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RESEARCH NEXUS

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From the Editorial Desk

"Research is seeing what everybody else has seen and thinking what nobody else has thought."

Albert Szent-Györgyi

It is with great pride and a deep sense of academic purpose that we present the inaugural issue of the Faculty Research Papers Magazine. This first edition marks more than the launch of a publication; it signifies the beginning of a shared intellectual journey rooted in curiosity, critical inquiry, and the pursuit of knowledge.

With technological innovation accelerating and societal expectations of higher education expanding, research has assumed a central role in driving knowledge creation and social transformation. Consequently, academic institutions today function not only as centres of instruction but as dynamic hubs of innovation and thought leadership. This magazine reflects that transition, serving as a platform to showcase the diverse research endeavours of our faculty and amplify their scholarly voices.

Faculty members represent the greatest intellectual strength of any institution. Their research reflects sustained commitment, rigorous inquiry, and a dedication to advancing knowledge across disciplines. By bringing these efforts into collective focus, this magazine seeks to foster interdisciplinary dialogue, encourage collaboration, and nurture a vibrant research ecosystem. Through the systematic documentation and dissemination of faculty research, we aim to inspire mentorship, student engagement, and a deeper culture of scholarship.

This inaugural issue lays the foundation for what we envision this magazine to become: a credible academic forum, a record of institutional research excellence, and a catalyst for future inquiry. Each paper featured herein contributes uniquely—addressing contemporary issues, advancing theoretical understanding, or proposing innovative solutions—together reflecting the breadth and depth of our academic community.

Supporting this research culture is the Faculty Industry Immersion Program (FIP), through which faculty members gain first-hand exposure to industry practices, emerging technologies, and real-world challenges. The insights gained through FIP are meaningfully integrated into research work, resulting in context-driven studies that offer practical perspectives and valuable experiential knowledge for future researchers.

Research plays a pivotal role in advancing society by extending the boundaries of human understanding and creating a permanent scholarly record that informs generations to come. In this context, a Faculty Research Papers Magazine assumes great significance as a structured and credible platform that bridges knowledge creation and knowledge sharing. We hope this publication will disseminate research across regional, state, and wider horizons, reinforcing our institution's commitment to academic excellence, innovation, and societal impact.

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Department of Biotechnology
Synopsis of High-Impact Research Themes

The high-impact research outputs from the Department of Biotechnology, VFSTR in 2025 collectively reflect a strategically integrated vision of biotechnology that addresses global priorities in nutrition, sustainability, green chemistry, and clean energy. These works converge on the central theme of harnessing biological and carbon-based resources through advanced biotechnology and nanomaterial engineering to develop sustainable solutions for human health and energy security.

A major thematic pillar is algal biotechnology for functional nutrition and human health. The comprehensive review on algae-fortified foods positions microalgae as versatile biofactories capable of producing high-value proteins, lipids, polysaccharides, pigments, and antioxidants. This work integrates metabolic pathway analysis, bioactive compound profiling, food biotechnology, and techno-economic evaluation to demonstrate how algae-based ingredients can be translated into safe, scalable nutraceutical products. The emphasis on immune modulation, antioxidant defense, and therapeutic potential highlights a strong interface between biotechnology, functional foods, and preventive healthcare, reinforcing VFSTR's contribution to nutraceutical innovation and sustainable bioresource utilization.

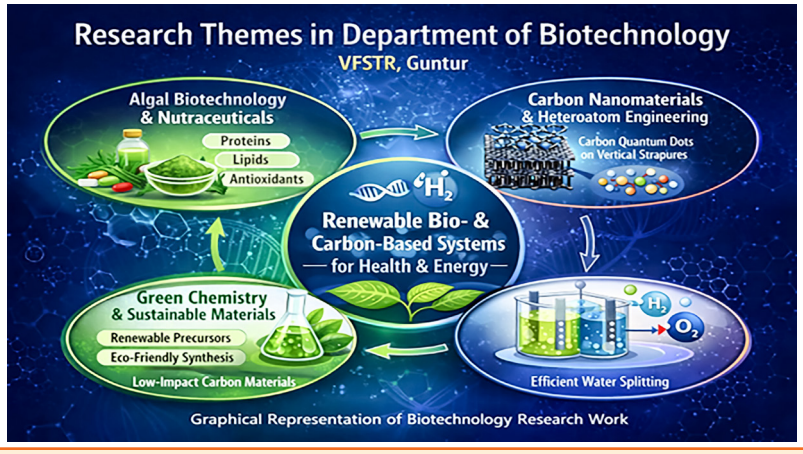
A second dominant theme is carbon nanomaterials for green hydrogen production and electrochemical energy conversion. Two complementary studies advance the design of all-carbon, heteroatom-engineered electrodes based on carbon quantum dots anchored on vertical graphene. Through rational heteroatom and halogen doping, these works elucidate how electronic structure modulation, synergistic dopant interactions, and surface engineering can create highly active, bifunctional catalytic sites for both hydrogen and oxygen evolution reactions. The demonstrated low overpotentials in acidic and alkaline media establish non-metal, earth-abundant catalysts as viable replacements for precious metals, directly addressing economic and scalability barriers in water electrolysis. This theme positions the department at the forefront of sustainable hydrogen technologies and electrochemical biotechnology.

