through theoretical considerations of CO_2 sequestration and CH_4 production during the cultivation and processing of microalgae biomass in natural and controlled environment. Microalgae sequester CO_2 during photosynthesis and release oxygen (O_2), which was estimated by subtracting the CO_2 released during respiration from the amount consumed during photosynthesis. Microalgae biomass can also be converted to biomethane via anaerobic digestion, with the amount of CH_4 produced estimated based on the biochemical methane potential (BMP) of the biomass and the efficiency of the anaerobic digestion process. Volatile solids (VS) play very important role BMP. The GHG potential of microalgae can be calculated by subtracting the amount of CO_2 sequestered from the amount of CH_4 produced. Global warming potential (GWP) is multiplied to get net GWP of gas. A negative value indicates a net reduction in GHG emissions, while a positive value indicates a net increase. In lakes case positive results were found.

Results and Discussion:

CO_2 consumed by most of microalgae lies between 1.8-2.4 Kg/Kg of biomass depending upon type of species and growth conditions. Furthermore, loss in respiration is around 0.6-1.2 Kg of CO_2/Kg of biomass. Although few species like Chlorella vulgaris takes up to 4 Kg. If we take former as reference and calculate CO_2 sequestration, it comes out to be 1.2 Kg CO_2. CH_4 produced came out to be 0.252 Kg/Kg of biomass. It was found that GHG potential was 5.856 Kg CO_2-equivalent/ Kg of biomass which can contribute climate change.

Conclusions:

Waste algae from eutrophicated lakes has significant potential for GHG mitigation through the production of biomethane. By harnessing the biomethane potential of waste algae from eutrophicated lakes, these GHG emissions can be mitigated while providing a renewable energy source. The GHG potential of waste algae is influenced by various factors, such as nutrient content, algal species, and harvesting methods. This makes waste algae a promising candidate for sustainable energy production in regions with high nutrient pollution and eutrophication problems. Further research is needed to optimize biomethane production and determine the economic feasibility of large-scale production.

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PP010 - Modulating nutrient regimes to augment photosystems and metabolite synthesis in microalgae

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ABSTRACT

Microalgae, as a cutting-edge resource, have the potential to address various global demands and alleviate environmental pressures. They are a diverse group of microscopic organisms that offer not only treatment but also additional health benefits, as they contain various bioactive compounds. Two microalgal cultures *Chlorella sorokiniana* SVMIICT 8 and *Tetradesmus* sp. SVMIICT4 were grown mixotrophically using dairy wastewater as a nutrient source to understand the photosynthetic transients and quantum yields in terms of its biomass. Photosystem complexes (PSII and PSI) and Chlorophyll (Chl) a fluorescence induction (Fv/Fm, ETo/RC, and Abs/RC) deduced through OJIP transients depicted improved growth concomitantly with significant reduction of organic pollutants. The absorption flux per reaction centre (ABS/RC) showed a significant rise due to higher chlorophyll content resulting in higher electron transport and less light dissipation, as evidenced by ET/RC and non-photochemical quenching (NPQ). Integrated wastewater treatment showed good COD (95.5%) and nutrients (Nitrates -65.2/Phosphates -57.35%) removal efficiency accounting for biomass (2.38 g L-1) with substantial accumulation of carotenoids (16.36 mg g−1), carbohydrate (21.48 mg g−1) and protein (19.52 mg g−1). Algae-lipids showed biodiesel properties with a relatively higher number of USFA over SFA with lipid productivity of 0.112 kg/kg of biomass. Utilizing wastewater as nutrient source makes the process economically feasible and facilitates pollutant uptake, resource recovery and valorisation of algal biomass for energy and chemical intermediates in biorefinery framework.

Keywords: *Photosystem complexes;DUAL-Pulse amplitude modulator (DUAL-PAM);Biomolecules; Lipids* and *Bioeconomy*

PP011 - Exogenous supply of growth modulator to uncouple growth with energy reserved compound accumulation in *Scenedesmus spp.* Under various long-term stress conditions and to acquire an integrated biorefinery approach

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ABSTRACT

Microalgae have the potential to accumulate high-energy-reserved compounds such as lipids and carbohydrates. The concentration of these compounds increases in various environmental stress conditions such as nitrogen, phosphorous starvations, and salinity stress. However, such conditions lead to arrest growth. Previous research showed that the exogenous supplementation of growth modulators can uncouple growth and energy-reserved compound accumulation for a short-term period (3-4 days). In the current study, we investigate the uncoupling of the accumulation of lipids and carbohydrates content with normal growth of *Scenedesmus* spp. by supplying exogenously 1:10 time diluted seaweed extract (*Kappaphycus alvarezii*) under various environmental stress conditions for a long-term period (9 days). The results indicated that on the 9th day in nitrogen starvation conditions, biomass concentration was enhanced by 2.14-fold (146 mg/L), in phosphorous starvation by 1.52-fold (178 mg/L), and in salinity stress by 1.52-fold (88 mg/L) increases compared to the controls. At the same time, lipids and carbohydrate content were also higher in all the stress conditions. Altogether this study presents positive results for exogenous-supplied seaweed extract. It is playing important role in producing normal growth along with higher lipid and carbohydrate productivity in the *Scenedesmus spp* for a long period of cultivation. Additionally, we performed a multiple-product extraction from single biomass by applying an integrated biorefinery approach. This study highlights the improvement in terms of better yield of biomass and biofuel with other industrially important compound production in a commercial setup.

Keywords: Biofuel, Biorefinery, Growth modulator, High energy-reserved compounds, Microalgae.

Background:

Microalgae is well known for biofuel and bioenergy production. Increasing biofuel productivity by applying exogenously seaweed extract as a growth modulator to the microalgae in various stress conditions leads to improving high energy-yielding compounds productivity with enough amount of biomass. The second thing is to overcome the production cost by acquiring an integrated biorefinery concept and increase the more industrially feasibility.

Materials and Methods:

The experiment was carried out in 500ml of BG-11 medium having nitrogen, phosphorous, and salinity stress with positive and negative control conditions in a triplicate manner for 9 days. The growth was measured by the dry cell weight method, Pigment, and carbohydrate content estimated according to Chokshi et al. 2017. Lipid content was estimated following Sanjiv et al. 2013 and Protein content was estimated according to Paliwal et al. 2021.

Results and Discussions:

Treatment	Biomass (mg/L)	Fold change	Biomass productivity (mg/L/D)	% Lipid	% Carbohydrate
BG-11(N-)	68.52	1.00	6.06	18.8	36
BG-11(N-) + 1% sap	146.75	2.14	13.68	21.4	36.2

(Table 1: Biomass productivity with lipid and carbohydrate content in *Scenedesmus spp*. After 9 days of cultivation.)

In nitrogen stress conditions after 9 days of cycle biomass content increased by 2.19-fold and biomass productivity increased by 2.25-fold compared to the control condition meanwhile lipids content was around 3% increase and carbohydrate content was almost the same as compared to the control. Here, 1% sap (1:10 diluted) plays an important role in stress conditions as a growth modulator to uncouple growth with lipids and carbohydrate accumulation.

Conclusion:

This study gave positive results for exogenous-supplied seaweed extract and it is playing an important role in uncoupling of normal growth with higher lipid and carbohydrate accumulation in the microalgal cell stress condition for a long period of time. The idea of acquiring an integrated biorefinery approach that increases the suitability of microalgae for commercialization.

Acknowledgment:

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PP012 - Valorization of Aqueous Phase derived from Hydrothermal Liquefaction of Algal Biomass

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ABSTRACT

Algae has emerged as a sustainable source of biofuel production and other value-added products. Several technologies are being explored for the conversion of algal biomass to biofuel. Among the various available technologies, hydrothermal liquefaction (HTL) shows promising commercial potential to produce biofuel from wet algal biomass. Furthermore, this technology can be proven more profitable if all the by-products are used to their full potential. The end products of HTL are bio-oil, biochar, aqueous phase (AP), and gas. In the HTL process, nearly 25-50% AP is generated, which is considered a waste stream and can cast doubt on the possibility of scaling up HTL technology.[1] AP is an untapped source of nutrients, energy, and valuable chemicals. The distribution of nutrients and other valuable resources in AP is majorly dependent on the HTL processing parameters. Hence, this review focuses on a better understanding of the HTL mechanisms involved in the nutrient distribution among the end products. The influence of process parameters (temperature, biochemical composition, biomass loading, initial pressure) on the composition of the AP has also been discussed. The methods to recover the nutrients (nitrogen and phosphorous) and valuable organic compounds have been compared. Furthermore, this paper also includes a discussion on other methods to valorize AP (biomass cultivation, fertilizer, anaerobic digestion).[2] The paper concluded that constraints of HTL for scaling up can be overcome through the efficient valorization of AP.

Keywords: *Algae, Aqueous Phase, HTL, Nutrient recovery, Valorization.*

Background

HTL technology has some limitations, including aqueous phase formation and a challenging commercial scale-up process. AP generally has high COD, nutrients, and certain chemicals such as sugars, acids, ketones, furans, alcohols, N-heterocyclic compounds, and cyclic hydrocarbons etc. Hence AP can be used to produce biofuels, chemicals, and fertilizers.

Methodology

A general search was done to find the studies carried out in this area by reading a number of published papers. The available scientific data and information were collected and tabulated systematically. A scientific draft was written by analyzing the tabulated information.

Result and discusión

Some work has been done in this field where researchers showed the potential of AP as a growth medium, in energy production, for the recovery of nutrients, and for making fertilizer. AP having high COD is generally explored for energy production through anaerobic digestion. High nutrient-loaded AP is suitable for nutrient recovery and for fertilizer production.

Processed AP can further be used as a growth medium for microbes. In Figure 1, the possible ways of AP valorization have been depicted based on the current state-of-the-art review. Despite of these works, maintenance of the toxicity of AP and the recovery of valuable chemicals still needs to be explored.

