ALPHA ARTS AND SCIENCE COLLEGE

PORUR, CHENNAI

(A Christian Minority Insitution)

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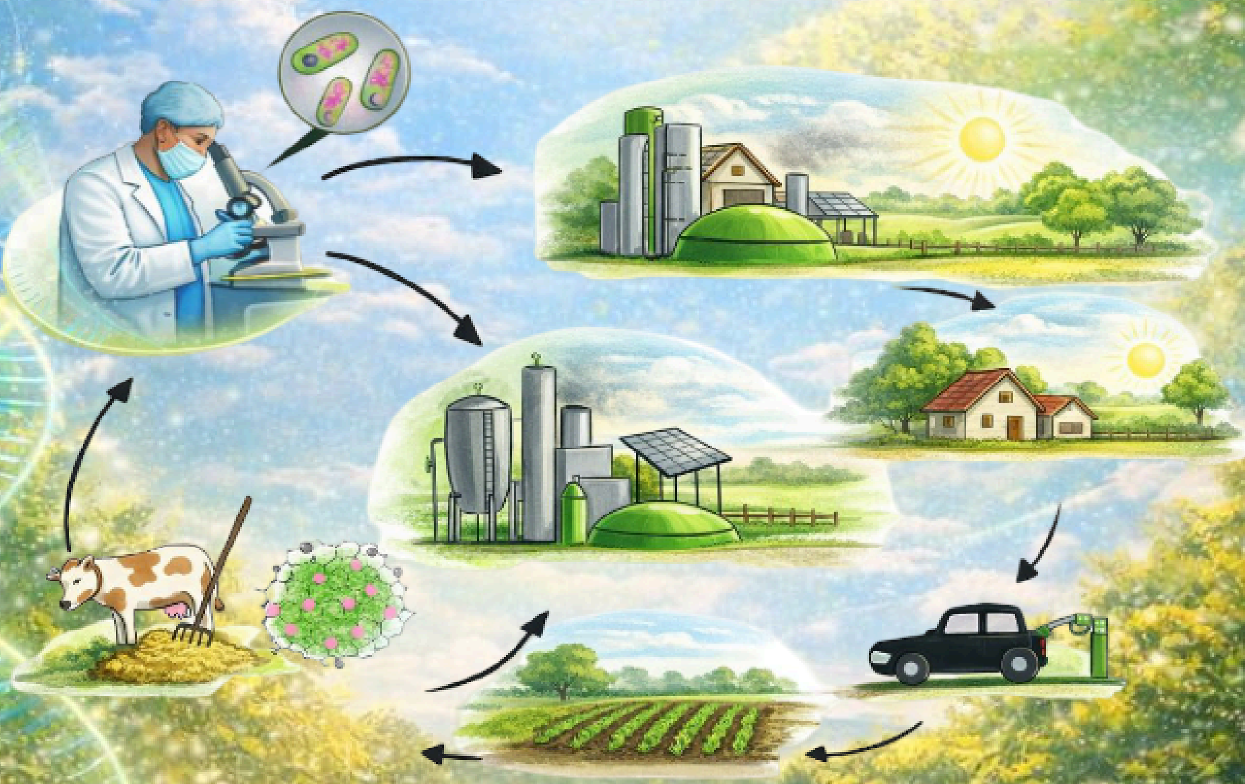
Affiliated to University of Madras

PG Department of Biotechnology

9th National Colloquium on NextGen Bioenergy - 2026

11th FEBRUARY, 2026



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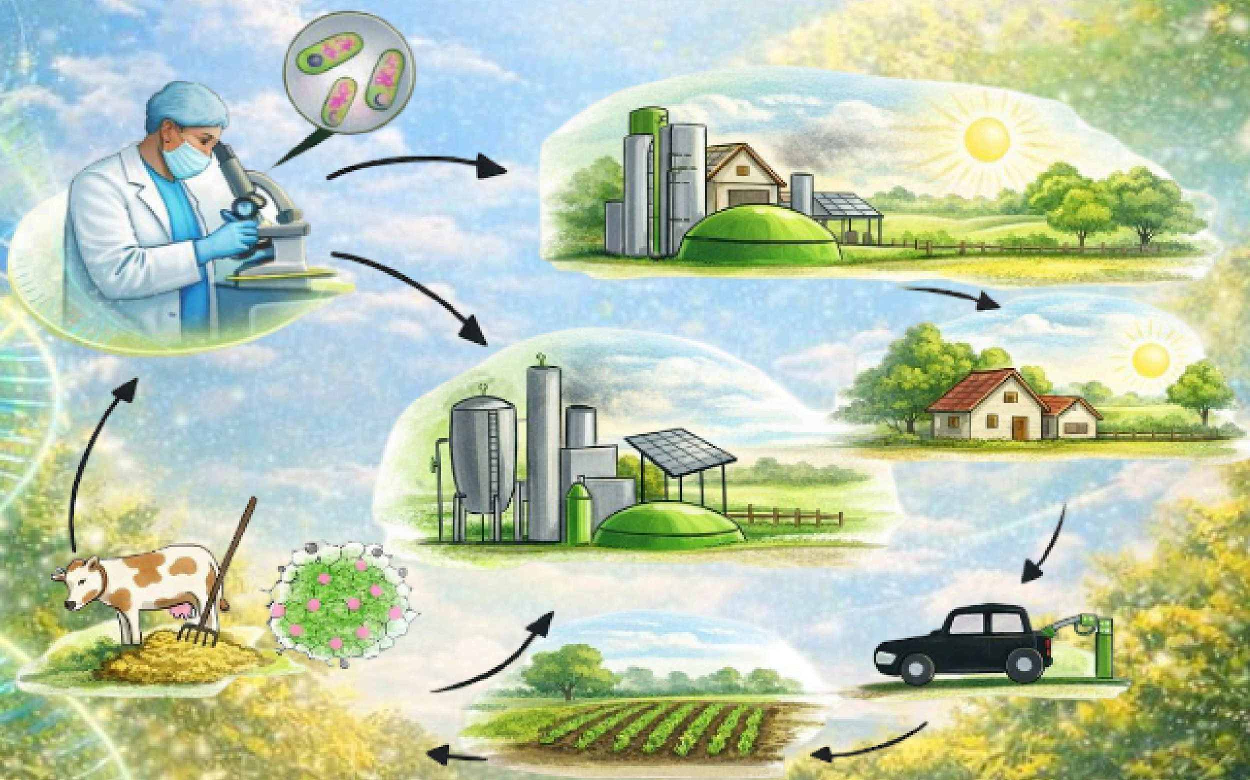

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CHAIRPERSON MESSAGE

The National Colloquium on "Next-Generation Bio-energy" stands as a timely and meaningful academic initiative that resonates strongly with our institution's commitment to innovation, sustainability, and societal responsibility. It is a matter of great pride to associate with this scholarly endeavor and to present the proceedings that emerge from it.

As the world navigates the dual challenges of energy demand and environmental stewardship, next generation bioenergy offers a transformative pathway—one that blends scientific creativity with ecological consciousness. This colloquium serves as an important platform for re-imagining energy solutions through biotechnology, fostering ideas that have the potential to influence industries, policies, and communities alike.

Our institution firmly believes that higher education must go beyond classrooms and laboratories to actively contribute to national priorities and global goals. The diverse research contributions compiled in these proceedings demonstrate the power of collaborative thinking and interdisciplinary research in shaping a sustainable future. They also reflect the enthusiasm and intellectual rigor of researchers who are committed to translating science into real-world impact.

I appreciate the Department of Biotechnology and the organizing team for conceptualizing and executing this national event with clarity of purpose and academic depth. I also acknowledge the active participation of researchers, experts, and young minds whose contributions have added value to this publication.

Mrs. Suja George

Chairperson

Alpha Group of Institutions

PRINCIPAL MESSAGE

It gives me immense pleasure to present the conference proceedings of the **National Colloquium on "Next-Generation Bioenergy"**, organized by the Department of Biotechnology.This colloquium has been conceived at a crucial time when sustainable energy solutions are no longer optional but essential for global environmental and economic stability.

Bio-energy, particularly next-generation bio-fuels and bio-based energy systems, holds tremendous promise in addressing challenges related to climate change, energy security, and sustainable development. The theme of this national colloquium aptly reflects the growing need to integrate scientific innovation, industrial applications, and policy frameworks to advance the bio-energy sector.

The colloquium has brought together eminent academicians, researchers, industry experts, and young scholars from across the country, fostering meaningful discussions and knowledge exchange.

I commend the efforts of the organizing committee, faculty members, and student volunteers for their dedication and meticulous planning, which have contributed to the successful conduct of this national event. I also extend my sincere appreciation to all the contributors and reviewers for enriching these proceedings with high-quality scholarly work.

Dr. A. Sivasankar

Principal

Alpha Arts and Science College

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PG Department of Biotechnology

9th NATIONAL COLLOQUIUM ON

NextGen Bioenergy 2026

National Colloquium
NextGen Bioenergy 2026
PG DEPARTMENT OF BIOTECHNOLOGY
2026

11th February 2026

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Mrs. Suja George
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Dr. A. Sivasankar
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Mr. George John
Joint Director, AGI

Ms. Anna John
Joint Director, AGI

Time: 09:00 AM

Venue: Seminar Hall

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Comparative formulation and characterization of *Aloe barbadensis* gel-based moisturizers enriched with Spirulina phycocyanin – Biosynthesized zinc oxide nanoparticles

Varshini. G [1], Dr. Preethy P Raj [1], Dr. Rajesh Kanna [2]

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Abstract

The global cosmetics market is growing rapidly, driven by consumer demand for natural, effective, and sustainable skincare products, with moisturizers playing a crucial role in skin hydration and protection. Aloe vera gel provides a hydrating base due to its humectant and occlusive properties, along with anti-inflammatory and wound-healing benefits. Phycocyanin contributes potent antioxidant, anti-inflammatory, and antimicrobial effects, mitigating oxidative stress and skin irritation from environmental factors.This study focuses on developing multifunctional Aloe vera-based moisturizers enhanced with Spirulina-derived phycocyanin and eco-friendly green-synthesized zinc oxide (ZnO) nanoparticles. The green synthesis of ZnO nanoparticles using orange peel extract offers biocompatibility and multifunctional benefits including antimicrobial activity, anti-inflammatory effects, UV protection, and moisture retention. Characterization by FTIR confirmed molecular interactions between ZnO and the gel matrix, while SEM verified nanoparticle morphology. Antioxidant (DPPH) and antibacterial assays demonstrated that the combined formulation exhibits enhanced bioactivity and stability compared to phycocyanin alone. These results suggest a synergistic effect enabling development of a natural, "clean-label" moisturizer addressing hydration, antioxidation, infection control, and photoprotection. This approach aligns with the growing market preference for multifunctional, safe, and environmentally responsible cosmetic products.

Keywords: Aloe vera gel; phycocyanin; zinc oxide nanoparticles; green synthesis; antioxidant; antibacterial; FTIR (Fourier transform infrared spectroscopy); SEM (scanning electron microscopy); multifunctional moisturizer; natural skincare.

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Phytoremediation potential of naturally occurring plants in Heavy-metal contaminated soils

Shobana J [1], Ilavarasi R [2], Sudha.V *.

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Abstract

Heavy metal contamination of soils poses a serious threat to environmental quality, food safety, and human health. Conventional remediation methods are often costly, energy intensive, and disruptive to ecosystems. Phytoremediation—the use of plants to remove, immobilize, or neutralize toxic metals—has emerged as an eco-friendly and sustainable alternative. This study emphasizes the role of naturally occurring plant species that thrive in heavy-metal-contaminated sites. These plants often display inherent tolerance and adaptive mechanisms that allow survival under metal stress, making them valuable prospects for remediation. Such vegetation employs mechanisms including phytoextraction, phytostabilization, and rhizofiltration, which can reduce the mobility, bioavailability, and ecological risks of contaminants such as cadmium, lead, chromium, and arsenic. Utilizing plant species already established in contaminated areas offers unique benefits: they are ecologically compatible, require minimal maintenance, and contribute to natural site restoration. In addition, understanding the physiological and molecular mechanisms underlying their tolerance provides valuable insights for enhancing phytoremediation strategies and developing genetically improved varieties. By integrating ecological observations with molecular insights, this study highlights the potential of native species as natural resources in reclaiming degraded lands. The exploitation of such plants represents a cost-effective, eco-efficient, and sustainable approach to environmental remediation and long-term ecosystem recovery.