A unifying cross-cutting theme is green chemistry and sustainable material design. The Green Chemistry publication underscores environmentally benign synthesis strategies for carbon materials, emphasizing renewable precursors, biomass-derived feedstocks, waste minimization, and energy-efficient processing. By embedding green chemistry principles into nanomaterial development, this work strengthens the sustainability foundation of both nutraceutical and energy-related research, aligning material innovation with circular economy concepts and reduced environmental footprints.

Together, these studies reveal four interconnected research themes:

1. **Green chemistry–driven sustainable synthesis.**
2. **Carbon nanomaterials and heteroatom engineering,**
3. **Electrocatalysis and green hydrogen production, and**
4. **Algal biotechnology and nutraceutical development**

Collectively, they establish a coherent biotechnology research ecosystem that integrates bioresources, nanotechnology, material science, and energy biotechnology, positioning VFSTR as a contributor to both next-generation health solutions and the emerging clean energy economy.



Turning Waste into Wealth: A Global Green Chemistry Breakthrough

Dr. CH. Anjani Devi et al.

Modern society generates organic waste on a scale that is both unprecedented and unsustainable. Food residues, agricultural by-products, animal manure, and organic industrial waste accumulate daily across cities and rural landscapes alike. Yet within this challenge lies a remarkable opportunity.

Anaerobic digestion (AD), a biological process operating in the absence of oxygen, has long been recognized for its ability to convert organic waste into biogas, a renewable source of energy. However, the story does not end with biogas. What remains after digestion, digestate, is now emerging as a critical resource in the global transition toward sustainability.

The Anaerobic Digestion Process: More Than Energy

Inside sealed digesters, diverse microbial communities work in coordinated stages:

- Hydrolysis breaks complex organic matter into simpler compounds.
- Acidogenesis converts these compounds into organic acids.
- Acetogenesis produces acetic acid, hydrogen, and carbon dioxide.
- Methanogenesis generates methane-rich biogas.

While biogas contributes to electricity generation, vehicle fuel, and renewable methane production, digestate retains significant quantities of nutrients—particularly nitrogen, phosphorus, potassium, organic carbon, and microbial biomass.

With the rapid expansion of AD facilities worldwide, millions of tonnes of digestate are generated annually. Its effective management is therefore essential—not only environmentally, but also economically.

Digestate as a Sustainable Fertilizer

One of the most immediate applications of digestate lies in agriculture. Unlike synthetic fertilizers—which require substantial fossil energy for production—digestate recycles nutrients already present in organic waste streams.

When stabilized and properly treated, digestate can:

- Enhance soil organic matter
- Improve microbial activity
- Reduce dependence on chemical fertilizers.
- Lower greenhouse gas emissions

However, the review emphasizes that digestate quality depends on process parameters, feedstock selection, and treatment conditions.

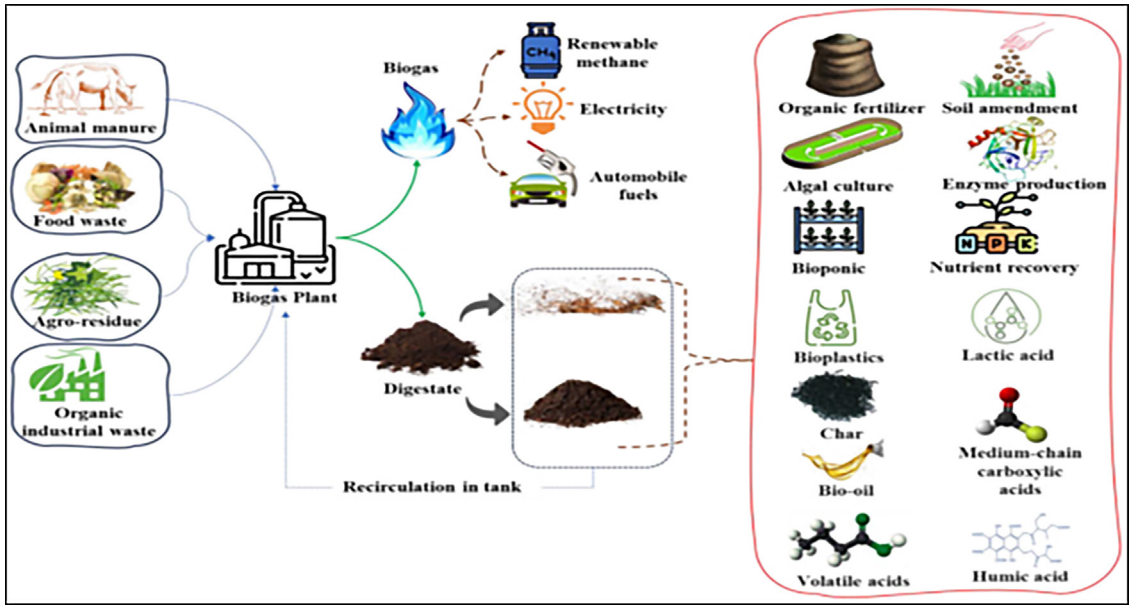


Fig.1: Circular flow of organic feedstocks—animal manure, food waste, agro-residues, and industrial organic waste—into anaerobic digesters. The outputs include renewable methane, electricity, vehicle fuels, and a wide spectrum of digestate-derived products such as organic fertilizers, algal culture media, bioplastics, bio-oil, char, and high-value chemicals.