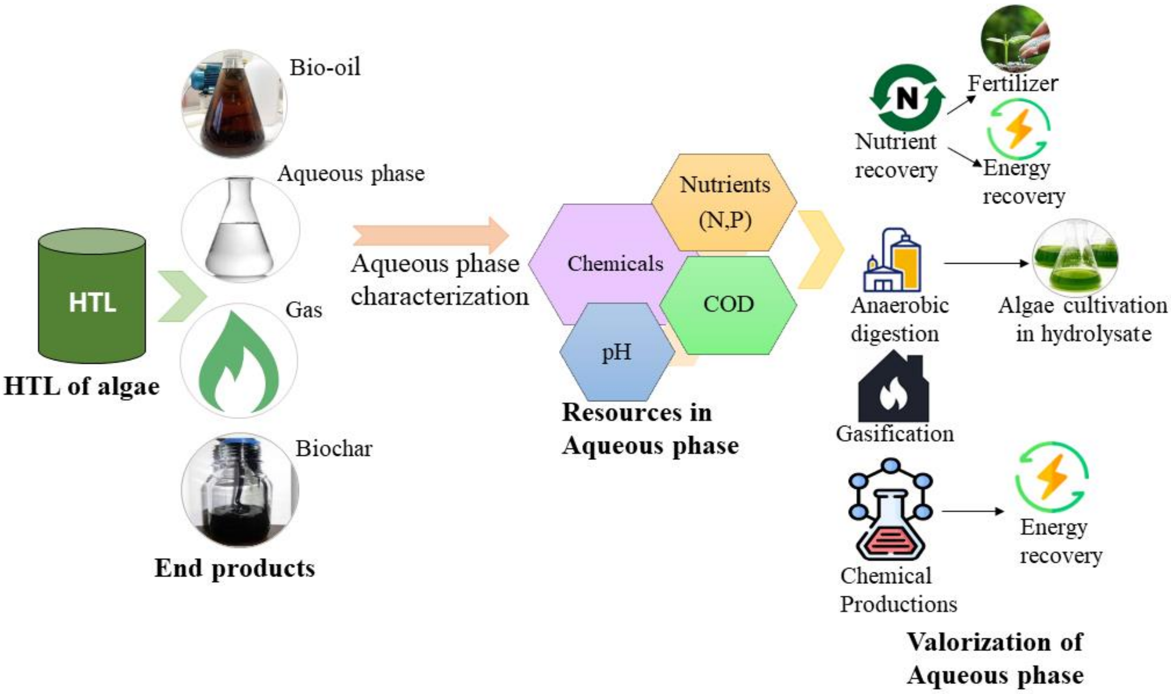

Figure 1: Schamtic represntation of possible process of valorization of aqueous phase from algal-HTL

Conclusions

Overall, valorization of the aqueous phase from HTL of microalgae can improve the economics and sustainability of the process, by recovering valuable products and reducing waste. By exploring the most suited valorization routes for AP, commercialization of HTL can be done. This work has scope of developing some integrated model having potential for HTL-AP valorizations.

Acknowledgments

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PP013 - Indoor Air Purification using Non-Activated Microalgal Biochar with Diatom Embedment for Removal of Particulate Matter, Formaldehydes, and Total Volatile Organic Compounds (TVOC's)

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ABSTRACT

Indoor air pollution caused by harmful components such as TVOC, HCHO, and particulate matter has resulted in negative impacts on respiratory health and reduced life expectancy. Biochar, which is produced from organic feedstocks such as wood and agricultural waste, has been studied as a potential solution to remove particulate matter and volatile organic compounds from the air due to its high surface area and porosity. However, other sources of biochar have limitations such as high turnaround time, pre-treatment requirements, and low porosity. To address these issues, a novel indoor air scrubbing tube has been designed using diatoms embedded microalgae biochar cultivated on waste biogas slurry. Considering this, we have designed a simple first of its kind indoor air scrubbing tube based out of diatoms embedded microalgae biochar cultivated on waste biogas slurry. Scrubbing tube of packed column length of 5 cm has capacity to filter air at the rate of 1ft^3/sec. VOC's removal efficiency was obtained at 99.99% at very high concentration of 1.50 HCHO (mg/m^3) and 9.57 TVOC (mg/m^3) and PM 2.5, PM10 and PM1 removal efficiency was 80%, 92% and 65% respectively. However, gradual decrease in PM removal is observed after 90 minutes. Additionally, the biochar was prepared from microalgae cultivated in discharged biogas slurry in an 100L pilot plant making it a self-sustainable and feasible process to implement making it a novel green approach.

Keywords: Biochar, Volatile Organic Carbons, Particulate Matter, Microalgae, Indoor Air Pollution

Background:

Air pollution, an eminent threat, is being studied intensively. Pollutants such as SOx, NOx, PM 2.5, PM 10. Biochar is conventionally used for contamination removal from wastewater. Less heed has been given to use of biochar in gas scrubbing for SOx, NOx and particulate matter that are high in concentration effluent from industries and automobiles. Removal of hydrogen sulphides and carbon dioxide sequestration have been studied so far using microalgal based biochar [1]. Removal of the particulate matter and other gases is novel approach for the application of biochar obtained from microalgal biomass from wastewater treatment. Additionally, improvement in terms of economic feasibility of the overall process. Approach for the solution will be production and optimization of graphene-oxide (GO) based Biochar-GO filter for the removal of PM 2.5 and PM 10. Further presence of high nutrient content and ion-exchange capacity, waste biochar will also used as soil amendment for agriculture purposes or adsorbents in wastewater treatment [2, 3]. Multiple technologies are being implemented such as algal bio- curtains, Algen Air (Indoor Air Purifier), Algal Cells, Microfluidic Algal bioreactor. All are based on live algal culture systems. Studies has been conducted using live algal biofilms on cotton canvas where the particulate matter removal did occur but on day 1 itself. Later Moisture loss efficiency of microalgae and hydrogel reached 83.95% and 19.13%, respectively, when exposed to the ambient environment for 8 hours, showing that hydrogel has much better moisture retention capacity than microalgae biomass and all have common issue moisture loss. [4]. Rural sector suffers with air pollution from burning of husk and affects the lungs and respiratory system of farmers and children. Additionally, workers working in coal mine are major sufferers here which requires a cheap and sustainable solution.

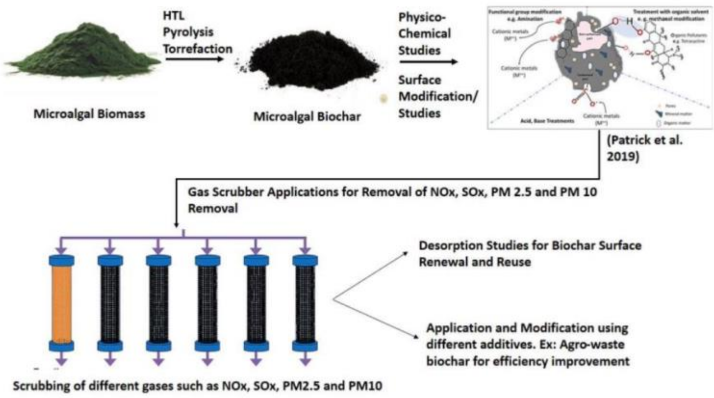

Figure 1: Research outline of the work

Material and Methods

1. Feedstock procurement

The feedstock microalgal biomass used in present stage was produced in 100 L pilot scale photobioreactor installed at Biogas and Bottling Laboratory, Gramodya Parisar, Centre for Rural Development and Technology, IIT Delhi.

2. Biochar Production

The pyrolysis studies were performed in a muffle furnace to generate biochar from powdered microalgal biomass. The pyrolysis experiments were performed in an inert atmosphere w using nitrogen gas. The 20 g raw microalgal biomass were manually fed into the furnace. Following that, the reactor was shut down, and an inert environment was given by a 0.08 L/min nitrogen gas supply. The pyrolysis runs began at a ramp temperature of 5 °C/min. All runs were completed in two steps: heating the sample and an isothermal reaction phase that kept the target temperature (300 °C, 500 °C, and 700 °C) constant for 1 h. After 60 minutes of, the system was turned off and cooled to room temperature.

3. Microalgal biomass and biochar characterization

The microalgal biomass and biochar characterization was done in terms of proximate and ultimate analysis followed by BET, XRD, FTIR, FESEM and EDX studies.

4. Experimental Setup

Air testing filter unit was fabricated using 8mm thick acrylic sheet. It consisted of two units, the inlet and outlet chamber having dimensions of 10in × 10in × 10in. The chambers were airtight with inlet and outlet chamber fitted with 12V DC fans to generate pressure difference across the filters. Face opposite to the 12V DC fans was cut out in circle to install filters across the chambers. The junction and top of the chambers were sealed airtight via nut-bolt embedded in the chamber and the lid.

Results and Discussion

Scrubbing tube of packed column length of 5 cm has capacity to filter air at the rate of $1ft^3$/sec. VOC's removal efficiency was obtained at 99.99% at very high concentration of 1.50 HCHO (mg/m^3) and 9.57 TVOC (mg/m^3) and PM 2.5, PM10 and PM1 removal efficiency was 80%, 92% and 65% respectively. However, gradual decrease in PM removal is observed after 90 minutes. Additionally, the biochar was prepared from microalgae cultivated in discharged biogas slurry in an 100L pilot plant making it a self-sustainable and feasible process to implement making it a novel green approach. Figure 2 shows removal of HCHO and TVOC's using microalgal biomass.

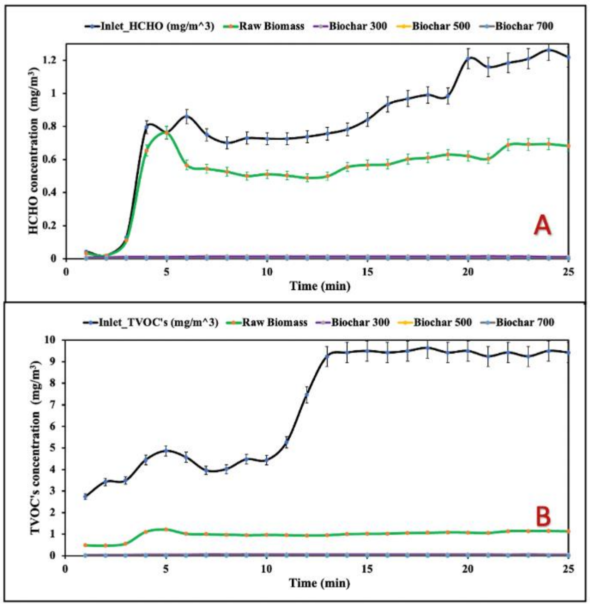

Figure 2: Removal studies of (A) HCHO using biochar pyrolyzed at different temperatures. B) TVOC's removal studies using biochar pyrolyzed at different temperatures

Conclusion

We were able to effectively show the removal effectiveness of biochar for TVOCs, and HCHO, which are important indoor pollutants. However, it was also established that removal of PM using microalgal biochar still possess challenge as choking is the main roadblock in filter systems which is also persistent here. Algal biochar has a high concentration of functional groups in the form of -OH and -NH2 groups, which have the ability to remove VOCs and HCHO.