Keywords: Heavy Metal contamination, Phytoremediation, Native plants, Soil pollution, Metal tolerance, Chromium, Ecosystem restoration, Sustainable remediation.

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Formulation and evaluation of Seaweed (*Sargassum wightti*) based hydrogel for *in-vitro* wound healing studies

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Abstract

Marine macroalgae have emerged as sustainable resources for developing bioactive biomaterials in tissue engineering and regenerative medicine. *Sargassum wightii*, a brown seaweed abundantly found along the Indian coastline, is particularly rich in polysaccharides such as alginate, fucoidan, and laminarin, which exhibit antioxidant, antimicrobial, and anti-inflammatory properties. In the present study, a bioactive hydrogel was formulated by incorporating *Sargassum wightii* extract into a carboxymethyl cellulose (CMC) matrix crosslinked with citric acid. The CMC–citric acid network provided a stable, porous, and highly hydrated structure that closely mimics the extracellular matrix, enabling sustained release of algal metabolites. Structural characterization demonstrated uniform gelation, porosity, and swelling behavior appropriate for biomedical application. For biological evaluation, the hydrogel was applied to Vero cell monolayers subjected to a standardized scratch assay. Results revealed that treatment with *Sargassum wightii* hydrogel significantly enhanced cell migration and proliferation compared to untreated controls, leading to faster wound gap closure. These findings suggest that *Sargassum wightii*–based hydrogel can serve as a promising natural wound healing material, providing a biocompatible, cost-effective, and eco-friendly alternative to conventional dressings. Future in vivo studies are required to further validate its therapeutic efficiency and safety. Overall, the integration of *Sargassum wightii* in hydrogel technology demonstrates the potential of marine resources in advancing regenerative biomedical applications.

Keywords: *Sargassum wightii*, hydrogel, wound healing, scratch assay, marine polysaccharides, tissue regeneration, biocompatibility.

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Guava Leaf Clarifying Serum

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Abstract

Guava leaves (*Psidium guajava*) and are used in traditional medicine, rich in antioxidants, flavonoids like quercetin, and bioactive compounds. They are consumed by brewing them into tea for potential benefits such as, supporting skin and eye health, and regulating blood sugar levels. A guava leaf clarifying serum demonstrates significant anti- wrinkling and anti-aging properties due to its abundance of bioactive compounds such as flavonoids, vitamins, and antioxidants. These constituents neutralize free radicals, inhibit oxidative stress, and protect skin cells from aging, thereby improving skin texture, elasticity, and overall radiance. Formulated as a fast-absorbing cosmetic product, the guava leaf serum offers deep skin penetration and delivers concentrated active ingredients that help diminish fine lines, lighten dark spots, and enhance moisture retention. Its antibacterial and anti-inflammatory effects further contribute to acne prevention and reduction of skin irritation, making it an effective choice for comprehensive anti-aging skin care. Guava leaf clarifying serum is a potent topical formulation leveraging the dense antioxidant, anti-inflammatory, and antimicrobial profile of *Psidium guajava* leaf extract. Rich in vitamin C, flavonoids, and bioactive phytochemicals, guava leaf extract effectively combats oxidative stress, neutralizes free radicals, and stimulates collagen synthesis, resulting in reduced wrinkle formation and delayed skin aging. The serum's quick absorption and deep penetration maximize the delivery of these active agents, improving skin hydration, reducing fine lines, and lightening hyperpigmentation. Regular use supports skin firmness, evens complexion, and minimizes imperfections, positioning guava leaf clarifying serum as a promising natural alternative for anti-wrinkle and anti-aging skincare regimens.

Keywords: Guava leaves (*Psidium guajava*), Natural skincare alternative, Hyperpigmentation, Anti - wrinkling, Anti-aging.

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Cyanobacterial exopolysaccharide as natural cryoprotectant for microbial preservation

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Abstract

The long-term preservation of microorganisms is fundamental to research, industrial biotechnology, and clinical applications. Cryopreservation using chemical cryoprotectants such as glycerol and dimethyl sulfoxide (DMSO) is routinely employed; however, these agents may exhibit cytotoxicity, alter cellular physiology, and pose environmental concerns. Consequently, there is increasing interest in identifying natural, biodegradable, and biocompatible alternatives. Cyanobacteria are known to secrete exopolysaccharides (EPS), high-molecular-weight extracellular polymers composed mainly of complex polysaccharides enriched with hydroxyl and charged functional groups. These properties confer strong water-binding capacity and protective functions, suggesting that EPS may stabilize cellular membranes and proteins during freezing and thawing stress. In this study, selected cyanobacterial strains were cultivated under controlled laboratory conditions, and EPS were extracted from the cell-free supernatant using ethanol precipitation. The crude EPS were purified by trichloroacetic acid-mediated deproteinization, dialysis, and lyophilization. Purified EPS were characterized for total carbohydrate and protein content using standard colorimetric assays. Different concentrations of EPS were evaluated for their cryoprotective efficiency using microbial model organisms and compared with glycerol as a conventional cryoprotectant. Cryopreservation was performed at −80°C, and post-thaw cell viability was determined by colony forming unit (CFU) enumeration. The study aims to demonstrate that cyanobacterial EPS significantly improve microbial survival following freeze–thaw cycles and offer comparable or superior protection to conventional cryoprotectants. The findings are expected to support the development of cyanobacterial EPS as sustainable, non-toxic cryoprotectants for microbial culture collections and biotech.

Keywords: Exopolysaccharides (EPS); Cryopreservation; Cyanobacteria.

****

Exploring the eco-nanovermi plus an advancement in Vermicompost

Vishwa. A, Dr. L. Krishnaswamy

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Abstract

Eco-nanovermi plus presents a dual-track circular economy model that revolutionizes urban waste management by converting problematic landfill and "dumpsters" into high-value agricultural resources with zero initial investment and zero pollution. By utilizing a hyper-local sourcing strategy, the project bypasses traditional logistics costs. Organic waste is diverted from anaerobic landfill conditions—which typically release methane—into a controlled vermicomposting environment that yields nutrient-rich biofertilizer while sequestering carbon. To address the non-biodegradable fraction, the project adopts trending mechanical and physical recycling techniques similar to those pioneered by industry leaders like Blue Polymers and SCGC, which focus on high-purity resin recovery. A comparative analysis reveals that while synthetic fertilizers provide an instant chemical spike that degrades soil structure and microbial health over time, Eco-vermi plus biofertilizer offers a sustained-release nutrient profile (N, P, K) enriched with antimicrobial properties. This not only promotes superior plant immunity but also restores the soil's natural ecosystem. By transforming a dumpster from a "waste site" into a "production hub" this project achieves a closed-loop system where garbage is the only raw material and environmental restoration is the only by product.

Keywords: Methane; Vermicompost; Blue polymer.

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Comparative antimicrobial studies of *Spirulina platensis* and Aloe vera solvent extracts against bacteria and fungi

P. K. Dhanalakshmi, S. Revathi Chitra, V.Sowmiya*, S. Vinu Sri*

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Abstract

For the past century, spirulina has been used as a human food supplement. It has a high protein content, vitamins (A, D, E, K, and B complex vitamins), beta-carotene, manganese, zinc, copper, iron, selenium, and gamma linolenic acid. Aloe vera (*Aloe barbadensis*) is widely recognized for its therapeutic properties due to its rich phytochemical composition, including proteins, carbohydrates, and steroids. Numerous research has shown that Spirulina has biological features such as immunomodulation, antioxidant, anticancer, and antimicrobial activities. The present work investigated the phytochemical analysis and *in vitro* antimicrobial activity of solvent extracts of *Spirulina platensis*, Aloe vera and combination of both. Antimicrobial activity against bacteria and fungi such as *Escherichia coli, Salmonella typhi, Aspergillus niger, Candida albicans* was assessed using the agar well diffusion technique and disc diffusion technique.

Keywords: Spirulina platensis; *Aloe barbadensis*; Phytochemical analysis; Antimicrobial activity; Bacteria; Fungi.

****

Pilot study on mushroom cultivation and Valorization of spent mushroom substrate for biogas production

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Abstract

Oyster Mushroom is an edible, fan-shaped mushroom that belongs to the family *Pleurotaceae* is cultivated worldwide for its high nutritional value and rich bioactivities. The edible mushroom value has been increasing in the global market worldwide because of the nutritional benefits and functional bioactivities of mushrooms. However, around 5 kg of wet byproducts—known as spent mushroom substrate, or SMS—are produced for every 1 kg of fresh mushrooms, approximately. Our study helps in the production of mushroom and SMS helps to mitigate the bio-waste conversion to an environmentally friendly biogas production. In our study, Oyster mushroom was cultivated in a polythene bag using the feedstock straws. Oyster spawn was collected from Tamil Nadu Agriculture University. The collected spawn was inoculated into the bags after 15 to 20 days; our first fruiting body was harvested; each bag gave around 4 times of harvesting after 44 days of fruiting of mushroom was stopped. The bag containing the spent substrate was taken and made into small pieces. After air drying, it was soaked in water for 24 hours to soften the lignocellulosic material present in the spent substrate. To that slurry, cow dung (10-20%) was mixed, then it was stored in the air tight container, and the temperature was maintained at (30-37ºC), and the pH was maintained at 6.8-7.5 retention time was 20- 40 days. The produced biogas was checked by connecting it with the vent pipe, and on lighting it flame was produced. Production of flame ensures the methane(biogas) production, and the leftover spent substrate can be used as animal fodder. The present study demonstrates the dual benefit of oyster mushroom cultivation and effective valorization of spent mushroom substrate (SMS) for sustainable biogas production. The results confirm that SMS, when co-digested with cow dung under controlled conditions, produces methane-rich biogas, as evidenced by flame formation. This approach not only reduces bio-waste but also generates renewable energy, while the residual substrate can be reused as animal fodder. Overall, the study supports an eco-friendly and sustainable method integrating mushroom cultivation with bio-waste management and energy recovery.

Key words: Biogas, Biofuel, Mushroom cultivation, renewable energy.

****

Development of sustainable Banana peel–derived nanocomposite anti fouling coatings for marine environments

Anjana Sai. Y. S

Department of Biotechnology, Prince Shri Venkateshwara Arts and Science College, Chennai

Abstract

Marine bio fouling, caused by the attachment and growth of microorganisms, algae and invertebrates on submerged surfaces, presents significant economic and environmental challenges, including increased hydrodynamic drag, corrosion and fuel consumption. Conventional anti fouling coatings commonly rely on toxic biocides that pose serious threats to marine ecosystems. In response to the growing demand for environmentally sustainable alternatives, this study explores the development of banana peel-based nanocomposite coatings as an eco-friendly anti fouling solution. Banana peels, an abundant agricultural waste, are rich in cellulose, pectin and polyphenolic compounds, making them suitable as bio polymer matrices and green reducing agents for nanoparticle synthesis. In this work, nanoparticle were synthesized using banana peel extract and incorporated into a banana peel derived bio polymer to form nanocomposite coatings. The coatings were applied onto model substrates and evaluated for anti fouling performance, water resistance, surface properties, mechanical stability and biodegradability. The nanocomposite coatings demonstrated a marked reduction in microbial adhesion and biofilm formation compared to unmodified bio polymer coatings. Enhanced surface hydrophobicity and antimicrobial activity contributed to effective inhibition of early-stage fouling. Adhesion and durability tests indicated that the coatings remained intact under simulated marine conditions. Biodegradation studies confirmed the environmentally benign nature of the material, minimizing long-term ecological impact. Overall, the results suggest that banana peel-based nanocomposite coatings offer a promising, low-cost and sustainable alternative to conventional anti fouling systems. This approach addresses marine fouling challenges while promoting waste valorization, circular bioeconomy principles and the development of green materials for marine infrastructure applications in coastal, offshore and aquaculture engineering contexts worldwide today globally.