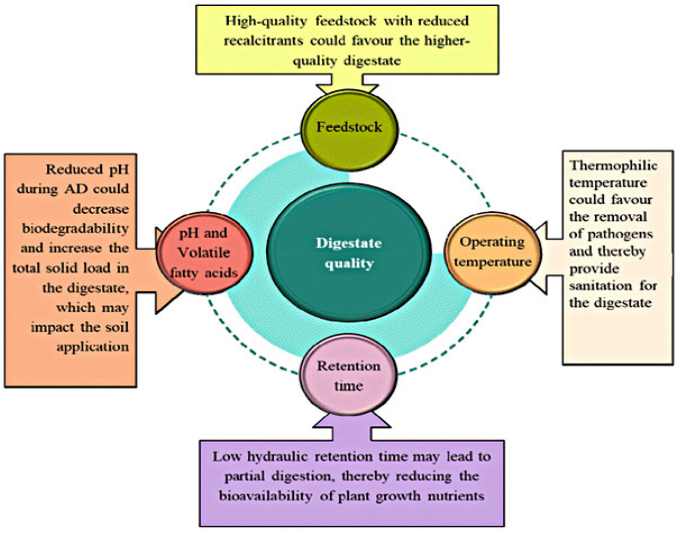


Fig.2: Key parameters influencing digestate quality, including feedstock characteristics, operating temperature, retention time, pH, and volatile fatty acid concentration. Optimizing these factors ensures stable and agriculturally safe digestate.

Ensuring Safety: Regulatory and Risk Considerations

Because digestate is frequently applied to agricultural soils, regulatory compliance is critical. Parameters such as pathogen content, heavy metals, organic contaminants, and nutrient balance must be carefully monitored.

The publication outlines a structured risk management framework linking hazards, exposure pathways, environmental compartments, and ecological receptors.

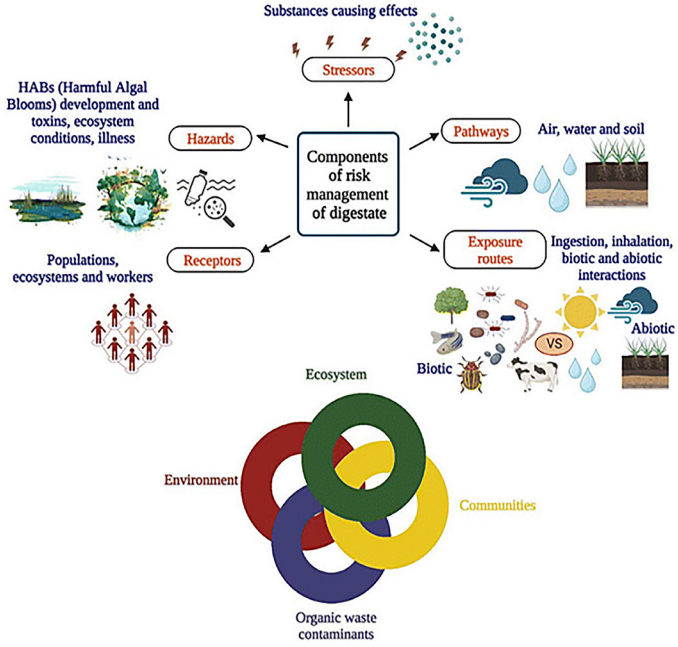


Fig.3: Environmental and public health dimensions of digestate management, demonstrating how regulatory oversight ensures safe and sustainable utilization.

Expanding the Horizon: Advanced Valorization Pathways

Digestate utilization extends far beyond soil application. Through innovative green chemistry strategies, digestate can be transformed into a spectrum of high-value products.

Algal Biorefineries: Turning Nutrients into Biomass

The liquid fraction of digestate is particularly rich in nitrogen and phosphorus—essential nutrients for microalgae growth. Rather than treating this as a disposal challenge, researchers have explored cultivating microalgae in diluted digestate.

This integration produces multiple benefits:

- Nutrient removal from digestate
- Biomass generation for biodiesel production
- Raw materials for animal feed, pharmaceuticals, and cosmetics
- Biogas upgrading potential

Fig.4: Utilization of liquid digestate as a nutrient-rich medium for algal cultivation, enabling the production of diverse value-added bio-based products such as biodiesel, bioethanol, biohydrogen, animal feed, bioplastics, and pharmaceuticals.

Bioplastics and Bio-Based Materials

Digestate-derived volatile fatty acids can be utilized as substrates for producing polyhydroxyalkanoates (PHA)—biodegradable bioplastics. These materials offer sustainable alternatives to petroleum-based plastics and can be applied in packaging, textiles, medical products, and consumer goods.

Additionally, thermochemical conversion techniques such as pyrolysis and hydrothermal carbonization enable the production of:

- **Biochar,** which improves soil health and supports carbon sequestration
- **Bio-oil and syngas**, contributing to renewable energy systems

This article highlights techno-economic assessments and life cycle analyses that support these pathways within circular bioeconomy frameworks.