Acknowledgement
Authors highly acknowledge the Prime Minister Research Fellow (PMRF) research grant aid for the execution of the project. The authors also acknowledge support of Central Research Facility (CRF), IIT Delhi for FTIR. Authors appreciate the support of Mr. Sabal Singh, Mr. Mahesh for their assistance in setting up the pilot scale reactor on site.

PP014 - Design and operation of a pilot-scale integrated system sparged with flue-gas CO_2 generated *in situ* for microalgal cultivation in an algal-biorefinery

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ABSTRACT

Excessive dependence on fossil fuels has triggered the burning issue of global warming driven climate change, caused mainly by anthropogenic CO_2 emissions from industries like thermal power plants as point sources. Due to this, the Governments and the major CO_2 emitting industries are looking for suitable technological solutions for carbon capture and utilization (CCU). Among the various CCU strategies known, strategic carbon capture using tiny photosynthetic cell factories like microalgae has emerged as one of the most efficient and green solutions. The present study is focused on the design and operation of a demonstrable 2000 L High-Rate Algal Pond (HRAP) open reactor system integrated with a flue gas generator via a 200 L Bubble Column Absorber for enhanced CO_2 delivery and biomass production. This flue gas generation system is designed with the unit operations required to overcome the inhibitory effects of several other components of flue-gas on biomass cultivation. Operation of this pilot-scale integrated microalgal biomass production facility in semi-continuous mode holds a lot of promise as a precursor of an innovative technological solution that can offer multiple benefits in terms of CCU, wastewater valorization and algal biomass generation for biofuels and value-added products in a biorefinery model.

Keywords: Pilot scale algal biomass production facility, Design and operation, *In situ* flue gas generation system, High-rate algal pond (HRAP), Bubble Column Absorber, Carbon capture and utilization (CCU), Algal biorefinery

PP015 - Algal Sheets; A Sustainable - Green Technology for Carbon Capture

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ABSTRACT

Anthropogenic activities had led to an increase in the levels of carbon dioxide in the atmosphere. Hence the mitigation of carbon dioxide from atmosphere is necessary to reduce the effect of global warming and greenhouse gases. Micro-algae possess the natural ability to sequester carbon dioxide from atmosphere. Here we present an algal sheet from micro-algae, *Phormidium valderianum* embedded within the alginate hydrogel and crosslinked with calcium chloride for carbon dioxide sequestration. The carbon dioxide acts a source of carbon for the algal growth. The mechanical, rheological properties of the algal sheet were studied to study the influence of resulting hydrogel on algal growth. The addition of crosslinking agents and plasticizers enhanced the strength of algal sheet. The immobilization of microalgae within the hydrogel protects the algae from harsh environment. This paper focusses on investigating the carbon dioxide capturing ability of *Phormidium valderianum* in the form of algal sheets from atmosphere.

Keywords: Algae, Algal sheet, Carbon dioxide sequestration, Hydrogel, Optimization

Materials and Methods:

The algal biomass of *Phormidium valderianum* BDU 10121 was purchased from the National Facility for Marine Cyano- bacteria (NFMC), Bharathidasan University, Tamil Nadu, and was cultured using the artificial sea nutrient (ASN III) medium at 25 ± 2°C, in 16:8 h light-dark cycle under cool-toned, fluorescent light. The cultivation was performed in 1000-mL Erlenmeyer flasks. During the exponential phase of growth, the algal biomass was harvested for the extraction of C-PC from 15 days, after inoculation. The algal biomass after harvesting was used for the fabrication of hydrogel sheet.

Results and Discussion:

Optimization for formulation of hydrogel was carried out based on several experimental runs. The concentration of constituents of hydrogel like sodium alginate (1%-5%) and polyethylene glycol (5%-20%) was varied for the optimization process. The algal culture was successfully immobilized in hydrogel sheets and was grown. The rheological, mechanical properties of the sheets were also studied. The algae *Phormidium valderianum* embedded in the hydrogel sheets were able to capture gaseous CO_2 for its growth, hence resulted in an increased biomass growth rate. The carbon content was analysed based on Walkley-Black method.

Conclusion:

In this study alginate network crosslinked with calcium chloride and PEG were used to immobilize algae. The optimization of the above process was also performed. The viability of the cells was studied and the findings showed that cells were viable at optimum conditions. The characterization of algal gel sheets was also carried out to study the mechanical and rheological properties of hydrogel. The carbon capturing ability of algae was studied over the period of cultivation. The algal sheets can serve as a portable bio sheet for the mitigation of CO_2 levels in the atmosphere.

PP016 - Enrichment of Tocopherol Yields Employing CO_2 Supplementation and Nitrate Limitation in Microalgae *Monoraphidium* sp.

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ABSTRACT

Tocopherols are the highly active form of the antioxidant molecules involved in scavenging free radicals and protecting the cell membranes from reactive oxygen species (ROS). The present study focused on employing carbon supplementation with varying nitrate concentrations to enhance the total tocopherol yields in the native isolate *Monoraphidium* sp. CABeR41. The total tocopherol productivity of NR_{HC} (Nitrate replete + 3% CO_2) supplemented was (306.14 $\mu g.L^{-1}\ d^{-1}$) which was nearly 2.5-fold higher compared to NR_{VLC} (Nitrate replete + 0.03% CO_2) (60.35 $\mu g.L^{-1}\ d^{-1}$). The best tocopherol productivities were obtained in the NL_{HC} (Nitrate limited + 3% CO_2) supplemented cells (734.38 $\mu g.L^{-1}\ d^{-1}$) accompanied by a significant increase in cell biomass (2.65-fold) and total lipids (6.25-fold). Further, global metabolomics using gas chromatography-mass spectrometry (GC-MS) was done in the defined conditions to elucidate the molecular mechanism during tocopherol accumulation. In the present study, the *Monoraphidium* sp. responded to nitrogen limitation by an increase in nitrogen assimilation, with significant upregulation in gamma-Aminobutyric acid (GABA). Moreover, the tricarboxylic acid (TCA) cycle upregulation depicted increased availability of carbon skeletons and reduced power, leading to increased biomass yields and other biocommodities. In conclusion, our study defines valorization of carbon dioxide as a cost-effective alternative for enhancing biomass along with tocopherols and other concomitant products like lipids and carotenoids in the indigenous strain *Monoraphidium* sp., as a potential industrial strain with relevance in nutraceuticals and pharmaceuticals.

Keywords: Carbon dioxide, Carotenoids, Microalgae, *Monoraphidium*, Tocopherols

Background:

Microalgae have developed multiple mechanisms for treating the inevitable generation of ROS as a by-product of oxidative metabolism. Similarly, the increased accumulation of antioxidant enzymes (superoxide dismutase and glutathione peroxidase, catalase and ascorbate peroxidase) [1] and other antioxidants like tocopherols, carotenoids tend to scavenge and quench ROS in response to oxidative stress [2]. Tocopherols and carotenoids are the major lipid-soluble antioxidants in the chloroplast envelope and thylakoid membrane, where photosynthetic light-harvesting and electron transport occur. They play a significant role against photooxidative stress, exhibiting an active fortification system contrary to O_2^- and lipid peroxidation in thylakoid membranes.

Materials and Methods:

Growth Conditions: Native isolate of freshwater microalgae *Monoraphidium* sp. CABeR41 was grown in minimal BG-11 medium, under 16:8 h light/dark photoperiods with the light intensity of ~150 µE m^{-2} s^{-1} at constant shaking of 150 rpm. Further, these cells in BG-11 medium were subjected to supplementation of very low carbon [VLC, 0.03% (*v*/*v*) CO_2 or 300 ppm] and high carbon [HC, 3.0% (*v*/*v*) CO_2 or 30,000 ppm] with varying concentrations of nitrogen *i.e.*, nitrogen replete (NR) containing 1.5 $g.L^{-1}$ of $NaNO_3$; nitrogen-limited (NL) with 0.5 $g.L^{-1}$ of $NaNO_3$; and nitrogen deplete (ND) having 0.0 $g.L^{-1}$ of $NaNO_3$, respectively.

Qualitative (Untargeted) Metabolomics: Approximately 1 × 10^8 cells were centrifuged at 8000× g for 10 min at 4 °C and immediately quenched in liquid nitrogen. 1 mL of ice-cold methanol/ethanol/chloroform (2:6:2) was added to cells for resuspension, followed by sonication of 15 min in a sonication bath. Samples were centrifuged at 10,000× g for 15 min at 4 °C. After centrifugation for 3 min at 14,000 ×*g*, *the* supernatant was further analyzed for different metabolites in the gas chromatography-mass spectrometry (GC–MS/MS).

Results and Discussions:

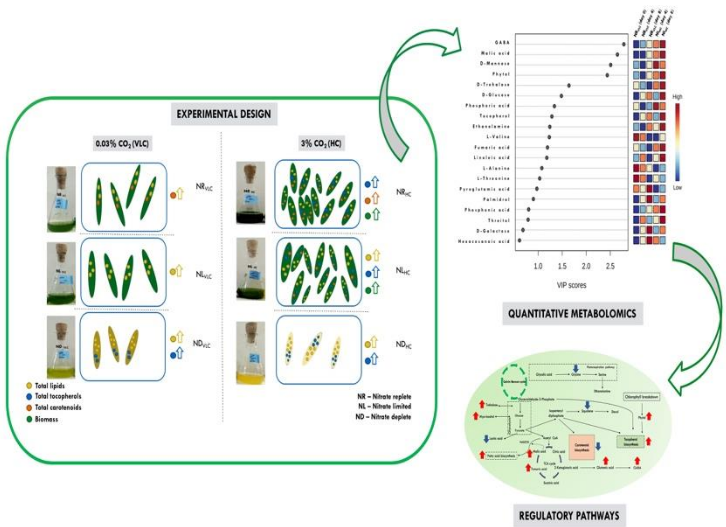

Figure 1. Schematic representation of the time-course qualitative (untargeted) metabolomics on the 4th and 8th days of the native isolate *Monoraphidium* sp. CABeR41 subjected to NR_{VLC} and NL_{HC} conditions.

Conclusion: In conclusion, the native isolate *Monoraphidium* sp. CABeR41, when subjected to NL_{HC} condition, demonstrates a concomitant increase in cell biomass (316.63 ± 15.47 $mg.L^{-1}$ d^{-1}), total lipids (76.12 ± 13.39 $mg.L^{-1}$ d^{-1}) and total tocopherols (734.38 ± 11.79 µg L^{-1} d^{-1}), respectively. Furthermore, such a strategy demonstrates the cost-effective method for accumulating increased levels of total tocopherols and lipids employing carbon supplementation with varying nitrate concentrations leading to multi-fold enhancement of biocommodities without compromising growth.