Keywords: Banana peel waste; Nanocomposite; Anti fouling coatings; Marine bio fouling; Green synthesis; Bio polymer coatings; Sustainable marine materials.

****

Algae and Cyanobacterial uses in biotechnology

Sandhiya.H. [1], Harini.M [2], Dr.N.Jayalakshmi [3]

Department of Biotechnology, Apollo arts and science college, Poonamallee, Chennai.

Abstract

Algal and cyanobacterial blooms are anticipated to increase in frequency, duration, and geographic extent as a result of environmental changes, including climate warming, elevated nutrient concentrations, and increased runoff in both marine and freshwater ecosystems. The eutrophication of aquatic environments represents a substantial threat to human health. The increasing need for sustainable agriculture has emphasized algae-based biofertilizers and soil amendments as eco-friendly alternatives to chemical fertilizers. Algae, including microalgae and cyanobacteria, are rich in essential nutrients and provide additional benefits such as nitrogen fixation, phosphorus solubilization, and organic matter enhancement. Algal biofertilizers enhance soil health, improve water retention, and promote beneficial microbial activity, which makes algae a valuable resource for enhancing crop growth, yield, and resilience to environmental stress Although algal biofertilizers show prospects for sustainable farming, high cultivation costs and scalability problems must be addressed. Although algal biofertilizers show prospects for sustainable farming, high cultivation costs and scalability problems must be addressed. This review identifies key technical and economic barriers, assesses the scalability of proposed methods, and outlines research and policy priorities for advancing algae-based biofertilizers. While algae hold promises for reducing chemical fertilizer dependence, their broad adoption will require integrated solutions that address cost-efficiency, regulatory support, and system-level integration into existing agricultural practices.

Keywords: Cyanobacteria; Biofertilizers; Algae; Soil; Agriculture; Yield.

****

An Overview of Biofuel Production Using *Ulothrix spp.*

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Abstract

The growing need for sustainable and renewable energy sources as increased interest in biofuels derived from biological systems. Algae-based biofuel are considered an eco-friendly alternative to fossil fuels biological systems due to their fast growth rate and ability to utilize the atmospheric carbon dioxide. *Ulothrix spp.,* a filamentous freshwater green alga, is an underutilized algal resource with potential application in bioenergy production. This review paper represents a conceptual analysis and the future research perspective on biofuel production. Ulothrix spp. shows several biological features such as rapid growth of biomass, high carbohydrate content, simple cellular structure and ability to grow in freshwater bodies with minimal nutrient requirements. These characteristics makes them suitable biofuel pathways such as bioethanol production through the carbohydrate fermentation and the biogas generation by anaerobic digestion. The filamentous nature of Ulothrix also capable of easier harvesting when compared to unicellular microalgae, which may reduce cost for processing in large-scale applications. This review highlights possible future research approaches, including the use of nutrient stress, light variation, and temperature control to improve biomass yield and biochemical composition. Cultivation of *Ulothrix spp.* In wastewater systems is introduced as a dual-benefit for biofuel production and environmental management. In addition, the combination of biofuel generation with bi-products such as biofertilizers could improve overall process of sustainability. Although commercial-scale production is still limited, Ulothrix spp. exhibits strong potential for biological resources for suitable bioenergy production. The review aims to encourage further experimental research and technological development by presenting Ulothrix-based biofuel production as a feasible and sustainable option for future energy needs.

Keywords: *Ulothrix spp;* biofuel production; algal bioenergy; freshwater algae; bioethanol; biogas; renewable energy.

****

Algae and Cyanobacterial biotechnology

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Abstract
In recent years, there has been growing interest in the commercial cultivation of algae due to their capacity to synthesize a wide range of bioactive compounds. Both microalgae and cyanobacteria are known to produce diverse primary and secondary metabolites that are valuable for industrial, nutritional, and pharmaceutical applications. For example, certain algal species generate antioxidants that protect photosynthetic cells against oxidative damage. In addition, microalgae can produce polyunsaturated and monounsaturated fatty acids that offer significant health benefits for human consumption. Products derived from cyanobacteria and microalgae have also demonstrated promising bio medical properties, including the production of polysaccharides, glycerol, glycoproteins, and antibiotic substances. The increasing prevalence of antibiotic resistance and the anticipated decline in the effectiveness of existing antimicrobial drugs have intensified the search for new antibiotic sources. In this context, cyanobacteria and microalgae represent a largely unexplored and highly promising reservoir of novel bioactive compost.

Keywords: Bioactive compounds; pharmaceutical applications; Primary and Secondary Metabolites; Microalgae; Cyanobacteria; Antimicrobial agents.

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Green nanocomposites

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Abstract

Green nanocomposites are an innovative class of sustainable materials engineered by integrating bio-derived nanofillers—such as cellulose nanocrystals, chitin nanofibers, graphene oxide, or green-synthesized metal nanoparticles (e.g., silver, zinc oxide)—into biodegradable polymer matrices like polylactic acid (PLA), polyhydroxyalkanoates (PHA), starch, or chitosan. These hybrids are primarily fabricated via eco-friendly "green synthesis" routes, including plant extract-mediated reduction, microbial fermentation, or solvent-free processing, which eliminate hazardous chemicals, volatile organic compounds, and energy-intensive methods traditionally used in conventional nanocomposites. This approach not only ensures renewability and cost- effectiveness but also imparts exceptional multifunctional properties: enhanced mechanical reinforcement (tensile strength up to 200% improvement), superior thermal stability, improved barrier performance against oxygen and water vapor, and bioactive attributes like antimicrobial activity, UV shielding, photocatalytic degradation of pollutants, and self-healing capabilities. Applications span packaging (biodegradable films extending food shelf-life), biomedical fields (drug delivery scaffolds, tissue engineering), environmental remediation (water purification membranes), and agriculture (controlled-release fertilizers). Despite challenges like nanofiller dispersion uniformity and scalability, ongoing research leverages life-cycle assessments to optimize performance while advancing circular economy principles through recyclability and minimal carbon footprint.

Keywords: Green nanocomposites; biopolymer matrices; nanofillers; green synthesis; plant extracts; sustainability; biodegradability.

****

AI-controlled smart biogas reactors for maximum energy recovery from food waste

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Abstract

Food waste represents a significant and underutilized resource for renewable energy generation through anaerobic digestion. Despite its potential, conventional biogas reactors often suffer from inconsistent performance due to fluctuations in feedstock composition and operating conditions. This work examines the application of intelligent control strategies in smart biogas reactors to enhance energy recovery from food waste. By incorporating data-driven decision support tools, reactor operating parameters such as temperature, pH, organic loading rate, and retention time are continuously adjusted to maintain favorable conditions for microbial activity. Rather than relying on fixed control settings, the proposed approach adapts to process variations, leading to improved process stability and more efficient methane production. The analysis indicates that intelligent reactor control can reduce process upsets, improve overall energy conversion efficiency, and support long-term reactor operation. This study emphasizes the practical role of advanced control systems in improving the reliability and energy output of food waste–based biogas plants, contributing to sustainable waste management and renewable energy generation.

Keywords: Smart Biogas Reactors; Food Waste; Anaerobic Digestion; Process Control; Energy Recovery; Renewable Energy.

****

AI-Enhanced biogas production from food waste using microbial consortia

R. Hindhu Priya 1 ., Dr.VA kinsalin 2*

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Abstract

Food waste generation is rapidly increasing worldwide, creating environmental concerns and disposal challenges. Anaerobic digestion offers a sustainable pathway for converting food waste into biogas; however, process efficiency is often constrained by complex microbial dynamics and operational instability. This study presents an AI-enhanced biogas production framework that integrates machine learning models with microbial consortia optimization to improve anaerobic digestion performance. Artificial intelligence techniques are used to analyze real-time process data, including pH, temperature, organic loading rate, and volatile fatty acids, enabling predictive control and adaptive process optimization. The targeted management of microbial consortia enhances metabolic synergy among hydrolytic, acidogenic, acetogenic, and methanogenic microorganisms, resulting in improved methane yield and system stability. The proposed approach demonstrates higher biogas productivity and reduced process fluctuations compared to conventional digestion methods. This work highlights the potential of AI-driven strategies to advance waste-to-energy technologies and support sustainable food waste valorization.

Keywords: Artificial Intelligence, Biogas Production, Food Waste, Anaerobic Digestion, Microbial Consortia, Machine Learning, Waste-to-Energy.

****

Harnessing microalgae and cyanobacteria for sustainable bioenergy Production: Integration of molecular engineering and AI-driven approaches

R. Kalpana 1, Dr. V. A Kinsalin 2*

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Abstract

Increasing pollution and global energy concerns, arising from the over reliance on fossil fuels, demand an urgent search for alternative energy sources. Microalgae and cyanobacteria hold multiple potential including high productivity of lipid and biomass, ability to use waste resources and eventually making them a sustainable source for biofuel production. It can generate a wide range of biofuels such as bioethanol, biobutanol, biohydrogen, and biodiesel. Recent advances in generation of biofuel from algae involves various indoor and outdoor cultivation strategies, genome engineering, metabolic regulation, omics-oriented tools, and techniques. Besides, the role of Artificial Intelligence (AI) and Machine Learning (ML) in production of biofuel like assistance in bioreactor designing, strain selection, improvement, and anticipation of lipid yield. Regardless of these outstanding innovations and technological developments, the persistence of certain bottlenecks including their scalability, environmental impacts and economic feasibility renders a barrier for its widespread acceptance and commercialization. Incorporation of interdisciplinary approaches such as multi-omics, synthetic biology, AI & ML can successfully allow them to overcome the challenges for sustainable biofuel production. Eventually, this review breaks down the unexplored capabilities of microalgae and cyanobacteria to contribute in the generation of sustainable energy and addressing the significant deficiencies in culture optimization and large-scale implementation.

Keywords: Artificial intelligence; Alternative energy; Metabolic regulation; Machine Learning; Synthetic biology.

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Role of rDNA in industrial biotechnology

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Abstract

Recombinant DNA (rDNA) technology is a key component of industrial biotechnology that enables the controlled modification of genetic material for the large-scale production of valuable biological products. This technology involves the isolation of specific genes, their insertion into suitable vectors, and expression in host organisms such as bacteria, yeast, fungi, or mammalian cells to obtain desired proteins and metabolites. rDNA technology has transformed the pharmaceutical industry by facilitating the safe and efficient production of therapeutic compounds including insulin, human growth hormone, interferons, clotting factors, and vaccines with high purity and consistency. In addition to pharmaceuticals, recombinant microorganisms are widely used to produce industrial enzymes applied in food processing, detergents, textiles, paper, leather, and biofuel industries, where they enhance process efficiency, reduce energy consumption, and lower production costs. rDNA technology also plays a significant role in environmental biotechnology through the development of genetically engineered microorganisms for bioremediation, waste management, and pollution control. Moreover, it supports sustainable industrial practices by enabling the biosynthesis of bio-based chemicals, biodegradable plastics, and eco-friendly alternatives to chemical processes. Overall, recombinant DNA technology improves productivity, quality, and sustainability of industrial processes, making it an indispensable tool in modern industrial biotechnology with far-reaching economic and environmental benefits.

Keywords: Recombinant DNA technology; Industrial biotechnology; Genetic engineering; Industrial enzymes; Pharmaceuticals; Sustainable biotechnology.