Closing the Nutrient Loop

Advanced recovery technologies – including ammonia stripping, struvite precipitation, and membrane separation – allow nitrogen and phosphorus to be captured in concentrated forms. This reduces reliance on finite mineral resources and decreases the environmental burden of fertilizer production.

By integrating digestate valorization with industrial symbiosis and circular bioeconomy models, the environmental footprint of anaerobic digestion systems can be significantly reduced.

The Road Ahead

Despite its promise, digestate valorization faces challenges:

- Variability in composition
- Infrastructure and capital investment requirements
- Regulatory harmonization
- Market acceptance

Future research must focus on process optimization, large-scale implementation, and policy incentives that encourage resource recovery.

A Transformative Perspective

Digestate is no longer merely a by-product of waste treatment. It represents a bridge between renewable energy, sustainable agriculture, green materials, and climate resilience.

In reimagining digestate as a resource rather than residue, science offers a powerful reminder: sustainability is not only about reducing waste, it is about redesigning systems so that nothing is wasted at all.

Reference:

Jacob S, Kundu D, Chintagunta AD, Samanta P, Mahata C, Dey S, Shibirathna RG, Barathi A, Kumar S, Wang Z, Goel G, “Anaerobic digestion-derived digestate valorization: green chemistry innovations for resource recovery and re-utilization,” *Green Chemistry.* 2025.

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Turning Salty Water into Opportunity: Microalgae That Help Clean Water and Capture CO_2

A simple, nature-based "water + carbon" idea inspired by tiny green life

Dr. Sankaran Krishnamoorthy, et al.

Why should we care?

Across the world (and in many parts of India), fresh water is becoming harder to find. In coastal and dry regions, people often turn to desalination—removing salt from seawater or brackish water to get usable water. Desalination works, but it can be costly in another way: it typically needs a lot of electricity and produces a very salty leftover liquid called brine. That brine is difficult to dispose of safely. So, while we solve a water problem, we may create an energy and environmental problem.

A small idea with big potential

What if we could use nature to support desalination and also reduce carbon dioxide (CO_2) at the same time?

Our published review looked at a promising approach called microalgae-based biodesalination. Microalgae are tiny, plantlike organisms found in ponds, lakes, and oceans. Like plants, they use sunlight to grow. In the process, they take in CO_2 and release oxygen. Some microalgae naturally live in salty water, which makes them interesting helpers for salt-rich water treatment.

Think of microalgae as tiny living sponges and mini "solar factories."

Microalgae can help in two ways at once:

1. They can help reduce salt (especially in moderately salty or brackish water).
2. They can capture CO_2 during photosynthesis and turn it into useful biomass (their own body material).

That biomass is not waste—it can be a resource, depending on how it is produced and processed (for example, pigments, feed ingredients, bio-based products, or other industrial uses) (Fig.1).

How do they remove salt?

In simple terms, microalgae deal with salt in two main steps:

Step 1: Salt sticks to the outside of the cell (fast).

The cell surface has natural chemical "hooks" that can attract and hold salt ions. This is like dust sticking to a slightly wet surface.

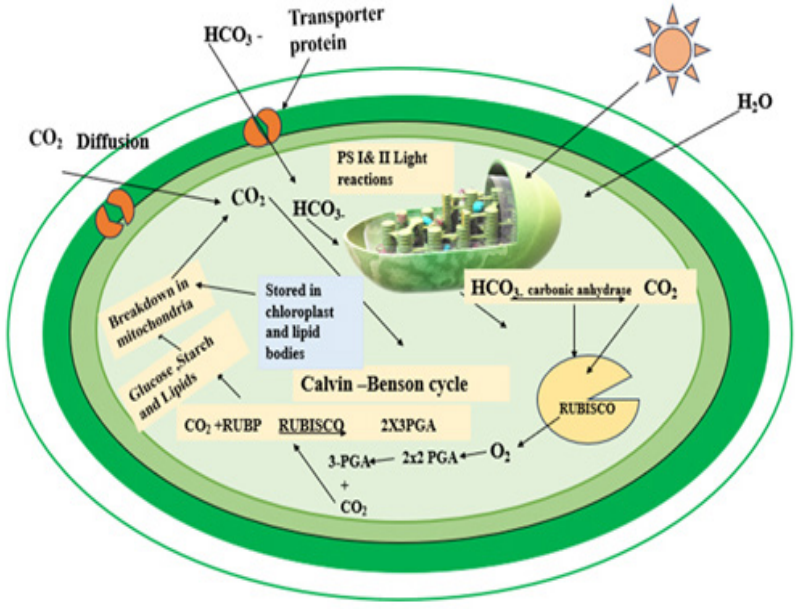

Fig.1 : *Schematic rendering of the CO_2 fixation process in microalgae*

Step 2: Some salt moves inside the cell (slower).

To survive in salty conditions, many microalgae can move ions into the cell and store them safely in specific compartments. This helps them balance water inside the cell and keep growing.

While doing this, the algae also activate protective systems (like antioxidants) so they can handle salt stress and continue to photosynthesis.

Why partnerships matter: microalgae + bacteria

In real water, microalgae rarely live alone. They often grow alongside helpful bacteria. This partnership can make the system more stable, especially when the water quality changes day to day.