Acknowledgement:

The work was supported by grants from the Department of Biotechnology, Government of India (Sanction No. BT/PB/Center/03/2011, Phase-II; BT/PR31155/PBD/26/725/ 2019).

PP017 - Nutrient and light availability syncretic effects on microalgal CO_2 bio mitigation and bioenergy production

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ABSTRACT

This research examines how the initial nitrogen concentration affects microalgae growth and its potential impact on CO_2 bio-mitigation and bioenergy production. This study investigates the relationship between nitrate concentration and cellular proliferation. The results indicate a significant correlation between higher initial nitrate concentrations and greater biomass development and efficiency. Nitrogen deficiency reduces biomass productivity and specific growth rates during cultivation. The study investigates the capacity of microalgae to capture and employ carbon dioxide for bioenergy transformation. Increased nitrogen levels improve the efficiency of carbon dioxide utilisation. Nitrogen levels affect the pH of the medium, with higher concentrations leading to elevated pH values. Identifying optimal nitrogen levels and feeding strategies is crucial for improving carbon and nitrogen assimilation, increasing biomass productivity, and achieving high-quality biomass production for bioenergy applications. The results offer guidance on how to enhance nutrient availability and light intensity to improve the effectiveness of microalgae-based CO_2 bio-mitigation and bioenergy generation.

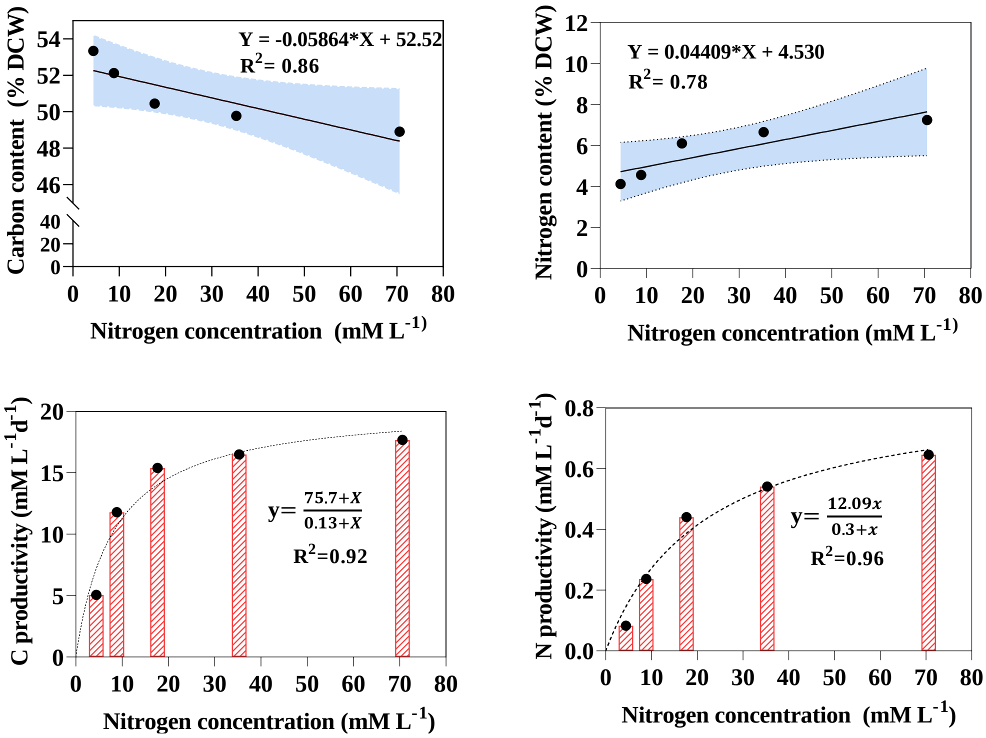
Keywords*:* Bioenergy; CO_2 fixation; Light; Microalgae; Stoichiometry

Background:

This study examines the influence of nitrogen levels on the growth of *Micractinium pusillum* microalgae and carbon accumulation under 15% CO_2 conditions. This research examines how light availability and nitrogen levels impact the carbon-to-nitrogen ratio, growth, and CO2-based carbon and bioenergy assimilation in microalgae biomass.

Materials and Methods:

The optical density at 680 nm (OD_{680}) was measured using a UV–visible spectrophotometer (Cary 50, Varian, Australia) and converted into dry cell weight using a linear equation. Biomass concentration was measured daily after 24 h from both reactors using a UV–visible spectrophotometer. At the completion of each batch, the specific growth rate (day-1), maximum productivity (Pmax, g L^{-1}).



Results and Discussions:

Increased nitrogen concentrations of 70.6 mmol/L improve the efficiency of CO_2 fixation and utilization in microalgae. Efficient assimilation of both nitrogen and carbon, leading to biomass growth, occurs within the optimal range of nitrogen concentration of 30-70.6 mmol/L. Controlling the availability of nitrogen and light within a specific range is important for regulating the buffering and dissolution of CO_2, which in turn impacts the growth of algae and the assimilation of carbon in biomass.

Conclusion:

This study emphasizes the significance of nitrogen levels in controlling microalgae growth, CO_2 absorption and utilization, and cellular carbon-nitrogen ratio. Improving nitrogen accessibility in growth substrates can increase biomass yield and prevent nitrogen depletion. These findings provide valuable insights for developing strategies to enhance the growth and CO_2 utilization of microalgae and storage in energy molecule precursor.

PP018 -Hydrothermal liquefaction of *Monoraphidium* sp. KMC4 grown on dairy wastewater for bio-oil production

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ABSTRACT

Keywords: bio-oil; calorific; hydrothermal; microalgae; sustainable

Background

The worldwide energy scarcity, combined with increasing environmental issues, has raised the demand for finding sustainable alternative energy resources. Microalgae offers a promising approach towards energy generation due to its advantages including multiplication rate, carbon sequestration, and wastewater treatment. The present study aims to produce bio-oil from algal biomass derived from dairy wastewater.

Materials and methods

The biomass KMC4 was thermochemically converted to bio-oil through hydrothermal liquefaction under conditions: temperature 275- 350 °C, residence time 30 min and agitation 300 rpm. The reaction mixture was extracted to bio-oil, aqueous and solid residue after addition of dichloromethane followed by centrifugation.

Results and Discussion

The energy density of microalgae grown on dairy wastewater represents its potential for energy generation through hydrothermal liquefaction. The increasing trend of bio-oil yield was outseen from 20.5 to 33.50 % with a rise in temperature from 275 to 350 °C. After 350 °C, a decreasing bio-oil profile was observed which might be due to the conversion of organic compounds to gases. The bio-oil obtained under optimal conditions represents a significant calorific value and constitutes majorly N heterocyclic compounds due to the presence notable protein content. Also, future studies on catalytic HTL by bimetallic catalyst may help in increasing the calorific value of bio-oil by removing nitrogen heteroatoms.

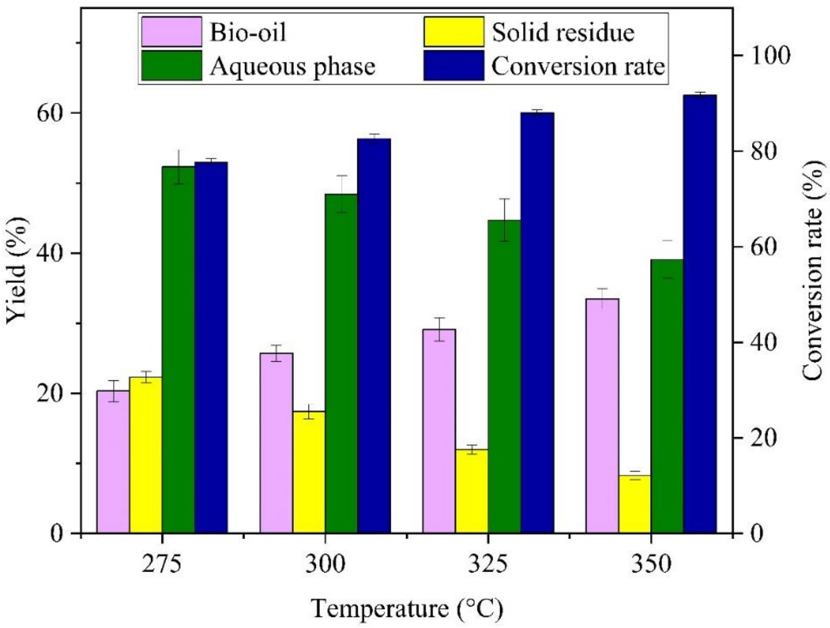

Figure 1. Impact of HTL temperature on conversion rate and products fraction

Conclusion

The bio-oil production from *Monoraphidium* sp. KMC4 was performed to analyze its potential in the bioenergy sector. The hydrothermal processing of high protein KMC4 has achieved good bio-oil yield along with its significant energy density suggesting a sustainable conversion process.

Acknowledgements

The authors acknowledge the financial support received from the Department of Biotechnology (DBT), Govt. of India under Indo-Danish Research and Innovation Cooperation in the area of ‘Water’ (Grant no. BT/IN/Denmark/61/KM/2018-19).

PP019 -Algal-bacterial trickling photobioreactor for domestic wastewater treatment: organic matter and nutrient removal

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ABSTRACT

In this study, an algal-bacterial trickling biofilm photobioreactor (AB-TPBR) was developed for treating domestic wastewater, and its performance was evaluated at different hydraulic retention times of 12, 9, 6, and 3 h. The reactor operated at room temperature in continuous mode, relying solely on natural aeration. The reactor consisted of a collection tank and a bio-tower, where the bio-tower had hanging silica cloth for facilitating algal-bacterial biofilm growth. The study found that the COD removal efficiency decreased as the hydraulic retention time decreased. COD removal efficiencies of 72.3%, 77.8%, 51.34%, and 41.8% were observed at 12, 9, 6, and 3 h HRT, respectively. SEM and metagenomics analysis were used to characterize the biofilm.

Keywords: algal-bacterial, biofuels, lipid, nutrient removal, wastewater treatment

Background:

The increase in freshwater scarcity and the environmental issues associated with wastewater treatment are demanding the development of sustainable wastewater treatment technologies. Conventional wastewater treatment systems, such as activated sludge systems, are very energy-intensive, and simultaneous carbon and nutrient removal is complex and expensive [1]. Therefore, the use of algal-bacterial culture in a single bioreactor for simultaneous organic carbon and nutrient removal is gaining research attention [2]. The carbon footprint of such a system is also lower, and algal biomass can be a value-added product. This study reports the performance of an algal-bacterial tricking photobioreactor (AB-TPBR) treating domestic wastewater treatment by relying only on natural aeration.