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Microbial enzyme used in biofuel

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Abstract

Microbial enzymes play a pivotal role in biofuel production by enabling the efficient breakdown of complex lignocellulosic biomass—such as agricultural residues, forestry waste, and energy crops—into fermentable sugars and other precursors for sustainable fuels like bioethanol, biodiesel, biobutanol, and biogas. Key enzymes from microbial sources, including cellulases (endoglucanases, exoglycanases, and β- glucosidases) produced by fungi like *Trichoderma reesei* and bacteria such as *Clostridium thermocellum*, hydrolyze cellulose into glucose; hemicelluloses (xylanases,mannanases) from *Bacillus subtilis* and *Aspergillus niger* target hemicellulose; amylases from Streptomyces species degrade starch; and lipases from *Pseudomonas aeruginosa* and *Burkholderia cepacia* facilitate biodiesel synthesis via transesterification of lipids into fatty acid methyl esters (FAME). These enzymes operate synergistically in pretreatment, saccharification, and fermentation stages, often consolidated in simultaneous saccharification and co-fermentation (SSCF) processes using engineered microbes like *Saccharomyces cerevisiae* or *Escherichia coli.* Advantages include thermophilic stability (up to 80°C), broad pH tolerance (4–9), and reduced inhibition by end-products, enhanced through genetic engineering, directed evolution, and metagenomics for novel variants from extreme environments. Applications extend to second-generation biofuels from non-food feedstocks, supporting circular economy goals by valorizing waste and cutting greenhouse gas emissions by 50–90% compared to fossil fuels, thus advancing global energy transition toward net-zero targets.

Keywords: Microbial enzymes; Biofuel production; Biodiesel; Lignocellulosic biomass; Saccharification; *Trichoderma reesei, Clostridium thermocellum*, Enzymatic hydrolysis.

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Molecular engineering of megakaryocytes for enhanced thrombopoiesis

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Abstract:

Megakaryocytes are bone marrow cells responsible for platelet production recombinant DNA technology enables the production of thrombopoietin (TPO), a key growth factor that induces megakaryocytes differentiation. This project explains the role rDNA technology in producing megakaryocytes for therapeutic and research applications. Which includes isolation of TPO gene, vector insertion, host cell transformation, protein expression & purification, stem cells differentiation. It helps in controlled platelet production, reduced donor dependency. Recombinant DNA technology enables efficient production of megakaryocytes through recombinant thrombopoietin. This approach has strong potential in transfusion medicine and treatment of platelet disorders.

Keywords: Megakaryocytes; TPO gene; Stem cell differentiation; Protein expression.

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Microalgal Biomass Valorization for Next-Generation Biofuels and Carbon Neutrality

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Abstract

The growing dependence on fossil fuels has intensified carbon emissions and climate change, highlighting the urgent need for sustainable and carbon-neutral energy alternatives. Conventional biofuels derived from food crops face major limitations, including competition with food resources, high land and water requirements, and limited environmental benefits. In this context, microalgal biomass valorization emerges as a promising next-generation solution for sustainable biofuel production. Microalgae are fast-growing, non-food organisms capable of efficiently capturing atmospheric and industrial carbon dioxide through photosynthesis. Their biomass is rich in lipids, carbohydrates, and proteins, enabling the production of multiple biofuels such as biodiesel, bioethanol, biogas, and biohydrogen. Adopting a biorefinery-based valorization approach ensures complete utilization of microalgal biomass, minimizing waste while maximizing energy output and economic viability. Additionally, the integration of microalgal cultivation with industrial CO_2 emissions supports a circular bioeconomy and contributes significantly to carbon neutrality. This study highlights the potential of microalgal biomass valorization as a scalable, eco-friendly, and future-ready pathway for achieving sustainable energy security and global net-zero carbon goals.

Keywords: Microalgal biomass, Biofuel production, Biorefinery, Carbon neutrality, Circular Bioeconomy

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Application of Microbial enzymes used in Biofuels

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Abstract:
Microbial enzymes are widely used in biofuel production as efficient biocatalysts for converting renewable biomass into energy-rich fuels. These enzymes, produced by microorganisms such as bacteria, fungi, and yeasts, catalyse the degradation of complex substrates including cellulose, hemicellulose, starch, and lipids into simpler compounds suitable for fermentation or further processing. Their ability to specifically target complex polymers makes them highly effective in biomass conversion processes. In addition, microbial enzymes operate under mild temperature and pH conditions, which significantly reduces energy consumption and environmental pollution when compared to conventional chemical methods. Their high substrate specificity and catalytic efficiency lead to improved conversion rates, higher biofuel yields, and minimal formation of undesirable by-products. Enzymes such as cellulases, hemicellulases, amylases, and lipases play a major role in the production of bioethanol, biodiesel, and biogas. Furthermore, microbial enzymes can be produced economically on a large-scale using fermentation technology, making them suitable for industrial applications. Recent advances in genetic engineering, metabolic engineering, and enzyme immobilization have enhanced enzyme stability, activity, and reusability, improving overall process efficiency. Therefore, the use of microbial enzymes supports sustainable, ecofriendly, and economically viable biofuel production.

Keywords: Microbial enzymes, biofuel production, renewable biomass, bioethanol, biodiesel, sustainable energy

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Harnessing plant power for nano synthesis: A review on green nanocomposites

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Abstract

Green nanocomposites are a new generation of high-performance materials that have been synthesized by employing eco-friendly materials, biodegradable natural polymers, and eco- safe techniques. Green nanocomposites are a combination of biodegradable natural polymers like cellulose, chitosan, starch, alginate, and polylactic acid with nanofillers such as metal nanoparticles, nanoclays, carbon nanotubes, and biodegradable nanofibers. The application of eco-safe techniques like plant extract-mediated synthesis of nanoparticles, solvent-free synthesis, and low-energy fabrication methods helps in reducing the environmental hazards and toxicity. Green nanocomposites have shown improved mechanical properties, thermal resistance, antimicrobial activity, barrier properties, and biocompatibility compared to traditional composites. Due to their unique properties, green nanocomposites have numerous applications in biomedical applications, drug delivery systems, tissue engineering, food packaging, environmental remediation, water purification, agriculture, and eco-friendly electronics. The synthesis of green nanocomposites is a major breakthrough in the field of sustainable nanotechnology.

Keywords: Green nanocomposites; Biodegradable natural polymers; Nanofillers; Eco-friendly Synthesis; Mechanical and thermal properties; Antimicrobial activity; Biocompatibility; Biomedical applications; Environmental remediation; Sustainable nanotechnology.

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Role of rDNA in Industrial Biotechnology

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Abstract

Recombinant DNA (rDNA) technology emerged as a core driving force in the advancement of industrial biotechnology by enabling the precise modification of microorganisms for large-scale and sustainable production processes. Industrial biotechnology focuses on then use of living cells and enzymes to manufacture chemicals, materials, and value-added products from renewable resources. Through genetic engineering, microorganisms can be tailored to over express target genes, improve metabolic pathways, and produce enzymes, and biochemical with yield and stability. The integration of rDNA technology has significantly transformed traditional fermentation processes by reducing dependence on petrochemical routes and promoting environmentally friendly alternatives. Genetically engineered microbes are widely used in the production of industrial enzymes, organic acids, pharmaceuticals and biodegradable polymers. These developments contribute to reduced energy consumption, lower greenhouse gas emissions, and minimized waste generation, aligning industrial production with the principles of green and sustainable chemistry. Furthermore, rDNA technology enables the development of robust microbial strains capable of tolerating harsh industrial conditions, utilizing diverse feedstocks and achieving cost-effective production at commercial scales overall rDNA technology has become an indispensable tool in industrial biotechnology.

Keywords: rDNA technology; Industrial Biotechnology; Enzymes; Proteins; Fermentation; Metabolic pathways; Value-added products; Biodegradable polymers.

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Role of microbial enzymes in sustainable Biofuel production

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Abstract

The global energy crisis and environmental pollution caused by fossil fuels have accelerated the search for sustainable and eco-friendly energy alternatives. Biofuels have emerged as a promising renewable energy source, and microbial enzymes play a pivotal role in their efficient production. Microbial enzymes such as celluloses, amylases, and lipases act as powerful biocatalysts in converting renewable biomass into clean energy Celluloses and amylases produced by bacteria and fungi efficiently hydrolyze lignocellulose biomass and starch into fermentable sugars, which are subsequently converted into bioethanol. Lipases are widely applied in biodiesel production by catalyzing the transesterification of plant oils and animal fats into fatty acid methyl esters. The use of microbial enzymes significantly enhances conversion efficiency, reduces energy consumption, and minimizes environmental impact, making biofuel production more sustainable. Recent advances in microbial biotechnology, genetic engineering, and enzyme optimization have improved enzyme yield, stability, and industrial applicability. These innovations have opened new pathways for cost-effective large-scale biofuel production using agricultural and industrial waste materials. Despite certain challenges, continuous research and technological advancements are driving microbial enzyme-based biofuels toward commercial viability. Overall, microbial enzymes represent a key technological solution for achieving sustainable bioenergy production and contribute significantly to global efforts in reducing carbon emissions and promoting a greener future.

Keywords: Microbial Enzymes; Biofuels; Cellulose; Amylase; Lipase; Bioethanol; Biodiesel; Sustainable Energy; Biotechnology.

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Genetically Modified Organisms (GMOs)

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Abstract

Genetically Modified Organisms (GMOs) are organisms whose genetic material has been deliberately altered using modern biotechnology to obtain specific desirable traits. This modification is commonly achieved through genetic engineering and recombinant DNA technology, where selected genes are transferred from one organism to another to improve characteristics such as resistance to pests, tolerance to herbicides, or enhanced nutritional value. GMOs have wide applications in agriculture, medicine, and industrial biotechnology. In agriculture, genetically modified crops help increase crop yield, reduce the use of chemical pesticides, improve resistance to diseases, and support global food security. In the medical field, GMOs are extensively used in the production of insulin, vaccines, hormones, and other therapeutic proteins that are essential for treating various diseases. Additionally, GMOs contribute to industrial processes such as enzyme production and biofuel development. Despite their significant benefits, GMOs have raised concerns regarding environmental safety, loss of biodiversity, ethical considerations, and potential long-term health effects. Therefore, thorough risk assessment, strict biosafety regulations, and proper monitoring are necessary to ensure their safe and responsible use. Overall, GMOs represent a major advancement in biotechnology and play a crucial role in addressing agricultural, medical, and industrial challenges when managed under appropriate regulatory frameworks.

Keywords: Genetically Modified Organisms; Genetic Engineering; Recombinant DNA Technology; Biotechnology; Transgenic Crops; Biosafety.

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Eco-Friendly Synthesis, Characterization and Multifunctional bioactivity of *Syzygium cumini* seed-mediated Zn-Ce nanocomposites

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Abstract

The green synthesis of zinc–cerium (Zn–Ce) nanocomposites using *Syzygium cumini (*Jamun) seed extract will serve as an environmentally benign alternative to conventional synthesis approaches. Reaction parameters such as pH, temperature, and metal precursor concentration will undergo optimization to achieve better control over nanoparticle size, morphology, and stability. Characterization techniques including UV–visible spectroscopy, FTIR, XRD, SEM, and TEM will provide confirmation of nanoparticle formation, crystallinity, surface functionalization, and nanoscale structural features. The nanocomposites will undergo evaluation for multifunctional properties through environmental and biological assessments. Photocatalytic activity will be examined through methylene blue degradation under UV and visible light irradiation. Antioxidant and anti-inflammatory potential will be determined using DPPH, ABTS, protein denaturation, and membrane stabilization assays. Antimicrobial potential will be tested against Gram-positive and Gram-negative bacterial strains through the well diffusion method, while anticancer efficacy will be examined using MTT-based cytotoxicity studies on selected human cancer cell lines. The combined influence of bimetallic composition and bioactive phytochemicals from *Syzygium cumini* seed extract will be analysed to explain nanoparticle stability and enhanced biological performance. This work will support the development of sustainable nanomaterials with strong potential for biomedical and environmental applications while aligning with green chemistry principles and Sustainable Development Goals related to health, clean water, and responsible innovation. Future work will focus on In vivo studies, toxicity assessment, and scale-up for industrial applications. The study aligns with SDG 3 (Good Health and Well-being) through biomedical applications, SDG 6 (Clean Water and Sanitation) via photocatalytic pollutant removal, SDG 9 (Industry, Innovation, and Infrastructure) by advancing green nanotechnology, and SDG 12(Responsible Consumption and Production) through eco-friendly synthesis approaches.