A simple way to picture this teamwork:

Microalgae produce oxygen during photosynthesis—bacteria can use that oxygen.

Bacteria release CO_2 as they break down organic matter—microalgae can use that CO_2.

Together, they can form natural sticky layers (biofilms/EPS) that can bind ions and help treatment work more reliably.

Where does CO_2 capture fit in?

Here is the key link: when microalgae grow, they use CO_2 as a raw material. If we place these systems near sources of CO_2(for example, certain industrial exhaust streams), the algae can use part of that CO_2 to grow faster while producing oxygen and biomass.

Not all algae behave the same. For salty water, salt-tolerant (marine or 'euryhaline') species are often better candidates. The choice of species matters because salinity affects how CO_2 dissolves and how easily algae can take it up.

How would this look in practice?

Microalgae are not meant to magically replace desalination plants. A more realistic role is to support them as a low-energy step before or after desalination.

For example, a hybrid system could work like this:

1. Pre-treatment: microalgae reduce some salts and organics, easing the load on membranes.
2. Main desalination: conventional system produces usable water.
3 Post-treatment / brine polishing: microalgae help reduce the impact of leftover brine and convert CO_2 into biomass.

Microalgae can be grown in open ponds (cheaper but less controlled), closed photobioreactors (better control but higher cost), or hybrid setups that combine both (Fig.2)

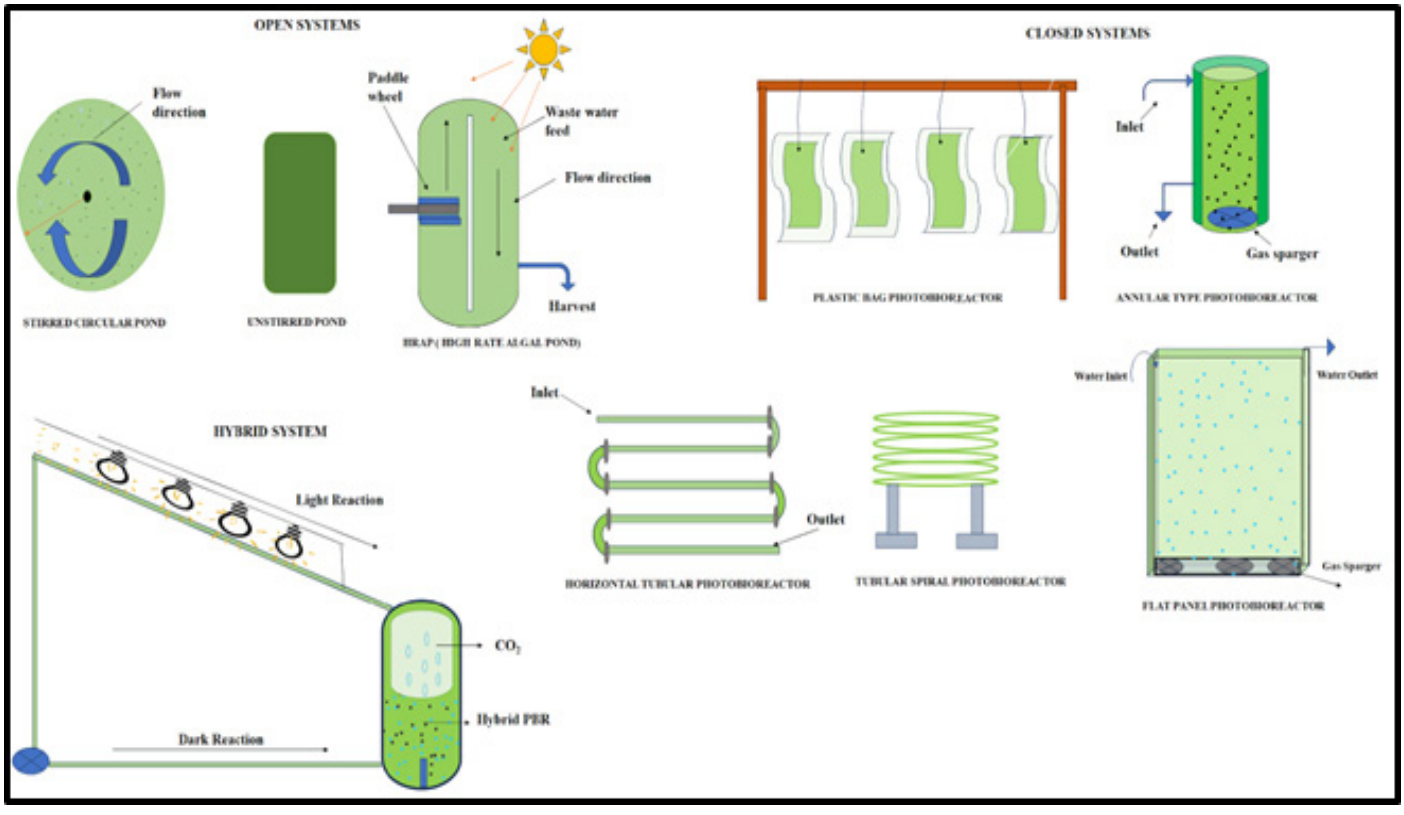

Fig. 2: Representative configurations of microalgae cultivation systems used in biodesalination and CO_2 biofixation

What are the challenges?