Materials & methods:

Reactor Configuration and Operation:
The pilot-scale AB-TPBR consists of two main components: a collection tank with a volume of 260 L and a bio-tower with dimensions of 1.1 x 1.1 x 2.85 m. The schematic representation of the reactor is shown in Figure 1. A submersible pump was used in the collection tank to keep the biomass in suspension. The bio-tower was fitted with vertical silica fabric to grow the algal-bacterial biofilm with a total surface area of 117.39 m^2. Blue LED light strips were used as the light source for promoting algal growth. The reactor was operated at hydraulic retention times of 12, 9, 6, and 3 h, and the wastewater was continuously recirculated between the bio-tower and collection tank using a pump.

Analytical Methods:
Samples from the inlet and outlet of the reactor were collected and analyzed for various wastewater quality parameters using the *Standard Methods for the Examination of Water and Wastewater* (APHA 2012).

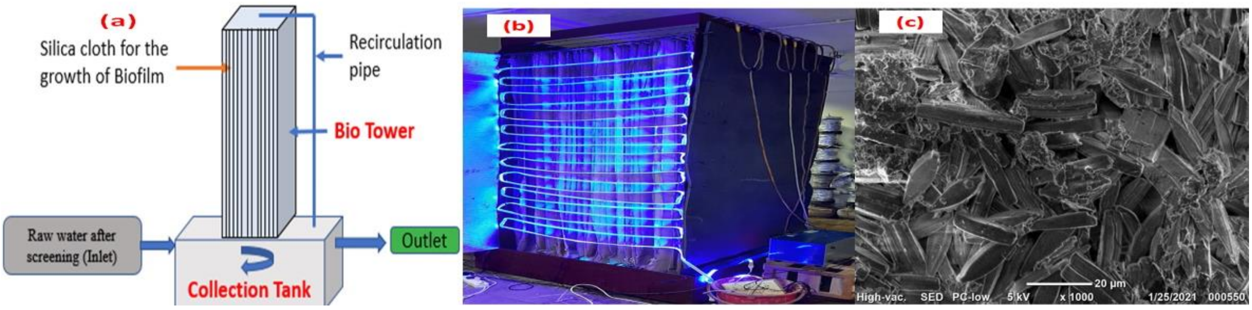

Figure 1. (a) Schematic representation of AB-TPBR (b) Reactor during operation (c) SEM image of biofilm grown on the silica cloth

Results

The influent wastewater COD ranged from 164 mg/L to 389 mg/L, while COD removal efficiencies of 72.3%, 77.8%, 51.34%, and 41.8% were observed at HRTs of 12, 9, 6, and 3 hours, respectively. The highest COD removal efficiency was achieved at the 9-hour HRT. The effluent maintained a DO value of over 4 mg/L throughout all retention times, and the total organic carbon (TOC) removal efficiencies were more than 40%. The TN concentration in the influent varied from 32.3 mg/L to 16.2 mg/L, and the TN concentration in the effluent ranged from 22.2 mg/L to 11.6 mg/L, with a maximum removal efficiency of 57.4% at the 9-hour HRT. The influent had phosphorus concentrations ranging from 10.9 mg/L to 6.5 mg/L, and the phosphate concentrations in the effluent were reduced to 2.9 mg/L and varied with HRT. The highest phosphate removal efficiency was 69.3%, achieved at the 9-hour HRT. The reactor effectively removed most of the micropollutants.

Conclusion:

An algal-bacterial trickling photobioreactor was developed as an intermediate treatment unit that works on natural aeration, eliminating the need for external mechanical aeration to remove pollutants. The reactor performance was assessed at various hydraulic retention times of 12, 9, 6, and 3 hours. The effluent dissolved oxygen was significantly increased as water trickled down through silica cloth, allowing oxygen transfer from air to the biofilm and photosynthetic oxygen generated by microalgae. The biomass was found to contain fatty acids like Palmitoleic acid (C16:1) and Palmitic acid (C16:0), which are suitable for the synthesis of biodiesel.

Acknowledgment:

This work was supported by the Ministry of Education and the Ministry of Science and Technology of the Government of India under IMPRINT, and FIST programs, respectively.

PP020 -Application of Extracellular Polymeric Substances in metal extraction produced by cyanobacteria grown in waste water

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ABSTRACT

Global expansion has led to a surge in energy and resource consumption along with waste generation. Innovative ways to reduce these issues are essential and also a challenge. Microalgal biotechnology represents a promising approach to this concept. These microorganisms can convert nutrients from wastewater into biomass with potential as a feedstock for obtaining bioproducts. In this research the cyanobacteria species (*Synechocystis sp*.) is grown in municipal waste water confers optimum growth similar to that of grown in Bolds basal medium. It is able to remove nitrate, phosphate, potassium and COD (94.6%, 98.1%, 93.02%, and 68.87%) with 1.3823 g/L of dry biomass and 1.496 g/L of EPS production. Extracellular polymeric substances (EPS) produced as a biproduct from the process is used for metal extraction from leached liquor. Upto 92.46% of 8.45 g/L $MnSO_4$ could be recovered using 0.1024 g/L of EPS. The simultaneous or sequential extraction of these products in a microalgae-based biorefinery could be an alternative to improve the economic feasibility of the process.

Keywords- Cyanobacteria, extracellular polymeric substances, metal extraction, municipal waste wáter

Background

When wastewater is disposed off without being treated, it frequently causes eutrophication, or an excessive enrichment of the water body with nutrients, which causes algal blooms and more long-term issues with heavy metals pollution. There have been a number of conventional chemical methods used in wastewater treatment, but they were not practical due to the development of harmful intermediates and high costs. In this scenario algae can provide a solution by removing the nutrients from waste water. In addition to bioremediation of waste water, high concentration of EPS is produced by the *Synechocystis sp.* during growth period having different environmental applications. As EPS has high binding affinity towards metal ions, we have extracted manganese from leach liquor using EPS. This EPS based extraction of metal could be a sustainable approach in comparison to other methods used. Different high value products could be extracted from the biomass harvested as a biproduct of bioremediation process.

Materials & Methods

The municipal wastewater was collected from the Acharya Vihar, Bhubaneswar, pump house, was autoclaved, filtered, and used as a culture media to grow *Synechocystis sp*. Nutrients such as nitrite (NO_2), nitrate (NO_3), phosphate (PO_4) were analysed spectrophotometrically (Varian 50 bio UV–visible spectrophotometer) following standard procedures (Grasshoff et al., 1999).

Potassium was measured using flame photometer. Chemical oxygen demand (COD) was determined according to the digestion method prescribed by APHA, 1998. Manganese was recovered from the leach liquor using EPS produced (biproduct). Recovery percentage of manganese was estimated by Atomic absorption spectrometry (AAnalyst200, version 8).

Results & discussions

Synechocystis is able to remove nitrate, phosphate, potassium and COD (94.6%, 98.1%, 93.02%, and 68.87%) with 1.3823 g/L of dry biomass production. 1.496 g/L of EPS was produced as a biproduct from the bioremediation process. Upto 92.46% of 8.45 g/L $MnSO_4$ could be recovered using 0.1024 g/L of EPS.

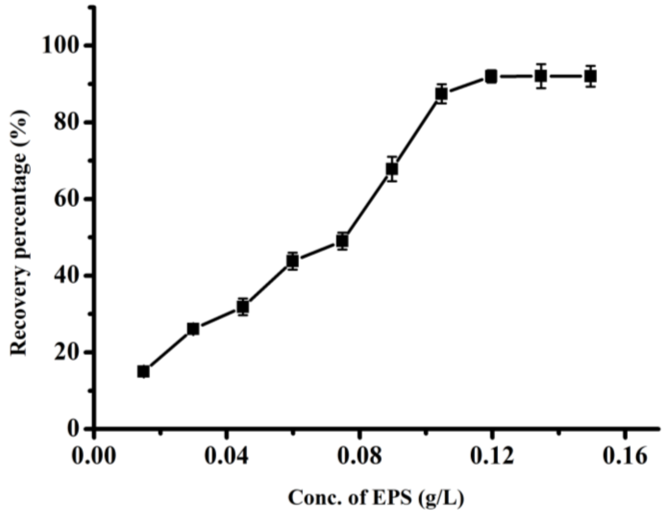

Fig-1- Concentration of EPS vs Manganese recovery percentage

Conclusions

Synechocystis sp. can provide eco-friendly solution for bioremediation by utilizing the pollutants as the main source of nutrients for its growth. EPS produced as a biproduct could be a sustainable method of metal extraction from leached liquor comparison with the high processing units used.

Acknowledgement

The authors are grateful to Director, CSIR-IMMT, Bhubaneswar, for permitting us to do the experiments. SP would like to thank University Grants Commission (UGC), Govt. of India, for providing the fellowship under the UGC-JRF Scheme (450/ CSIRNETJUNE2019).

PP021 - Microalgae mediated biodegradation of pharmaceuticals: An insight into removal kinetics, co-metabolism, and transformation products

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ABSTRACT

The primary objective of this study was to evaluate the toxicity and cellular stresses induced by azithromycin (AZY) on *Chlorella thermophila*, a freshwater microalga. The toxicological effects were assessed by monitoring the growth and biochemical characteristics of Chlorella thermophila, including total chlorophyll, carotenoid content, and malondialdehyde (MDA) levels. The study identified biodegradation as the primary mechanism for antibiotic removal, with minor biochemical alterations observed on the algal cell surface. Interestingly, Chlorella thermophila exhibited a modest capacity for AZY removal achieving a removal rate of 63 ± 1% after 11 days of cultivation with an initial AZY concentration of 100 µg/L. Kinetic studies revealed that the removal of AZY followed a first-order model (R^2 = 0.94–0.97), with apparent rate constants (k) ranging from 0.0121 to 0.079 d^{-1}. In summary, this study highlighted the inhibitory effects of AZY on the growth and biochemical characteristics of Chlorella thermophila. It also showcased the microalga's limited but noteworthy ability to remove AZY. These findings contribute valuable insights into the toxicological responses and potential remediation of AZY in freshwater microalgae.