Keywords: *Syzygium cumini;* Photocatalytic activity; Nanocomposite.

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Utilizing the redox potential of industrial rust: Microbial electrosynthesis of bio-hydrogen from iron oxide waste

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Abstract:

By combining the treatment of organic waste with the recycling of industrial scrap metal, this initiative suggests a revolutionary method for microbial biomass valorization. Traditional biofuels are based on plant sugars; however, this study investigates the operation of Microbial Electrolysis Cells (MECs) employing rust (iron oxides) as a solid-state electron mediator. This is accomplished by using electrogenic bacteria (*Shewanella oneidensis*) to break down organic waste in sewage. This metabolic process utilizes *Shewanella oneidensis* to produce electrons that will be stored in the form of Fe 3+ (iron III) from rust. Once the electron is transferred from the bacteria to the Fe 3+, it will be reduced to a more conductive and reduced state, Fe 2+, which will help produce high purity biological hydrogen gas (H 2 (g)). Furthermore, the “rust-to-fuel”; process reduces environmental impact of industrial metal waste while simultaneously lowering overall energy input required for hydrogen synthesis when compared to traditional methods. The proposed concept focuses on generating a circular bio- economy, where the iron substrate is not destroyed, but rather changed to a mineral product of higher value (magnetite). Experiments show that the capacity of iron oxide to have a high porous surface area promotes the growth of microorganisms on the rust surface and allows for greater levels of electron transport as compared to smooth metal surfaces. In the end, this study will demonstrate a biotechnological procedure that is safe, devoid of fossil fuels, and transforms two distinct waste sources—rusted iron and organic waste stream—into a clean, safely storable energy carrier.

Keywords: *Shewanella oneidensis;* Valorization; Rust.

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Green nanocomposite for life science

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Abstract

Green nanocomposites are environmentally friendly materials produced by combining Natural polymers with nanoparticles. These materials have gained attention in life science due to their sustainability and biological safety. In microbiology, green nanocomposites are mainly developed using green synthesis approaches that involve plants and microorganisms. This method reduces the use of toxic chemicals and support eco-friendly production. Green nanocomposite exhibit strong antimicrobial properties, making them suitable for applications such as drug delivery systems, wound dressing materials contribute to environmental protection by reducing non-degradable waste. Hence, green nanocomposites play a vital role in modern microbiological research and offer promising solutions for sustainable life science applications.

Keywords: Green Nanocomposites; Microbial Synthesis; Eco-friendly Materials; Antimicrobial Properties; Nanoscience; Life Sciences.

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Agricultural waste–derived bioash for synthetic dye removal: A preliminary treatment method.

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Abstract

The synthetic dyes, Crystal Violet (CV) and Methyl Violet (MV), are commonly used industrial dyes that are major environmental pollutants due to their toxic, persistent, and potential carcinogenic nature. The usual treatment processes for removing these dyes are expensive and not-efficient, which calls for the development of green adsorbents from farm wastes. In the present study, waste bioash from the sugarcane bagasse industry was obtained by thermal treatment of dry sugarcane bagasse at 500 °C and used for the removal of CV and MV dyes from aqueous solutions. Batch adsorption tests were designed to investigate the influence of various environmental factors such as temperature (15, 30, and 45°C), pH (5, 7, and 9), and contact time (30, 45, and 90 min) on dye removal. Crystal Violet recorded moderate adsorption, with optimal removal of 40.74% observed at 45°C and 42.59% at 15°C, pH 7, 90 min, which indicated that the compound has effective adsorptive properties at low temperatures. However, compound Methyl Violet has higher adsorptive properties, with 72.92% removal at 30°C under alkaline conditions, 50.00% removal at 45°C, and 60.42% removal at 15°C after 90 min. The bioash sugarcane bagasse bioash appears to be an eco-friendly and cost-effective adsorbent for the adsorption of Crystal Violet and Methyl Violet dyes from water bodies as part of its preliminary adsorption. Enhancement of its adsorption surface and scaling-up are advisable to optimize its application.

Keywords: Crystal Violet; Methyl Violet; Sugarcane bagasse bioash; Wastewater treatment; Agricultural Waste; Dye removal.

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A new potential source of anti-pathogenic bacterial substances from *Zamioculcas zamiifolia* (Lodd.) engl.leaf extracts

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Abstract

The increase of antibiotic-resistant bacteria is a problem for global health that needs to find new antibiotic drugs. The plant is the potential source of antibiotic substances that important to solve the antibiotic-resistant bacteria. This study was aimed to evaluate the antibacterial activity of *Zamioculcas zamiifolia* leaf extracts against four human pathogenic bacteria. *Z. zamiifolia* leaf were extracted with four extraction solvents. The screening of antibacterial activity of leaf extract was measured using agar disc diffusion assay. The Minimal Inhibition Concentration (MIC) and Minimal Bactericidal Concentration (MBC) values of extracts were determined using the broth microdilution assay. The results indicated that the lowest MIC value of 0.09 mg mL-1 against *Staphylococcus aureus* was obtained from hexane extraction. The lowest MBCs value of 1.56 mg mL-1 against Pseudomonas and Escherichia coli were obtained from ethanol extractions. The ethanolic leaf extracts of *Z. zamiifolia* demonstrated the highest anti-human pathogenic bacterial activity. This is the first report to demonstrate the high potential of antibacterial substance from *Z. zamiifolia* leaf extracts, which can be developed further as a natural drug for treating bacterial infectious diseases.

Keywords: Anti-bacterial activity; ZZ plant; *Zamioculcas zamiifolia* (Lodd.) Engl.;
Human pathogenic bacteria; Natural drug; Plant extraction; Leaf extracts.

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Developing synthetic biology for industrial biotechnology application

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Abstract

Recombinant DNA (rDNA) technology has revolutionized industrial biotechnology by enabling precise genetic modifications in microorganisms for sustainable production of chemicals, fuels, and enzymes. This review examines the evolution of rDNA technology through synthetic biology, focusing on industrial applications, challenges, and prospects. Using a comprehensive literature review methodology, this study analyses advanced synthetic biology frameworks including the Design-Build-Test-Learn (DBTL) cycle and bio foundry approaches. Results demonstrate that synthetic biology enhances traditional rDNA technology through standardized genetic components, automation, and computational integration, significantly improving efficiency and reproducibility. While applications in recombinant enzymes, biochemical compounds, and valuable metabolites show promise for sustainable industrial production, three major challenges persist: scale-up difficulties, high production costs, and regulatory hurdles. Despite these obstacles, industrial biotechnology demonstrates substantial growth potential, with future innovations poised to advance environmentally friendly manufacturing processes and establish rDNA technology as a cornerstone of sustainable industrial production.

Keywords: Recombinant DNA (rDNA) Technology; Industrial Biotechnology; Genetic Modification; Sustainable Production; Synthetic Biology; Bio foundry approaches, sustainable Industrial Production, Advance Environmentally friendly.

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Optimization of Lipase Production by Aspergillus flavus- One factor at a time approach

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Abstract

Fungal lipases are industrially important enzymes due to their versatile, stable, and eco-friendly nature, nurturing them as an attractive candidate for various biotechnological applications. In this study, crude lipase production by *Aspergillus flavus* was investigated under submerged fermentation. In the present study, lipase production by the selected fungi was evaluated through systematic optimization of nutritional and physical parameters using a one-factor-at-a-time approach. Incubation time exhibited a clear growth phase–dependent pattern, with enzyme response increasing from 24 h (0.61) and reaching a maximum at 96 h (2.90), indicating higher enzyme synthesis during the late exponential to stationary phase. Temperature markedly affected lipase production, with optimal enzyme variability observed at 30 °C (5.44), followed by a gradual decline at elevated temperatures. Initial pH significantly influenced enzyme activity, with pH 6 supporting the highest variation in lipase production (3.36 U/mL). Inoculum size analysis showed a lower inoculum levels were favorable, as 1% inoculum resulted in the highest response value (5.18), while increasing inoculum concentrations led to reduced enzyme production, likely due to nutrient limitation and metabolic stress. Overall, the ANOVA trends clearly demonstrate that cultivation conditions and substrate selection significantly regulate lipase production by *A. flavus*. The optimized parameters identified in this study provide a basis for further statistical optimization and support the potential application of fungal lipase in industrial and environmental bioprocesses.

Keywords*:* *Aspergillus flavus*; submerged fermentation; one-factor-at-a-time approach; growth phase–dependent pattern; ANOVA.

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Synergistic Bioremediation of Industrial Wastewater Using Multi-Species Algal Consortia

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Abstract

With the rapid progress in industrial and technological progress, the level of pollution in the living environment has been on the increase, particularly water pollution. This has consequently resulted in negative consequences, including water-borne diseases and water scarcity all over the world. Industrial wastewater discharge, particularly from automobile, textile, and leather industries, causes severe deterioration of water bodies and poses serious threats to ecosystems and public health. Many industries do not fully comply with Tamil Nadu Pollution Control Board (TNPCB) guidelines due to inadequate treatment processes. From recent research, the phytoremediation techniques using microalgae has emerged as an effective, eco-friendly, and sustainable biological approach for treating industrial wastewater. In this study, wastewater samples were collected from an automobile industry at different effluent generation points, namely PD1 (ED Booth), PD2 (Degreasing), PD3 (Phosphating), PD4 (Paint Booth), PD5 (PPS Outlet), and PD6 (Equalisation Tank – composite effluent). A customized microalgal consortium comprising five strains, including *Chlorella sp*. and *Spirulina sp.*, was used for the remediation. Among the sampling points, PD6 showed the most significant improvement in TNPCB-regulated parameters. The treatment resulted in a marked reduction in pollution indicators, with Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) reduced by 92.7% and 93.9%, respectively. Total Suspended Solids (TSS) were decreased by 65.8%, while Oil and Grease content showed a substantial reduction of 97.6%. The pH of the effluent improved from acidic (5.0) to near-neutral (7.5), indicating enhanced water quality. The treated wastewater was safely reused for non-potable applications such as washing and gardening. Additionally, the harvested algal biomass was utilized for value-added products including animal feed and bio-briquette production. This integrated approach demonstrates a circular economy model by combining wastewater remediation, resource recovery, and biomass utilization, highlighting the potential of microalgal phytoremediation as a sustainable solution for automobile industry wastewater management.

***Keywords**:* Wastewater; Automobile effluent; Phytoremediation; Circular Economy.

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A review on Applications of Artificial Intelligence in Biofuel Production and Optimization

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Abstract

The increasing demand for sustainable and renewable energy sources has accelerated research in biofuels as an alternative to fossil fuels. However, conventional biofuel production processes face challenges such as low conversion efficiency, high operational costs, and complex process control requirements. Artificial Intelligence (AI) has emerged as a powerful tool to address these challenges by enabling data-driven optimization, prediction, and automation in biofuel systems.AI techniques, including machine learning, deep learning, and neural networks, are widely applied in various stages of biofuel production, such as feedstock selection, pretreatment, enzymatic hydrolysis, fermentation, and downstream processing. Predictive models help in estimating biomass yield, optimizing microbial growth conditions, and improving biofuel conversion rates. AI-based control systems enhance bioreactor performance through real-time monitoring and adaptive control, reducing energy consumption and process variability.