- Like any real technology, there are hurdles:
- Keeping the culture healthy (avoiding sudden "crashes").
- Maintaining performance when sunlight, temperature, and water quality change.
- Handling and using the biomass efficiently.
- Supplying nutrients—without increasing cost or pollution.

The good news is that these are engineering problems we can work on: selecting robust strains, designing better reactors, using smart monitoring, and linking cultivation to wastewater streams that already contain nutrients (with careful safety checks) (Fig.3)

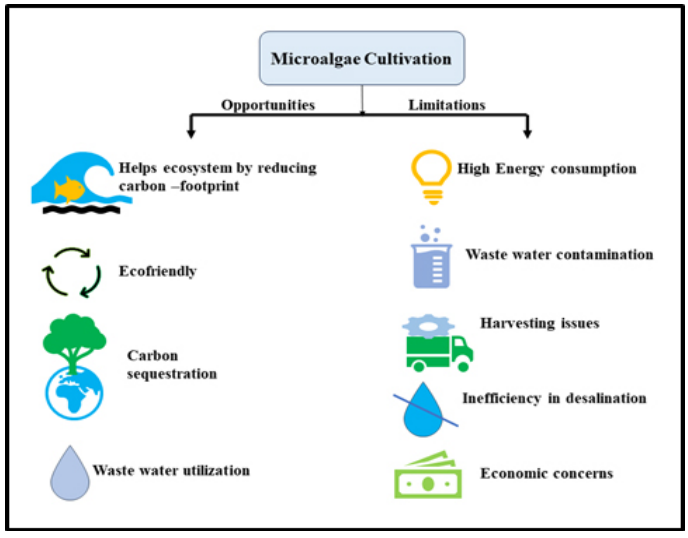

Fig.3: *Opportunities and limitations of microalgae cultivation*

Why this matters to society?

If developed responsibly, microalgae assisted systems can offer practical benefits:

- Cleaner water with lower environmental burden (reduced brine impact as part of hybrid desalination).
- A climate co benefit (CO_2 is used to build biomass rather than being treated only as waste).
- Resource recovery (turning sunlight + CO_2 + nutrients into useful biomass).
- Relevance to coastal and water-stressed regions that have saline water, wastewater, and nearby CO_2 sources.

A simple roadmap ahead

Our review highlights three directions that can help this idea move from lab studies to field use:

1. Stronger, salt-tolerant strains (including safe strain improvement tools).
2. Better hybrid integration with conventional desalination (pre- and post-treatment roles).
3. Nutrient recycling using wastewater to lower cost and improve sustainability.

In short, microalgae won't solve water scarcity alone but they can become a smart "green helper" that improves desalination sustainability while also supporting CO_2 reduction and a circular bioeconomy.

Reference:

Divyavalli Kolachalama, Sankaran Krishnamoorthy, "Harnessing microalgae for biodesalination and CO_2 sequestration toward integrated water-carbon solutions," *Journal of Environmental Chemical Engineering,* Vol. 13, Issue 6, 2025.

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From Kitchen Waste to Clean Fuel: How Carbon Is Being Reimagined for Green Hydrogen

"Turning simple carbon into a powerful catalyst shows how innovation can rewrite the rules of clean energy"

Dr. Shaik Firdoz, et al.

The world is searching for cleaner and more sustainable energy sources because fossil fuels cause pollution and climate change. Among the many alternatives, hydrogen is one of the most promising options. It is a clean fuel that produces only water when used, without releasing harmful gases. Hydrogen can also store energy generated from renewable sources like solar and wind power, helping to balance energy supply and demand. One of the cleanest ways to produce hydrogen is through water electrolysis, a process that uses electricity to split water into hydrogen and oxygen. However, this process requires special materials called catalysts or electrodes to make the reaction faster and more energy-efficient.

Traditionally, the best catalysts for water electrolysis are made from rare and expensive metals such as platinum and iridium, which makes green hydrogen production costly. To overcome this problem, researchers are exploring a new approach using carbon materials derived from waste. By carefully modifying carbon at the atomic level such as adding other elements or creating structural defects scientists can improve its performance and make it act as an efficient catalyst. This method not only reduces dependence on expensive metals but also promotes sustainability by converting waste into valuable materials. Such innovations could make hydrogen production more affordable and help move the world toward a cleaner energy future.

A Surprising Starting Point: Vinegar Residue

Instead of starting with expensive raw materials, this research uses vinegar residue, a type of biomass waste that is usually discarded. Rather than treating it as waste, the material is processed and converted into advanced carbon materials. From this simple starting material, researchers produce two important forms of carbon:

- **Graphene** – an ultra-thin, extremely strong sheet of carbon that conducts electricity very efficiently.
- **Carbon quantum dots (CQDs)** – extremely tiny carbon nanoparticles with unique electronic and surface properties that improve catalytic activity.

These two components are combined into a single, integrated structure. The carbon quantum dots are anchored onto vertically aligned graphene sheets, forming a highly organized surface.

At the microscopic level, the structure looks like:

- A dense "forest" of vertical carbon walls (graphene sheets).
- Tiny carbon dots attached across these walls.