Background

Since December 2019, the world has been facing a pandemic called COVID 19 caused by the novel coronavirus SARS-CoV-2. Although COVID is a viral disease, antibiotics are used to treat bacterial co-infections. Among the various antibiotics, azithromycin (AZY) from the class of macrolides, the third most widely consumed group of antibiotics is known as one of the most useful therapies for treating COVID 19. So, by a continuous introduction to the environment, it is considered a pseudo-persistent pollutant. AZY concentration in the environmental samples ranges between 360 - 500 ng/L. Hence, in the present study we have studied the removal of antibiotic azithromycin from the environment by the microalgal strain *Chlorella thermophila*.

Materials and Methods

The microalgal strain was cultivated in presence of varying concentration of azithromycin (0, 10, 20, 30, 40 and 50 µg/L). The toxicological effects of AZY on Chlorella thermophila were assessed by studying the growth and biochemical characteristics of the microalga including total chlorophyll, carotenoid content, and malondialdehyde (MDA) activity. HRMS analysis of the culture medium was carried out in regular interval of time to determine the degradation products and the metabolic pathway followed by the microorganism for efficient degradation of the pharmaceutical.

Main Results

The results demonstrated a significant inhibition of *Chlorella thermophila* growth with increasing concentrations of AZY. Moreover, the presence of higher AZY concentrations led to a notable increase in total chlorophyll, carotenoid content, and MDA activity, indicating cellular stress in *Chlorella thermophila*. The strain can degrade up to 63.15% of azithromycin (50 µg/L) within a span of 11 days.

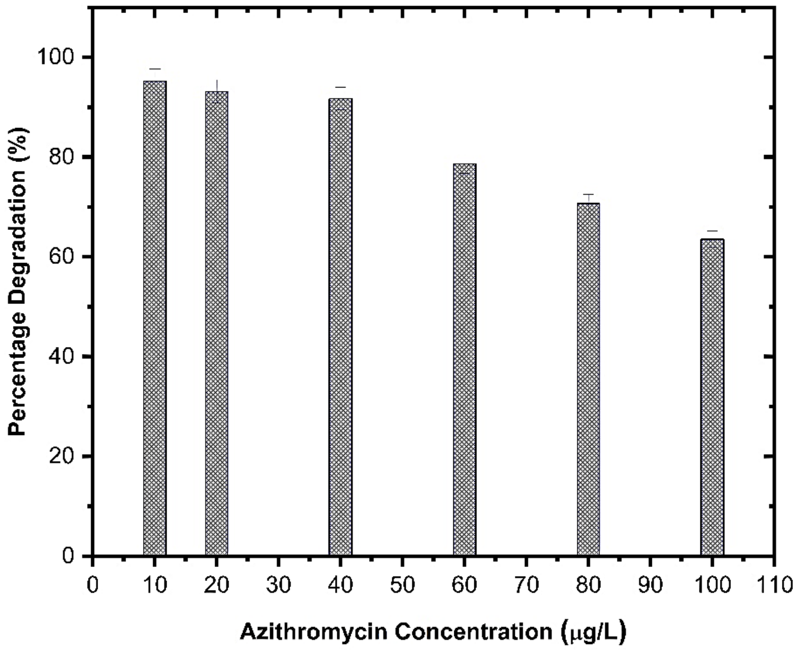

Fig I: Degradation profile of the microalgal strain *Chlorella thermophila* at various concentration of azithromycin

Conclusion

The stable algal population and the identification of various metabolites further emphasized the potential of *Chlorella thermophila* as an effective candidate for advanced treatment in antibiotic removal from wastewater.

PP022 - Synthesizing biogenic silver nanoparticles from *Graesiella emersonii* and assessing their antibacterial and decolorization of dye-contaminated water efficiency

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ABSTRACT

Green synthesis of silver nanoparticles (AgNPs) using aqueous extracts of a new algal species, *Graesiella emersonii,* has been conducted in the present work. The effect of different physiochemical parameters affecting AgNPs synthesis, like pH, precursor salt concentration, and salt-to-extract ratio, was studied using UV-Visible spectroscopy. Strong absorbance spectra due to the surface plasmon resonance (SPR) effect was observed at 438 nm. AgNPs were synthesized by reducing ions from the precursor salt solution with the algal extract. The crystalline structure of AgNPs was examined through XRD, and stability and size distribution through zeta-potential analysis. The morphological analysis was carried out through FE–SEM, and found to have spherical shape with an average diameter of 12 nm. The synthesized AgNPs demonstrated promising antibacterial activity against *Escherichia coli* (15.7 mm), *Salmonella* sp. (24 mm), and *Bacillus cereus* (16 mm). These nanostructures also exhibited potential for photocatalytic degradation of methylene blue dye up to 90% in 10 hours under direct sunlight, thus eliminating the need for UV exposure.

Keywords: Antibacterial, *Graesiella emersonii,* Microalgae, Photocatalytic dye degradation, Silver-nanoparticles

Background of the study:

Environmental pollution and antimicrobial resistance are two major concerns of the current world. Nanotechnology-enabled materials in recent times have been explored against several pollutants for remediation and pathogenic microbes. Silver nanoparticles have been used for biomedical applications for a very long time. Conventional physicochemical methods of silver nanoparticle synthesis are uneconomical as well as toxic to the environment due to the chemical loads involved. Thus, the development of green methods which are cost-effective and environmentally friendly is essential. In this direction, algal-based nanoparticle synthesis and its application for environmental remediation and antibacterial activity have been conducted in this study [1].

Materials and Methods:

Aqueous algal extract optim
ized for its efficient nanoparticle forming concentration was used with precursor salt for target metal nanoparticle synthesis under controlled conditions. For preliminary confirmation, spectrophotometric analysis was done, followed by FE-SEM, TEM, FTIR, Zeta potential

analyzer, and XRD for morphological and other properties. These nanoparticles were then assayed for their antibacterial activity using disc and well diffusion methods, and dye degradation efficiency using a spectrophotometer [2].

Conclusion:

Conventional methods of nanoparticle synthesis can be replaced by biogenic synthesis. Under biogenic synthesis, bio-based aqueous extract, which contains a diverse range of compounds, serves as the reducing, capping, synthesizing, and stabilizing agent, thus reducing the need for additional chemicals. One such approach is used in this study, to demonstrate the efficiency of a novel algae for green synthesis of silver nanoparticles, having diverse applications – antibacterial and environmental remediation.

Acknowledgment:

The authors would like to acknowledge the Department of Biotechnology, Delhi Technological University, Delhi, for their constant support.

PP023 - Critical Factors Influence on Photosynthetic Catalysed Polyhydroxyalkanoate Production

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ABSTRACT

Polyhydroxyalkanoate (PHA) is a biodegradable and biocompatible polymer that can be produced by certain microorganisms (bacteria, cyanobacteria, microalgae and plants) under specific responses of stress stimulus via carbon assimilation. Herein, microalgae hold great potential with the scope of carbon neutrality. The present study aims to investigates the regulatory factors and their concentrations that work as a channeling component in the metabolic pathway of PHA synthesis derived by photosynthetic mechanism within microalgae and cyanobacteria isolates. *Chlorella sorokiniana* SVMIICT8, *Scenedesmus sp.* SVMIIICT1 and *Desertifilum* sp. SVMIICT2 were studied for their feasibility in PHA production. Mixotrophic and autotrophic mode of cultivation with nutrient (C:N:P) and micronutrients concentrations was evaluated for their regulations.Eighteen experimental conditions were designed for growth conditions utilizing Taguchi DOE methodology considering eight critical factors at their respective three levels. Alongside biomolecules (Chlorophyll, carbohydrate, protein and lipid) profiling and photosynthetic transients (Chlorophyll a fluorescence) was monitored to analyze the shifts in central metabolic activities by virtue of the experimental conditions.The study primarily aims the biopolymer synthesis alongside evaluates the important metabolites for multiple product valorization in environmental and economical context of biorefinery.

Key Words: *Polyhydroxyalkanoate, Biodegradability, Photosynthetic Amplitude Modulator (PAM), Carbon dioxide sequestration, Biorefinery*

PP024 - Towards the sustainable production of vegan Eicosapentaenoic Acid (EPA): year around cultivation of *Nannochloropsis oculata* and scale up under tropical environment.

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ABSTRACT

The global market for omega-3-fatty acids is expanding on account of the food and nutraceutical industry. The marine algal genus *Nannochloropsis* is a promising candidate for vegan EPA production. However, outdoor cultivation of *Nannochloropsis sp.* under tropical cultivation has been a challenge due to light intensities and seasonal variations. Fluctuation in light intensity due to seasonal variation in the tropical environment affects the biomass productivity and yields poor EPA production and thus impose serious limitations on scaling up the cultivation. Hence, efforts have been made to acclimatize the *Nannochloropsis oculata* to tropical natural light for year around cultivation. Inoculum cell densities with initial biomass of 0.1,0.2,0.3,0.4 g^{-1} L were evaluated over one year while exposing cells to seasonal variations and varying natural light intensities in the range of 600 -1300 µmole Photon m^{-2} s^{-1}. A statistical nutrient model was designed using Plackett Burman Design (PBD) to study the effect of each media component lipid, EPA, and biomass production. Successful scale-up cultivation of *N. oculata* was carried out with optimized inoculum cell density and modified f/2 media under natural light environment in the environmental laboratory (EL) (560 µmole Photon m^{-2} s^{-1}) and outdoors (780 µmole Photon m^{-2} s^{-1}) using airlift photobioreactor (ALR). The ALR cultivation at EL and outdoor have yielded 150 mg/g and 118 mg/g of EPA content respectively. The inoculum cell density optimization along with modified media composition influenced the light tolerance, photo acclimatization, and transitional changes to successful scale up.

Keywords: Airlift photobioreactor, Eicosapentaenoic Acid (EPA), *Nannochloropsis oculata*, Scale up, Tropical light

Background:

Microalgae can reach much higher EPA contents and productivity compared with conventional sources like fish and krill oil. Unicellular marine microalgal species *N. oculata* is a known producer of EPA accumulating 20-30% of total fatty acids is a promising candidate for vegan EPA production [1]. Successful outdoor studies under natural light illumination accomplish a step ahead for economically sustainable method. The current work focused on devising strategies for year around cultivation and scale up of *N. oculata* under the Indian tropical conditions.

Materials and methods:

Acclimatization of the *N. oculata* was carried out under tropical natural light conditions with the target of year around cultivation. To study the effect of seasonal variation and light tolerance, the inoculum densities of *N. oculata* were optimized. Cell growth profile, lipid, and EPA content (Bligh and Dyer) and biomass production was analysed. Plackett Burman Design (PBD) was applied to study the response of nutrients of f/2 media such as nitrate, phosphate and trace metal solution on lipid, EPA, and biomass production. The screening parameters for

PBD were set in the range of Nitrate -75-300 mg/L, Phosphate- 5-20 mg/L and Trace Metal Solution 1-4X.