In addition, AI supports metabolic engineering and synthetic biology by identifying key genetic pathways and improving microbial strains for enhanced bioethanol, biodiesel, and biogas production. In algal biofuel research, AI-driven image analysis, and growth modelling assist in optimizing cultivation and harvesting strategies. Furthermore, AI tools contribute to techno-economic analysis, life cycle assessment, and supply chain optimization, facilitating sustainable and cost-effective biofuel commercialization. Overall, the integration of AI with biofuel technology offers significant potential for improving efficiency, reducing environmental impact, and accelerating the transition to renewable energy systems.

Keywords: Artificial Intelligence; Biofuels; Machine Learning.

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Biohydrogen and Biogas – A Review on Feedstocks and Enhancement Process

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Abstract

Bio hydrogen and biogas emphasizing their potential utility, sources, and production challenges. Growing environmental concerns and the depletion of fossil fuels have intensified interest in renewable energy options that can convert waste into valuable energy carriers. Among these, bio hydrogen stands out as a carbon-free fuel that releases only water upon oxidation, making it highly attractive for sustainable energy systems. It can be used either through direct go to start combustion or in fuel cell technology to generate electricity, offering versatility and clean energy outputs. Biogas, another major product of organic waste conversion, typically contains about two-thirds methane and the remainder mostly carbon dioxide, along with trace gases. This composition allows biogas to serve as a substitute for natural gas after simple enrichment processes. Additionally, the residual slurry from biogas production can be repurposed as a nutrient-rich fertilizer, contributing to circular biomass management and supporting agricultural productivity Waste streams such as agricultural residues and municipal solid waste can be transformed into these fuels via biological and biochemical pathways. Key feed stocks and their challenges are compared, while current technologies and enhancement methods are discussed to highlight ways of improving yield, efficiency, and environmental benefits. Encouraging results from recent studies suggest that integrating optimized biological processes with pre-treatment strategies can significantly enhance fuel production.

Keywords: Bio hydrogen production; Biogas; Renewable fuels; Anaerobic digestion; Feedstock enhancement; Sustainable energy; Fermentation processes.

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Sustainable and Commercial DHA production using *Aurantiochytrium*

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Abstract

DHAs are essential omega-3 polyunsaturated fatty acids necessary to the development of the brain, visualization, and cardiovascular conditions. DHA has traditionally been sourced as marine fish oils, but due to problems including overfishing, heavy-metal contamination, distasteful smell, and poor reliability, the search has been on to find a sustainable substitute source. In this regard, marine heterotrophic microalgae, especially Aurantiochytrium have become an efficient and dependable producer of DHA. Aurantiochytrium is a microalga, thraustochytrid, which is usually isolated in marine and mangrove ecosystems. It is typified by rapid development and high lipid accumulation ability and DHA makes up about 35-60 percent of its total fatty acid. As opposed to photosynthetic microalgae, another heterotrophic fermentative, heterotrophic organism (Aurantiochytrium) grows in the dark and requires simple organic carbon sources, making it easy to control and scale it in industrial production systems. The production of DHA in this organism is mainly by the polyketide synthase (PKS) pathway that effectively achieves the synthesis of the long-chain polyunsaturated fatty acids. Aurantiochytrium oil is also odorless, stable and does not contain marine pollutants, and thus is used in infant formula, nutraceuticals, pharmaceuticals, and functional foods. In this way, Aurantiochytrium will be an eco-friendly and commercially feasible microbial source of DHA.

Keywords: Omega-3 fatty acids; Aurantiochytrium; Polyketide Synthase (PKS) pathway; Aurantiochytrium oils; Pharmaceutical; Nutraceutical; Eco-friendly; Commercially feasible; Microbial source of DHA.

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Developing Enzymes for Biocatalysis

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Abstract

Since natural enzymes often lack the necessary characteristics for efficient chemical synthesis, modern biocatalysis mostly depends on enzyme engineering. Wild-type enzymes' intrinsic limits in stability, catalytic activity, and selectivity frequently make them unsuitable for chemical synthesis.

Protein engineering methods have advanced at an extraordinary rate during , enabling enzymologists to precisely tailor enzymes to the requirements of organic synthesis. We outline some of the most important methods in enzyme engineering and their importance in promoting chemical synthesis in this talk. Because of their effectiveness, selectivity, and environmental sustainability, enzyme technology and biocatalysis are essential components of contemporary biotechnology. Enzymes are useful tools in industrial, medicinal, culinary, textile, and environmental applications because they function as highly selective biocatalysts that speed up biological processes under moderate circumstances. Process economics has improved as a result of the substantial increases in enzyme stability, activity, and reusability brought about by developments in enzyme manufacturing, purification, immobilization, and genetic engineering. Compared to traditional chemical catalysis, biocatalysis has a number of benefits, such as lower energy consumption, less by product creation, and environmentally favorable procedures. By making it possible to create customized biocatalysts for particular processes, recent advancements in protein engineering and recombinant DNA technology have considerably broadened the range of applications for enzymes. This article highlights the increasing significance of biocatalysis in sustainable and green chemistry by reviewing the basic concepts of enzyme technology, the many techniques used in enzyme manufacturing and modification, and their varied industrial applications.

Keywords: Biocatalysis; Directed evolution; Semi-rational design; Iterative saturation mutagenesis.

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From Policy to Practice: Bridging the Gap in India's Energy Transition Strategy

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Abstract:

India's energy transition is central to its commitments toward climate change mitigation, energy security, and sustainable economic development. Over the past decade, the country has introduced ambitious policies and regulatory frameworks aimed at accelerating the adoption of renewable energy and achieving net-zero emissions targets. However, despite well-defined policy goals, significant gaps remain between policy formulation and on-ground implementation. This paper examines the disconnect between energy transition policies and their practical execution in India, highlighting the key regulatory, infrastructural, financial, and institutional challenges that hinder effective implementation. Issues such as inconsistent state-level regulations, grid integration constraints, delayed approvals, and limited access to financing continue to slow the pace of transition. Through a critical analysis of existing energy policies and regulatory mechanisms, this study identifies structural weaknesses that prevent policy objectives from translating into tangible outcomes. The paper further proposes strategic measures to bridge this policy–practice gap, including strengthened regulatory enforcement, improved centre–state coordination, investment-friendly reforms, and capacity building for emerging clean energy technologies. By emphasizing the need for integrated and adaptive governance, this study argues that India's energy transition can move beyond ambitious targets toward measurable and inclusive outcomes. This findings aim to contribute to policy discourse by offering practical insights for strengthening India's energy transition strategy and ensuring long-term sustainability.

Keywords: Energy Transition; Energy Policy; Regulatory Framework; Renewable Energy; Policy–Practice Gap; Sustainable Development; India.

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Harnessing Microbial Enzymes for Efficient Biofuel Production

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Abstract

Microbial enzymes play a crucial role in the sustainable production of biofuels by enabling the efficient conversion of renewable biomass into usable energy. This poster highlights the importance of enzymes produced by microorganisms such as bacteria, fungi, and yeast in biofuel production processes. Key enzymes including cellulases, hemicelluloses, amylases, lipases, and lignin-degrading enzymes are discussed for their roles in breaking down complex biomass into fermentable sugars and biofuel precursors. These enzymes are essential in the production of biofuels such as bioethanol, biodiesel, and biogas. The poster also emphasizes the advantages of microbial enzymes, including high specificity, eco-friendly nature, and cost-effectiveness. Advances in enzyme engineering and microbial biotechnology have further enhanced biofuel yields and process efficiency. Overall, microbial enzymes are vital components in developing next-generation biofuels and supporting a sustainable, low-carbon energy future.

Keywords: Enzymes; Microbes; Bio-energy; Bio-fuels.

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From Waste Carbon to Biofuel: Harnessing *Yarrowia lipolytica* as a Microbial Biorefinery

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Abstract

The escalating global demand for energy, coupled with the environmental constraints of fossil fuel based systems necessitates the development of sustainable, non-food competitive and resource efficient bioenergy platforms. Microbial biomass valorization has emerged as a promising strategy for next-generation biofuel production by enabling the conversion of waste derived carbon streams into renewable energy carriers. Among oleaginous microorganisms, *Yarrowia lipolytica* is a well-established industrial model organism due to its generally recognised as safe (GRAS) status, metabolic robustness and exceptional intracellular lipid accumulation capacity.

Yarrowia lipolytica efficiently converts waste derived substrates into lipids via enhanced acetyl-CoA flux and fatty acid biosynthesis,achieving lipid contents of 40–50% of dry cell weight under optimized aerobic conditions. This performance surpasses conventional crop- and algal-based biofuel systems while minimizing land use, freshwater demand, and food–fuel conflicts.

This poster critically examines the biochemical and metabolic mechanisms underlying lipid biosynthesis in *Y. lipolytica* and highlights the downstream conversion of lipid enriched microbial biomass into biodiesel via transesterification-based processing routes. Integration of microbial biorefineries with wastewater treatment systems and circular bioeconomy framework further enhances carbon recovery and process sustainability. Continued advances in metabolic engineering, strain optimization, and bioprocess intensification reinforce *Y. lipolytica* as a scalable and economically viable platform for next-generation bioenergy production aligned with global sustainability and climate goals.

Keywords : Microbial biomass valorization; *Yarrowia lipolytica*; Oleaginous yeast biorefineries; Next-generation bioenergy; Circular bioeconomy; Lipid-based biofuel production.

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Microbial Electrosynthesis: A Next-Generation Bioenergy Methodology for Sustainable CO_2 to-Biofuel Conversion

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Abstract:
Next-generation bioenergy technologies are increasingly focusing on microbial systems that can directly convert carbon dioxide (CO_2) into value-added fuels and chemicals, offering an innovative pathway to sustainable energy production and carbon recycling. Among these, Microbial Electrosynthesis (MES) stands out as a promising methodology that integrates bioelectrochemical systems with microbial catalysis to achieve high-efficiency CO_2 utilization. In MES, electroactive microorganisms act as biocatalysts at the cathode, receiving electrons supplied by an external electrical source—often renewable electricity—to reduce CO_2 into multi-carbon organic compounds such as acetate, ethanol, butyrate, and medium-chain fatty acids. The process exploits either direct electron transfer between microbes and the electrode or mediated electron transfer via soluble redox molecules, enabling selective and enhanced synthesis of desired biofuels under controlled electrochemical conditions. Recent studies highlight improvements in electrode materials, reactor designs, and microbial strain selection that have significantly increased coulombic efficiencies and product yields, establishing MES as a scalable candidate for future biofuel production. MES not only addresses limitations of conventional biofuel technologies—such as dependence on agricultural biomass and competition with food production—but also synergizes with renewable energy infrastructures by converting intermittent electrical energy into storable chemical energy. Despite challenges in optimizing electron transfer mechanisms, reactor scalability, and economic viability, microbial electrosynthesis represents a cutting-edge methodology in the bioenergy landscape that aligns carbon capture with sustainable fuel generation, contributing to decarbonization and circular carbon economies.

Keywords: Microbial electrosynthesis; bio electrochemical systems; CO_2 conversion; Biofuels; Electroactive microbes; Renewable energy integration; Electron transfer mechanisms.

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The Next Development in Cell-Free Synthetic Biology

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Abstract

Biological Materials innovations in sustainable biomanufacturing are made possible by developments in cell-free synthetic biology, which could eventually change the global manufacturing paradigm in favor of regionalized and environmentally friendly production methods. Techniques for cell-free synthetic biology have been developed for the bioproduction of biological materials, biofuels, and fine chemicals. To assemble and analyse biosynthetic pathways, cell-free workflows usually use combinations of purified enzymes, cell extracts for biotransformation, or cell-free protein synthesis processes. Crucially, by directly adding co-factors, substrates, and chemicals—including lethal ones—cell-free processes may integrate the benefits of metabolic and chemical engineering. Automated design cycles, which allow for the parallel testing and optimization of a variety of biological materials and their underlying biosynthetic processes, are equally applicable to cell-free synthetic biology. Although there are still obstacles to overcome, new areas of materials research are made possible by recent developments in cell-free synthetic biology and the materials sciences. The industrialization of sustainable materials manufacturing is starting to benefit from the use of cell-free synthetic biology, a potent, highly adaptable, and promising biotechnology. Crucially, as part of the development process, synthetic biology businesses still support interdisciplinary partnerships with designers and materials scientists. We believe that if these trends continue, they will open up new possibilities for the manufacture of sustainable cell-free materials and the expanding bioeconomy.