This smart design offers several important advantages:

- **Fast electron movement** due to the excellent conductivity of graphene.
- **Large number of active sites** created by carbon quantum dots.
- **Easy access for water molecules** because of the open and porous structure.
- **Improved reaction efficiency** during water splitting.

Fig.1: The waste-to-carbon pathway for metal-free electrocatalytic green hydrogen production

The Power of Tiny Changes: Adding the Right Atoms

Pure carbon is already useful, but the researchers took the idea further by **adding** very **small amounts of other elements** into the carbon structure. This process, known as doping, can completely change how a material behaves, even if only a few atoms are added.

In this study, the carbon material is first modified with **fluorine and chlorine**. Then, four different versions are created by adding one more element: **nitrogen, boron, phosphorus, or sulfur**. Each of these elements changes the carbon structure in a slightly different way.

Why does this matter? Because water splitting depends on how well electrons move through the material and how easily the surface can hold and release reaction partners like hydrogen and oxygen. By changing the atoms inside the carbon, the researchers can fine-tune these properties.

When all four versions were tested, one clearly stood out: the nitrogen-modified carbon electrode

Why Nitrogen Makes Such a Big Difference

Inside the nitrogen-modified material, some of the bonds between carbon and fluorine shift into a form that is especially good at carrying electrical charge. The article describes these as “semi-ionic” bonds, which strike a balance between being stable and being highly active for reactions

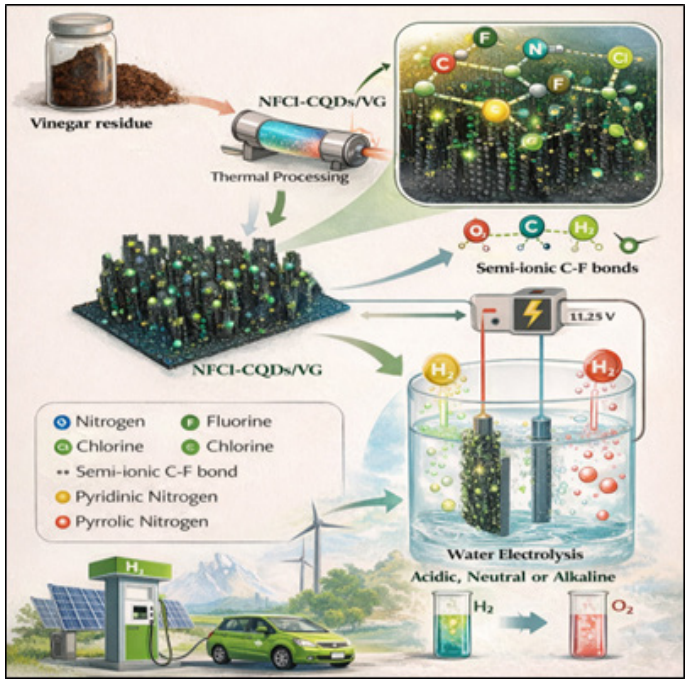

Fig.2: NFCl-CQDs/VG for metal-free water electrolysis and green hydrogen production

This change has two major effects:

1. **Electricity flows more easily** through the material.
2. The surface develops more **active sites** where the water-splitting reactions can take place.

In simple terms, the material becomes faster and more efficient at turning water into hydrogen and oxygen.

Strong Performance in Different Conditions

When tested in real electrolysis conditions, the nitrogen-enhanced carbon electrode performed impressively. It was able to:

- Produce hydrogen with lower energy input than the other versions.
- Work well in acidic, neutral, and alkaline environments, which is important for practical applications.
- Maintain high efficiency and stability over time, showing that it can keep working without quickly wearing out.

The study also measured how efficiently electrical energy was converted into actual hydrogen and oxygen gas, finding high Faradaic efficiencies, which means very little energy was wasted in side reactions

Perhaps most importantly, all of this was achieved using only carbon-based materials, without relying on precious metals that are expensive and limited in supply.

More Than a Result: Understanding Why It Works

One of the strengths of this work is that it does not stop at showing good performance. The article also explains why the nitrogen version works better than the others.

By combining experiments with detailed analysis, the study shows that nitrogen creates more useful defects and active regions in the carbon structure. These regions help change the nature of certain carbon–fluorine bonds and improve how charges move through the material. This deeper understanding means future material can be designed more intelligently, rather than by guesswork

A Step Toward Sustainable Hydrogen

There is also a bigger picture here. The entire process starts with biomass waste and ends with a high-performance energy material. This fits perfectly with the idea of sustainable technology: reducing waste, lowering costs, and avoiding rare resources, all at the same time.

The study shows that it is possible to compete with traditional, metal-based catalysts using carefully engineered carbon

alone. While more work is needed before such materials are used everywhere, the direction is clear and promising.

Reimagining What Carbon Can Do

This article presents a powerful idea: small changes at the atomic level can create major improvements in material performance. By carefully modifying carbon's structure such as introducing defects, adjusting its surface chemistry, and integrating carbon quantum dots with graphene the researchers significantly enhance its catalytic activity. These precise changes increase the number of active sites, improve electrical conductivity, and make the material more efficient for water splitting. The study shows that advanced performance does not always require rare or expensive elements; sometimes, it simply requires smarter engineering of common materials.