Results and discussion:

Successful photo acclimatization of *N. oculata* was achieved by tolerating light intensity up to 1200 µmole Photon m^{-2} s^{-1} with 25-27% of EPA in total fatty acids with 0.1 g/L/d of biomass productivity. Indian winter season with the light intensity of 600-800 µmole Photon m^{-2} s^{-1} were observed to be optimum for biomass, lipid as well as EPA content (Table 1). The Placket Burman design studies suggested that nitrate concentration has a significant effect on biomass production. Scale-up studies of *N. oculata* with modified f/2 were successfully carried out in 5L airlift photobioreactor in the EL and outdoors achieving 0.61 g/L and 0.46 g/L of biomass production.

Conclusion:

The present study established successful acclimatization of *N. oculata* under Indian tropical light condition for year around cultivation followed by outdoor scale up using airlift photobioreactor.

Acknowledgement:

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Table 1: Year around cultivation of *N. oculata* with optimization of inoculum cell density

Seasons	Light intensity µmol Photon	% EPA in TFA content	EPA Content (mg/g)	Lipid % (g/g)	Biomass productivity (g/L/d)
Summer	1100-1300	8-9	1.2-1.6	18-22	0.04
Monsoon	500-1000	13-14	3-4	30-33	0.09
Post monsoon	800-900	25-27	4-6	21-27	0.07
Winter	600-800	29-33	6-8	29-31	0.10

PP025 - Dynamic Metabolic Crosstalk Between Microalgae *Chlorella saccharophila* and its New Symbiotic Bacteria Improves Lutein Production Without Compromising Growth

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ABSTRACT

Microalgae grow in the aquatic environments associated with mostly symbiotic bacteria. However, such associations' existence are generally nutrient-dependent and needs to be exploited to understand their interactions, which will benefit in developing sustainable biorefineries. The present study focused on unveiling such interactions with an indigenous isolated novel bacterial strain *Exiguobacterium* sp., with the microalgae *chlorella saccharophila* UTEX247. Furthermore, the bacteria were co-cultured with *C. saccharophila* in different inoculum ratios to determine the growth profiles and lutein productivities. Under optimal conditions, the lutein productivity of co-culture was 298.97 μg L^{-1} d^{-1}, which was nearly 1.45-fold higher compared to monocultures 103.3 μg L^{-1} d^{-1}. The best lutein productivities were obtained in co-cultures, accompanied by a significant increase in cell biomass up to 0.84-fold. Further, these conditions were analyzed using an untargeted metabolomics approach to reveal the relevant metabolites involved in such associations for enhancing valuable biorenewables, i.e., lutein, without compromising growth. Identified metabolites included 30 from monoculture microalgae, 41 from bacteria, and 75 from co-culture. Interestingly 46 of the co-culture-specific metabolites were generated. Co-culture-specific metabolites studies demonstrated the role of thiamine precursors and reactive sugar anomers like furanose and branched-chain amino acids (BCAA) in central metabolism cycle upregulation and increased availability of carbon skeletons, leading to increased cell biomass and carotenoids. In conclusion, the co-cultures induce the production of relevant metabolites which regulate growth and lutein production in *C. saccharophila* UTEX247 simultaneously as a new perspective in microalgal biorefineries.

Keywords: Biorefineries, Carotenogenesis, *Chlorella saccharophila*, *Exiguobacterium* sp., Lutein

Background:

Microalgal biorenewables imply a broad range of applications and have gained importance owing to their cost economics in global markets. Little has been reported on the controlled exploitation of algal-microbes interactions for the production of carotenoids, which has a plethora of mechanisms that need to be exploited [1]. In the present study, we have investigated a new approach to enhance lutein production employing co-culturing the microalgae *C. saccharophila* UTEX247 with the new bacterium *Exiguobacterium* sp. to decipher dynamic metabolic crosstalk occurring during these biotic interactions.

Materials and Methods:

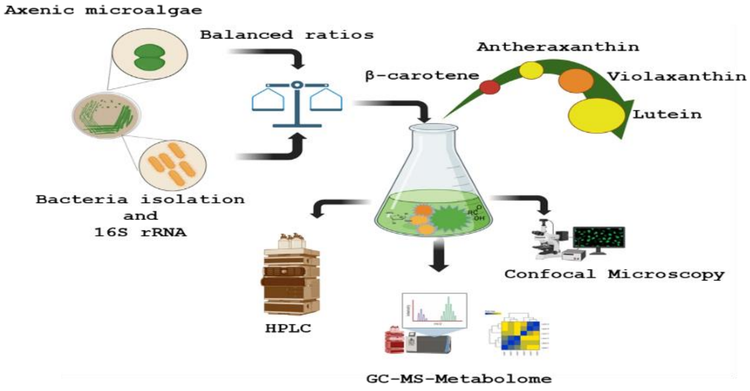

Figure 1. Co-culture was done in Erlenmeyer flasks containing 150 ml of BG-11 medium at room temperature, light/dark cycles of 16/8 h, and light intensity of 50 μmol photons·m^{-2}·s^{-1} on an orbital shaker (150 rpm).

Results and Discussions:

Interactions between bacteria and microalgae grown in co-culture with microalgae/bacteria ratios (A1:B10000) and monoculture control cultivated for 9 days. (*statistical significance by one-way ANOVA, P<0.05) (Table 1).

Table 1. Table depicts the different growth parameters and lutein productivity

Treatments	Specific growth rate (day $^{-1}$)	Doubling time (h)	Biomass productivity (mgL^{-1} day^{-1})	Lutein productivity (ugL^{-1} day^{-1})
A	0.31 ± 0.02	54.39 ± 0.43	22.55 ± 1.44	103.30 ± 8.26
AB (1:10000)	0.40 ± 0.03	42.09 ± 0.78	50.86 ± 0.56	298.97 ± 4.53

Table 1. Growth parameters, biomass and lutein productivities of mono- and co-cultures.

Conclusion:

In the present study, we have investigated a new approach to co-culture microalgae with newly identified bacteria. Our findings have suggested that synergistic effects of differential metabolites caused by bacteria in co-culture enhanced the carotenoid production of *C. saccharophila* UTEX247 without compromising growth. This will be a beneficial approach for the sustainable production of biorenewables, a circular bieconomy perspective.

Acknowledgement:

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PP026 - Screening of microalgal strains for enhanced biomass production with simultaneous carbon dioxide sequestration

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ABSTRACT

Microalgae have gained significant attention as a sustainable feedstock for production of biofuels, nutraceuticals cosmetics due to their high lipid - carbohydrate content and rapid growth rate. Being photosynthetic they are promising candidate for CO_2, sequestration with simultaneous biomass production. This can be used to reduce the green-house gases and control global warming. However, to ensure a sustainable production of microalgae, a well-optimized and sustained biomass production is prerequisite. The major factor determining the high productivity of algae is availability and uptake of CO_2 for biomass growth. In this study four microalgal strains are screened for an improved CO_2 sequestration. Four microalgae strains IMMTR-3, IMMTR-4, IMMTR-5, IMMTR-32 isolated from different water bodies of Odisha & maintained at CSIR-IMMT were used for this study. The cultures were grown in BBM liquid media with artificial light arrangements and grown at temperature of 30^0C ± 2^0C. From the above culture IMMTR-3 showed the maximum rate of CO_2 fixation of 0.1821g/L/D. Hence IMMTR-3 is suitable for further sequestration studies.

Keywords: Microalgae, Biomass yield, CO_2 sequestration

Background

Carbon capture and sequestering technology are used to reduce carbon emission. One of the promising methods is the use of algae to absorb flue gases and convert it into biomass [1,2]. Algae have great potential as renewable fuel sources and carbon dioxide capture using photosynthesis for carbon fixation [3]. This work presents an extensive and in-depth report on utilization of algae for carbon capture and accumulation. The performance and productivity of this biosystem depends on various condition including algae type, light sources, nutrient, pH, temperature. This work also investigates algal cultivation to effectively mitigate carbon emission. In this work we explored the suitability of algal species for carbon capture and sequestration along with biomass production.

Materials & Methods

Four different microalgal strains used in this study were obtained from CSIR-Institute of Minerals Technology (CSIR-IMMT), Bhubaneswar, Odisha. The strains were originally isolated from different water habitats (estuaries) of Odisha and maintained at CSIR-IMMT. All primary stock culture were maintained in liquid media (Bold basal medium) and allowed to grow aerobically at 30 ± 2°C under a 12:12 h light/dark photoperiod with light intensity of 3500 lux (YOROCO lux meter, YSI 606) provided by cool white fluorescent tubes. The cultures were hand shaken thrice daily to avoid sticking of microalgae to the flask wall and incubated till exponential growth phase. 0.01M of NaOH added to the growth medium.

Gaseous CO_2 was directly infused in medium from the cylinders (9.98%CO_2 gas) until the pH (measured using calibrated pH meter, SYSRONICS 362) came down to pH 7.0 ± 0.2. Every 24 hour samples were aseptically collected and checked absorbance at 750 nm.

Result & discusión

IMMTR-3 showed the maximum rate of CO_2 fixation of 0.1821g/L/D with 1.214g/L biomass production. IMMTR-32 showed CO_2 fixation of 0.1476g/L/D with 0.9842g/L biomass production IMMTR-4 showed CO_2 fixation of 0.1269g/L/D with 0.8462g/L biomass production. IMMTR-5 showed CO_2 fixation of 0.11384g/L/D with 0.75896g/L biomass production.

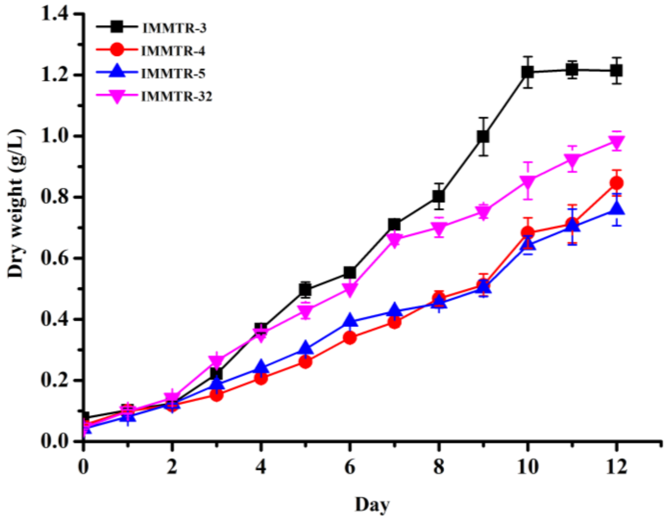

Figure 1: Growth curve of different microalgal strains with respect to day**.**

Conclusions

The use of microalgae for CO_2 sequestration diminishes the carbon in the atmosphere and also helps in mitigating the increasing trend toward global warming. In this work IMMTR-3 strain can provide better CO_2 sequestration with high biomass production which is an ecofriendly solution for reduce CO_2 emission in sustainable manner.