Keywords: Automated design cycles; Cell free synthetic biology; Biosynthetic process; Cell free protein synthesis; Purified enzyme.

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Algae And Cyanobacterial Biotechnology

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Abstract:

Algae and cyanobacteria have emerged as promising biological resources in modern biotechnology due to their high photosynthetic efficiency, rapid growth, and ability to utilize carbon dioxide and sunlight. These organisms are exploited for the production of a wide range of valuable products, including biofuels, pharmaceuticals, nutraceuticals, pigments, enzymes, and biopolymers. Algal and cyanobacterial systems play a significant role in sustainable bioenergy generation, wastewater treatment, carbon sequestration, and environmental bioremediation. Advances in genetic engineering, metabolic pathway optimization, and cultivation technologies have further enhanced their commercial potential. Cyanobacteria, as prokaryotic photosynthetic organisms, serve as excellent model systems for studying photosynthesis and for developing bio factories for renewable chemicals. Despite challenges such as large-scale cultivation, harvesting costs, and genetic stability, ongoing research continues to improve productivity and economic feasibility. Overall, algae and cyanobacterial biotechnology offer eco-friendly and sustainable solutions to global challenges in energy, environment, and health, making it a vital field in future biotechnological applications.

Keywords: Algae; Cyanobacteria; Photosynthesis; Biofuels; Sustainable; Genetic engineering; Bioproducts.

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Sustainable Biohydrogen Production

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Abstract

Biological hydrogen gas generation through dark fermentation of wastewater has been accepted as an effective strategy for developing renewable energy in an environmentally friendly manner. Dark fermentation is microbes that convert organic substances in the absence of oxygen, resulting in the production of hydrogen, carbon dioxide, and other organic compounds. Dark fermentation is quicker in generating hydrogen gases and allows for easier hydrogen gas separation in contrast to traditional anaerobic decomposition. Treatment of microbes that have been inhibited by heat, acid, or high dilution rates can be used to stimulate the growth of hydrogen gas-producing microbes, for example, *Clostridium, Streptococcus*, and *Thermoanaerobacteriacea.* However, it is crucial to avoid the inhibition of hydrogen gas-producing microbes by microbes that degrade hydrogen, for example, methanogens and homoacetogens. Therefore, environmental factors such as pH, temperature, and hydrogen gas pressure are the most crucial factors for maximizing hydrogen gas output. Reduction of hydrogen gas pressure through gas sparging can stimulate microbes to produce hydrogen gas

The maximum amount of hydrogen that is produced from fermentation is usually in the range from one to two and a half moles. The by-products, butyric, lactic, propionic acids, and ethanol, decrease hydrogen production by consuming some of the energy required for hydrogen production. Consequently, only 15% of the energy yielded from wastewater is obtained from the dark fermentation method. A two-step method, which combines both dark fermentation and methanogenic digestion, also produces desirable energy results from wastewater treatment. The unutilized materials are converted to methane, which is used to produce more hydrogen gas. Hydrogen leaks and its challenges in scaling up are bigger problems for green energy technology.

Key Words: Fermentation; Methanogenic; *Clostridium; Streptococcus;* Homoacetogens; Hydrogen; Hexose; Butyric lactic; Propionic acid.

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Microbial Energy Systems: Electricity Generation Using *Geobacter sulfurreducens*

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Abstract:

Electricity generation using microorganisms is a new and environmentally friendly method in microbial energy systems. In this process, microorganisms take the chemical energy stored in organic materials and convert it into electricity. This happens mainly in a device known as microbial fuel cells. Among many types of Microorganisms, *Geobacter sulfurreducens* is one of the most effective bacteria for producing electricity. *Geobacter sulfurreducens* is an anaerobic bacterium, which means it doesn't need oxygen to grow. It uses organic compounds like acetate as a source of energy. During its metabolism it releases electrons and protons. Special feature of this bacterium is its ability to send electrons directly to solid surfaces like electrodes through a structure called conductive pili and proteins in its membrane. This makes it well suited for use in microbial fuel cells. In microbial fuel cells, *Geobacter sulfurreducens* forms a layer or biofilm structure on the anode. As the bacteria produce electrons during their metabolism these electrons will travel from the anode through A circuit to the cathode, creating electricity. At the cathode the electrons join with protons and oxygen to make water to close the circuit. A big benefit of this system is that it can use wastewater and organic waste as fuel allowing for both waste treatment and energy production at the same time. However, scientists are still doing research to make this system more efficient and to support sustainable electricity generation in future energy system.

Keywords: Electricity generation; Microbial fuel cells; *Geobacter sulfurreducens;* Microbial energy systems, Renewable energy; Wastewater treatment.

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Electricity Generation from Water Evaporation Using Microbial Biofilm

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Abstract

Sustainable energy production requires innovative materials and approaches that minimize environmental impact. Microbial biofilms, produced sustainably from renewable feedstocks, can serve as functional materials for continuous electricity generation by harnessing energy from evaporating water. Xiaomeng Liu and their coworkers engineered Biofilm sheets (~40 µm thick) from *Geobacter sulfurreducens* strain CL-1 achieve remarkable power density (~1 µW/cm²), surpassing engineered nanomaterials by over tenfold without requiring living cells or organic feedstock. The biofilms' natural nanofluidic channels (100-500 nm) and high surface area (~8 m²/cm³) enable efficient streaming potential generation. Biofilm devices maintain electrical outputs when integrated with mesh electrodes and scaled through series and array configurations, enabling practical power production suitable for small electronics. Notably, biofilm devices sustain energy generation in ionic solutions and seawater, attributed to their amphiphilic surface groups and high density of protein nanowires, which support charge transport and maintain streaming efficiency even at elevated ionic strengths. When applied as skin-patch devices, these biofilm materials harvest moisture from sweat or skin humidity to continuously power wearable sensors, including pulse, respiration, and glucose monitoring systems. The results demonstrate that diverse biofilms from different microbial species produce electricity via water evaporation, pointing to a broadly applicable evaporation-based strategy for sustainable energy harvesting in various aqueous environments. These findings highlight the potential of microbial biofilms as renewable, scalable, and flexible materials for clean energy applications.

Keywords: Microbial biofilms; Water evaporation; Electricity generation; Sustainable energy harvesting; Wearable electronics.

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Sustainable Microbial Fuel Cells: Waste-to-Energy Innovations for Power and Biofuels

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Abstract

Microbial fuel cells (MFCs) offer a promising sustainable solution to the global energy crisis, where fossil fuels still dominate approximately 80% of consumption amid climate challenges and depleting reserves. By harnessing exoelectrogenic bacteria like *Geobacter sulfurreducens, Shewanella oneidensis* and *Pseudomonas aeruginosa* to convert organic waste like biomass into electrical energy. MFCs address waste management while generating renewable power without non-toxic byproducts. Key applications span direct power generation and biofuel production. Innovations include membrane-less MFC stacks, powering public sanitation facilities and LED lighting systems at high-footfall locations, achieving stable illumination levels without exceeding regulatory energy standards or requiring external energy storage. Advanced electrodes, such as carbon nanotube-supported cobalt phosphate (CNT/Co-Pi), boost power densities to 1200 mW m^{-2} via enhanced bacterial adhesion and electron transfer. MFCs also produce biofuels like biogas, biodiesel, bioethanol, and biobutanol through optimized substrates, microbial strains like *Geobacter sulfurreducens, Shewanella oneidensis* and *Pseudomonas aeruginosa*, metabolic engineering, and nanomaterials, integrating into biorefineries for decentralized use in refugee camps or remote areas. In conclusion, MFCs represent a reliable, eco-friendly alternative to fossil fuels, minimizing emissions and pollution. Overcoming challenges in design, efficiency, and scalability via innovative catalysts and engineering will unlock their commercial viability, transforming waste-to-energy into a cornerstone of sustainable development.

Keywords: Microbial fuel cells; Waste-to-energy, Exoelectrogenic bacteria, Biofuels.

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Lignocellulosic Biomass Pretreatment: Pathways to Sustainable Bioenergy and Value-Added Chemicals

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Abstract

Lignocellulosic biomass, the most abundant renewable resource on Earth, stands as a promising alternative to dwindling fossil fuels, addressing the global energy crisis and climate change. Comprising cellulose, hemicellulose, and recalcitrant lignin, it serves as the fourth major energy source after coal, petroleum, and natural gas. However, its heterogeneous structure hinders efficient bioconversion into biofuels like bioethanol, biogas, biohydrogen, and value-added chemicals. Pretreatment technologies such as gasification, catalysis, biological hydrolysis, and emerging strategies effectively fractionate components, exposing cellulose for hydrolysis into fermentable sugars e.g., glucose, xylose. Strains like *Clostridium butyricum* and *Clostridium thermocellum* excel in direct utilization of lignocellulosic wastes straws, bagasse, agricultural residues, producing hydrogen yields enhanced by pre hydrolysis and co cultures. Beyond fuels, over 200 value added compounds and polymers derive from pretreated biomass, mapping a vast scope for modern chemical and polymer industries. Significantly challenges include lignin's biodegradation resistance and variable yields from biomass sources and strains. Innovations like simultaneous hydrolysis fermentation and advanced pretreatments overcome these barriers, enabling highly efficient bioconversion. This review synthesizes pretreatment advances and applications, highlighting lignocellulosic biomass's potential to supplant petroleum-dependent fuels and materials. Strategic developments will accelerate sustainable bioenergy and chemical production, fostering a bio-based economy.

Keywords: Lignocellulosic; Biomass; Pretreatment technologies, Bioenergy production.

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Computational and Metabolic Engineering Strategies for Optimizing Sustainable Biofuel Production

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Abstract

The escalating global energy demand underscores the urgency for sustainable biofuel production, particularly bioethanol and advanced compounds like succinic acid from biomass and industrial by-products. Metabolic engineering and computational optimization emerge as pivotal strategies to enhance microbial cell factories, addressing challenges in fermentation efficiency, substrate utilization, and scalability. Innovative approaches integrate dynamic real-time optimization (DRTO) with evolutionary algorithms (genetic algorithm and differential evolution) to manipulate fermenter feed rates and batch times, yielding superior ethanol productivity amid disturbances. Systems-based modeling, flux balance analysis (FBA), transcriptomics integration, and machine learning predict optimal gene deletions—targeting enzymes like fumarase and pyruvate dehydrogenase—for glycerol-to-succinic acid bioconversion in *Escherichia coli*, achieving high yields via adaptive laboratory evolution (ALE). Advances in synthetic biology, CRISPR-Cas editing, and consolidated bioprocessing optimize lignocellulosic breakdown like cellulases, hemicellulases, in yeast, bacteria, and algae, enabling 3-fold butanol increases, 91% biodiesel efficiency, and 85% xylose-to-ethanol conversion. Data-driven process control and ^{13}C-metabolic flux analysis further refine pathways, promoting circular economy integration through waste recycling. These multidisciplinary tools overcome biomass recalcitrance, economic hurdles, and low yields, paving the way for scalable, carbon-neutral biofuels. By combining rational design, AI, and experimental validation, this framework guides efficient microorganism engineering for bioenergy diversification and industrial biotechnology.

Keywords: Biofuels; Metabolic engineering; Dynamic real-time optimization.