Acknowledgement

The authors are thankful to Director, CSIR-IMMT, Bhubaneswar, for permitting us to carry out the experiments. Debidatta Barik would like to acknowledge University Grants Commission (UGC), Govt. of India, for providing the fellowship under the UGC-JRF Scheme (CSIRNETJUNE2022).

PP027 - Extraction, purification, characterization and bioactivity evaluation of high purity C-phycocyanin from *Spirulina* sp. NCIM 5143

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ABSTRACT

The study demonstrates an end-to-end downstream process for extraction and purification of C-phycocyanin from *Spirulina* sp. NCIM 5143. High C-phycocyanin yield of 155.8 mg g^{-1} DCW, achieved in a single freeze thaw cycle and significantly shorter treatment time of 6.5 h, attributed to the optimized combinatorial process engineering strategy of: screening of suitable biomass condition (wet) and freezing with buffer at an optimized biomass to solvent ratio (1:100). High purity (2) of extracted crude pigment at food grade level made it a suitable starting material for purification. Due to this, the purification methodology involving ammonium sulphate precipitation and dialysis resulted in achieving analytical grade purity of C-PC in a lesser number of steps. Characterization of purified C-phycocyanin demonstrates the spectral properties and compares its structural similarities to commercial analytical grade C-phycocyanin. Bioactivity evaluation of purified C-phycocyanin shows its potential as anti-oxidant compound with an IC50 value of 123.62 µg mL^{-1}, and as anti-cancer compound with an IC50 value of 232.2 ± 4.2 µg. mL^{-1} with significant effects on cell migration and cell cycle arrest in G2 phase in HeLa cells.

Keywords: C-phycocyanin (C-PC), *Spirulina* sp., Extraction, Purification, Anti-oxidant, Anti-cancer

Background:

C-phycocyanin is a blue coloured water-soluble pigment having wide range of application in food and pharmaceutical industries. C-phycocyanin from spirulina is graded as food grade (0.7), cosmetic grade (0.8-1.5) and analytical or reagent grade (>4). Currently, phycocyanin production from Spirulina biomass is plagued by multiple extraction cycles, low yields and purity. Hence, researchers are striving to achieve maximal recovery of high-purity (analytical-grade) C-phycocyanin from spirulina biomass in limited steps and minimal processing time. The current work focusses on extracting maximum amount of food grade phycocyanin in a single freeze thaw cycle from Spirulina biomass followed by purifying it to analytical grade level in minimal number of steps, to reduce time and cost involved. Further characterization of the purified C-phycocyanin was performed to compare its quality with of industrial analytical reagent (Merck). To establish the bioactive potential of *Spirulina* sp. NCIM 5143 generated C-phycocyanin, in vitro anti-oxidant, anti-cancer studies on HeLa cells (Cervical cancer cell lines) were performed.

Materials and Methods:

Extraction of crude C-phycocyanin from *Spirulina* sp. NCIM 5143 was optimized based on (i) selection of harvesting time with maximum C-phycocyanin concentration (ii)identification of susceptible biomass condition (wet, sun-dried, oven-dried, lyophilized biomass) (iii) optimization of biomass to solvent ratio (freezing with buffer FWB vs freezing without buffer FWoB, 1:2 to 1: 100) for total C-phycocyanin extraction from spirulina biomass at food grade level purity (Purity:2). Purification strategy of C-phycocyanin to analytical grade (Purity:6) was developed by ammonium sulphate precipitation saturation percentage optimization, dialysis and gel filtration chromatography. Spectral characterization and comparison with commercial analytical grade reagent (Merck) using CD spectroscopy, Fluorescence spectroscopy and UV-Vis spectroscopy followed by SDS-PAGE was performed. Bioactivity evaluation (anti-oxidant and anti-cancer activity)was performed by DPPH radical scavenging activity, MTT assay, Cell migration assay and Cell cycle analysis assay on HeLa cells.

Results and Discussion:

Extraction: Dynamic pigment content analysis revealed high intracellular C-phycocyanin accumulation in Spirulina biomass during the 15th day (with gradual increase during growth) at the onset of stationary phase which was selected as the harvesting time. Further among the biomass conditions, wet biomass resulted in high pigment amounts of 56.89 mg. g^{-1} DCW under unoptimized freeze-thaw process conditions. Optimization of freeze thaw method for maximum phycocyanin extraction resulted in a high yield of 155.8 mg. g $^{-1}$ DCW, in a single freeze thaw cycle with a purity ratio of 2 (food grade) under the positive influence of lower biomass to solvent ratios and freezing with buffer (FWB) in 6.5 h. **Purification:** At 20% and 50% saturation concentrations, entire C-phycocyanin was precipitated with a remarkable purity of 5.6. Further, salt and small protein removal by dialysis resulted in purity to analytical grade C-phycocyanin (purity>6). The Gel filtration chromatogram analysis confirmed the presence of pure C-phycocyanin similar to that of C-phycocyanin analytical standard with a molecular weight of 135 kDa (Fig1.). **Characterization**: (i) UV-Vis spectroscopy revealed significant similarity showing characteristic maximum absorbance at 620 nm.(ii) The Fluorescence spectroscopy of purified C-phycocyanin, with excitation at 609 nm and emission spectrum at 643 nm. (iii) The Circular Dichroism spectroscopy confirmed intact polypeptide backbone with stable secondary structure of the purified C-phycocyanin (Fig1). **Bioactivity evaluation:** Anti-oxidant potential showed a DPPH scavenging activity with an IC50 value at a concentration of 123.62 µg. mL^{-1}. The *Spirulina* sp. NCIM 5143 produced C-phycocyanin showed an IC50 value of 232.2 ± 4.2 µg mL^{-1} in MTT assay on HeLa cells along with significant effects on cell migration and cell cycle arrest in G2 phase.

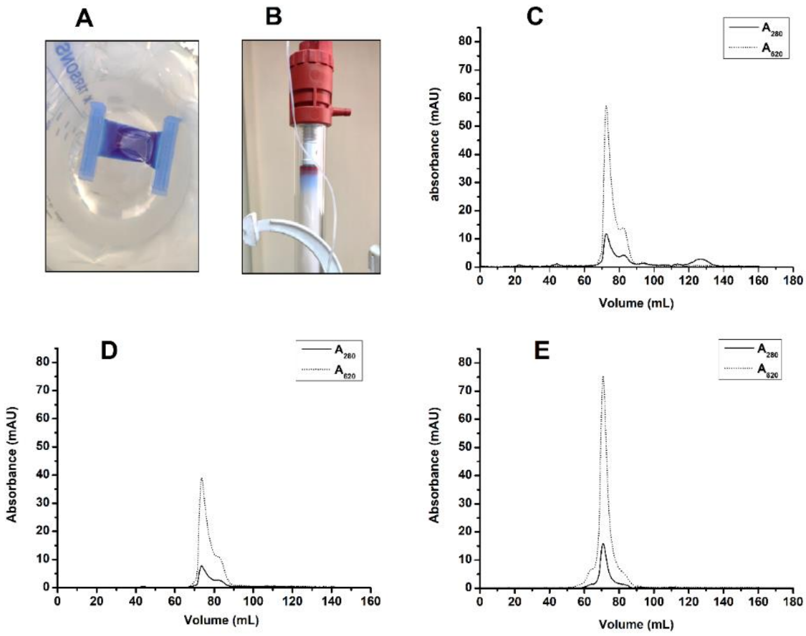

Fig1: Purification of C-phycocyanin (C-PC) (A) dialysis of ammonium sulphate extract, (B) dialysis extract loaded on to gel filtration chromatography column. Gel filtration chromatogram of (C) C-PC ammonium sulphate extract, (D) C-PC dialysis extract and (E) C-PC analytical standard.

Conclusion:

Combinatorial process engineering strategy resulted in significantly improved C-PC yield in single extraction step. Further, analytical grade C-PC was produced in a smaller number of purification steps, thereby reducing the overall cost. The purified C-PC extracted from *Spirulina* sp. NCIM 5143 possessed similar spectral characteristics to that of analytical standard and showed its potential as an anti-oxidant and an anti-cancer compound (HeLa cells).

About IIT Guwahati

Indian Institute of Technology Guwahati, the sixth member of the IIT fraternity, was established in 1994. The academic programme of IIT Guwahati commenced in 1995. At present the Institute has eleven departments, seven inter-disciplinary academic centres and five schools covering all the major engineering , science, healthcare, management and humanities disciplines, offering B.Tech., B.Des., M.A., M.Des., M.Tech., M.Sc., MBA and Ph.D. programmes. Within a short period of time, IIT Guwahati has been able to build up world class infrastructure for carrying out advanced research and has been equipped with state-of-the-art scientific and engineering instruments. Besides its laurels in teaching and research, IIT Guwahati has been able to fulfil the aspirations of people of the North East region to a great extent since its inception in 1994.

Indian Institute of Technology Guwahati's campus is on a sprawling 285 hectares plot of land on the north bank of the river Brahmaputra around 20 kms from the heart of the city. With the majestic Brahmaputra on one side, and with hills and vast open spaces on others, the campus provides an ideal setting for learning.

IIT Guwahati is the only academic institution in India that occupied a place among the top 100 world universities – under 50 years of age – ranked by the London-based Times Higher Education (THE) in the year 2014 and continues to maintain its superior position even today in various International Rankings. IIT Guwahati gained rank 41 globally in the 'Research Citations per Faculty' category and overall 395 rank in the QS World University Rankings 2022 released recently. IIT Guwahati has retained the 7th position among the best engineering institutions of the country in the 'India Rankings 2021' declared by the National Institutional Ranking Framework (NIRF) of the Union Ministry of Education. IIT Guwahati has been also ranked 2nd in the 'Swachhata Ranking' conducted by the Govt. of India. Recently, IIT Guwahati has been ranked as the top-ranked University in 2019 for IT developers by HackerRank in the Asia-Pacific region.

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी · Indian Institute of Technology Guwahati

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