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Electricity Generation with Microbial Fuel Cells

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Abstract

Microbial fuel cells (MFCs), a bio-electrical system, is an important sustainable technology that produce electricity to clean wastewater by using microorganisms. The fuel cells are made up of four parts, the anode, the cathode, the proton exchange membrane and the external circuit. MFCs can be used in battery cells, hydrogen fuel cells for an efficient current generation. In these systems, certain bacteria break down organic materials and pass electrons to an electrode, creating electrical energy and reducing pollution. The MFCs producing organisms include E. coli and Pseudomonas aeruginosa. The study focuses on the working principle of MFCs, its setup and uses. Using wastewater sludge as the starting material, a two-chamber MFC was built and the maximum voltage produced was 0.295V in 120 min. The results showed a slow but steady rise in voltage, showing that electricity is being made by microbial activity. The MFCs can also be used in hydrogen gas production by the bio- electrochemically assisted microbial reactor and in waste water management efficiently based on maximum power density, Columbic efficiencies and Chemical oxygen demand (COD) and also used in biosensors for evaluating the pollutant level of wastewater effluents. Genomic scale metabolic modeling coupled with genetic engineering may yield strains which enhance current production. Mutagenesis and rDNA technology can be used in the future to obtain super bugs for MFCs. An advanced treatment system was developed that utilizes exoelectrogens where the microbes are in direct contact with electrodes to produce electricity. Thus, MFCs are considered as an eco-friendly energy source that can be used more widely in energy recovery and environmental cleanup.

Keywords: Microbial fuel cell; Electricity generation; Waste water treatment; Reduce pollution; Exoelectrogens.

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Microbial biomass valorisation for fuels

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Abstract

Microbial biomass valorization for fuel production focuses on converting biomass obtained from microorganisms into sustainable energy sources. Microorganisms such as microalgae, bacteria and fungi are considered efficient biomass producers due to their rapid growth, high adaptability and ability to utilize diverse substrate. The process start with the cultivation of selected microorganisms under controlled conditions to obtain maximum biomass yield. Factors such as nutrients availability, temperature, light and aeration play a crucial role in optimizing microbial growth. Once adequate biomass is produced, it is harvested using suitable separation techniques. The collected biomass is then proceed to make it suitable for fuel conversion. Pre-treatment is an important step that improve the availability of cellular components and enhance conversion efficiency. Different pre- treatment strategies are applied based on the composition of the microbial biomass. The valorised biomass can be transformed into various types of biofuels through multiple conversion pathways. Lipid rich biomass is commonly utilized for biodiesel production, while carbohydrate rich biomass is suitable for fermentation-based fuels such as bioethanol. In addition whole microbial biomass can be converted into biogas through anaerobic digestion. Advanced thermochemical methods allow the conversion of wet biomass into liquid and gaseous fuels without extensive drying. Fuel products obtained from microbial biomass are analysed to assess their quality and energy potential. Microbial biomass valorization supports renewable energy generation while reducing dependency on fossil fuels. This approach also promotes sustainable waste utilization and contribute to environmental protection, making it a promising strategy for future energy application.

Keywords: Microbial biomass; Biomass valorization; Biofuels; Renewable energy;

Sustainable fuels.

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Sustainable green composites for antibacterial and wearable patches

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Abstract

The growing interest of epidermal electronics and wearable systems has intensified the need for sustainable, biocompatible, and mechanically compliant materials, positioning green composites as a promising alternative to inorganic composites. This work highlights recent advances in bio-based and biodegradable composite systems engineered for wearable patches capable of energy harvesting and physiological sensing. Green nanocomposite matrices such as polymers that are eco-compatible functional fillers to achieve enhanced flexibility, tensile resilience, and conformal skin adhesion. Functionalization with conductive metal oxide nanostructures—enables piezoelectric, thermoelectric, and triboelectric responses, facilitating self-powered sensing and low-power energy generation from heat and biomechanical motion. The present work aims at preparation of PANI-coated textile substrates that could demonstrate effective inhibition against both Gram-positive (e.g., *Staphylococcus aureus*) and Gram-negative (e.g., *Escherichia coli*) bacteria, making them suitable for skin-contact biomedical wearables. Material design strategies addressing interfacial compatibility, and scalable fabrication approaches are evaluated for their suitability in large-area, breathable epidermal patches. Overall, green composites demonstrate significant potential for next- generation self-powered biomedical wearable patches, offering a convergence of sustainability, functionality, and skin-compatible performance aligned with circular materials design.

Keywords: Wearables, Composites, Energy Harvesting, Electric, Biomaterials, Microorganisms.

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rDNA Technology in therapeutic protein production

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Abstract

The production of therapeutic proteins is vital for the treatment of various life-threatening and chronic diseases such as diabetes, hormonal deficiencies, immune disorders, and genetic conditions. Conventional methods of therapeutic protein production relied heavily on extraction from animal tissues or human sources, which posed several challenges including limited availability, high cost, slow production rates, inconsistent supply, and risk of pathogen contamination. Recombinant DNA (rDNA) technology has emerged as an effective and reliable alternative to overcome these limitations in the pharmaceutical industry. In recombinant DNA technology, the gene encoding the desired therapeutic protein is isolated and inserted into a suitable plasmid vector, which is then introduced into a host microorganism such as Escherichia coli or yeast. These genetically engineered microorganisms act as efficient biofactories, producing large quantities of the target protein under controlled fermentation conditions. The expressed proteins are subsequently purified and formulated for therapeutic use. This approach ensures high-yield, large-scale production with improved safety, reduced production cost, elimination of animal tissue dependency, and consistent product quality. Additionally, the controlled production environment significantly lowers the risk of disease transmission. Recombinant DNA technology has revolutionized therapeutic protein production by providing a safe, economical, and sustainable method to meet the growing global demand for life-saving pharmaceuticals.

Keywords: Recombinant DNA technology; Therapeutic Proteins; Genetically engineered

Microorganisms; Biopharmaceutical production; Large-Scale fermentation; Protein purification.

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A simplified approach to biofuel production using direct microbial enzyme action on organic waste

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Abstract

The increasing demand for energy and the environmental problems caused by fossil fuels have created a need for sustainable and eco-friendly alternatives. Biofuels are renewable sources of energy produced from organic materials such as plant and kitchen waste. In this study, a simple and innovative approach for biofuel production using microbial enzymes is presented. Microorganisms such as bacteria, fungi and yeast are used directly to produce enzymes in situ, eliminating the need for enzyme extraction. Enzymes like cellulase, amylase, and lipase play an important role in breaking down complex biomass components such as cellulose, starch, and oils into simpler molecules like sugars and fatty acids. These simpler compounds are then converted into bioethanol and biodiesel through microbial fermentation. The process is carried out in a single container, known as a one-pot system, which reduces cost, time and technical complexity. The results indicate that organic waste can be effectively converted into biofuel using natural biological processes without the use of harmful chemicals. This method is environmentally friendly, cost-effective and suitable for small-scale and educational applications, highlighting the role of microbial enzymes in sustainable energy production.

Keywords: Biofuel; Microbial enzymes; Cellulase; Fermentation; Biomass; Renewable

Energy; Waste-to-energy.

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Cyanobacterial exopolysaccharide as natural Cyroprotectent for Microbial Preservation

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Abstract:

The long-term preservation of microorganisms is fundamental to research, industrial biotechnology, and clinical applications. Cryopreservation using chemical cryoprotectants such as glycerol and dimethyl sulfoxide (DMSO) is routinely employed; however, these agents may exhibit cytotoxicity, alter cellular physiology, and pose environmental concerns. Consequently, there is increasing interest in identifying natural, biodegradable, and biocompatible alternatives.

Cyanobacteria are known to secrete exopolysaccharides (EPS), high-molecular-weight extracellular polymers composed mainly of complex polysaccharides enriched with hydroxyl and charged functional groups. These properties confer strong water-binding capacity and protective functions, suggesting that EPS may stabilize cellular membranes and proteins during freezing and thawing stress.

In this study, selected cyanobacterial strains were cultivated under controlled laboratory conditions, and EPS were extracted from the cell-free supernatant using ethanol precipitation. The crude EPS were purified by trichloroacetic acid-mediated deproteinization, dialysis, and lyophilization. Purified EPS were characterized for total carbohydrate and protein content using standard colorimetric assays. Different concentrations of EPS were evaluated for their cryoprotective efficiency using microbial model organisms and compared with glycerol as a conventional cryoprotectant. Cryopreservation was performed at −80 °C, and post-thaw cell viability was determined by colony forming unit (CFU) enumeration.

The study aims to demonstrate that cyanobacterial EPS significantly improve microbial survival following freeze–thaw cycles and offer comparable or superior protection to conventional cryoprotectants. The findings are expected to support the development of cyanobacterial EPS as sustainable, non-toxic cryoprotectants for microbial culture collections and biotech

Keywords: Cryopreservation, cyanobacteria, EPS, polysaccharides, DMSO

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EPS - Based Biofertilizer: An Eco-Friendly Approach to Improve Crop Productivity

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Abstract:

Freshwater ecosystems support a wide range of cyanobacteria, which are photosynthetic microorganisms known for their ability to produce extracellular polymeric substances (EPS). EPS is a natural biopolymer that plays an important role in soil conditioning by improving aggregation, water retention, and nutrient availability. Due to these properties, cyanobacterial. EPS has gained attention as a sustainable alternative to chemical fertilizers.In the present study, water samples were collected from freshwater sources and cyanobacteria were isolated using selective culture media. The obtained isolates were purified through repeated sub-culturing and identified based on microscopic morphological features, followed by molecular confirmation using 16S rRNA sequencing. To maximize EPS production, key culture parameters such as temperature, pH, light intensity, and nutrient availability were optimized under controlled laboratory conditions. EPS was extracted from both extracellular (released) and cell-associated (bound) fractions u sing centrifugation, filtration, ethanol precipitation, and dialysis purification. The purified EPS was quantified using the phenol–sulfuric acid assay and characterized using analytical techniques including FTIR and NMR to confirm functional groups and structural properties.Finally, the extracted EPS was formulated into liquid and solid biofertilizer preparations and evaluated for its potential agricultural benefits. EPS-based biofertilizers can enhance soil aggregation, improve nutrient retention, stimulate beneficial microbial populations, promote root growth, and increase plant tolerance to drought and salinity stress. This study highlights the promising potential of freshwater cyanobacteria-derived EPS as an eco-friendly, cost-effective, and sustainable input for modern agriculture.

Keywords: Cyanobacteria , Freshwater , Extracellular Polymeric Substances (EPS) , EPS Extraction, Biofertilizer , Sustainable Agriculture .

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Tiny Cells, Big Solutions: Algae & Cyanobacteria in Biotechnology

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Abstract

Algae and cyanobacteria are photosynthetic microorganisms that play an important role in industrial biotechnology. They use sunlight and carbon dioxide for growth and can produce a wide range of useful products such as biofuels, pigments, pharmaceuticals, nutraceuticals, enzymes, and biofertilizers. These microorganisms grow rapidly, require less land, and can be cultivated in wastewater, making them an eco-friendly and cost-effective alternative to conventional resources. The importance of algae and cyanobacteria lies in their ability to support sustainable development while reducing environmental pollution. By absorbing carbon dioxide during photosynthesis, they help in lowering greenhouse gas levels and contribute to climate change mitigation. Their biomass contains valuable compounds like lipids, proteins, carbohydrates, vitamins, and bioactive substances, which can be utilized in various industries. Implementing algal and Cyanobacteria technologies is essential due to the increasing demand for renewable energy and sustainable industrial processes. Their use can reduce dependence on fossil fuels, promote waste recycling, and support green technologies. Overall, algae and cyanobacteria serve as promising biofactories that offer practical solutions for energy production, environmental protection, and sustainable industrial growth.

Keywords: Algae, Cyanobacteria, Industrial Biotechnology, Biofuels, Sustainable Development, Green Technology, Biofactories

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