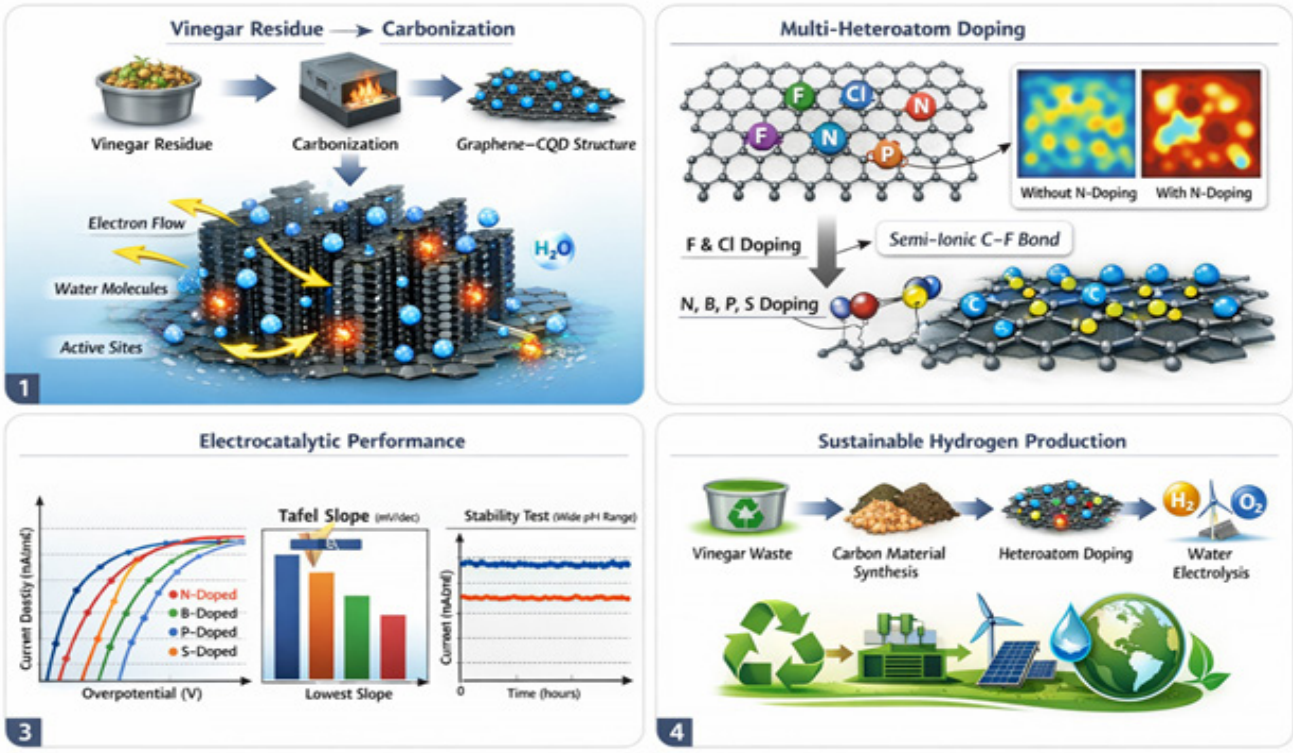

Fig.3 : *Vinegar-derived doped graphene–CQD electrode for efficient and sustainable hydrogen production.*

Reference:

Feng F, Yin H, Ren Z, An Y, Shaik F, Jiang B, "Vinegar-derived nitrogen-based multi-heteroatom doped bifunctional All-carbon electrodes for overall water splitting in a wide pH range," *Colloids and Surfaces A: Physicochemical and Engineering Aspects.* 2025 May 20;713:136521.

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An overview of the role of algae-fortified foods in nutraceutical industries: Synthesis pathway of value-added bioproducts and co-products

Dr. K. Chandrasekhar et al.

Background and Global Context

The world is currently facing a dual challenge: ensuring nutritional security for a rapidly growing population while minimizing environmental degradation caused by conventional food systems. By 2050, global food demand is projected to increase dramatically, with protein demand alone expected to double. Traditional agriculture and animal-based protein systems are approaching ecological and economic limits due to land scarcity, water stress, greenhouse gas emissions, and biodiversity loss. In this context, algae, both microalgae and macroalgae, have emerged as promising, sustainable, and nutrient-dense alternatives for food and nutraceutical applications. Algae have been consumed for centuries in various cultures, particularly in coastal regions of Asia. However, in recent decades, advances in biotechnology, food science, and biorefinery concepts have transformed algae from niche foods into high-value ingredients for functional foods and nutraceuticals. Regulatory approvals by agencies such as the US Food and Drug Administration (FDA), which recognize several algal species as Generally Recognized as Safe (GRAS), have further accelerated their commercial adoption.

This research review comprehensively combines current knowledge on algae-fortified foods, focusing on their nutritional composition, health-promoting properties, commercial products, techno-economic feasibility, regulatory frameworks, and future opportunities. The findings highlight algae as a cornerstone for sustainable, health-oriented food systems and a circular bioeconomy.

Fig 1. *An overview of the role of algae-fortified foods*

1. Nutritional Richness of Algae: Nature's Compact Bio-factories

Proteins and Essential Amino Acids

Microalgae such as Spirulina (Arthrospira) and Chlorella contain up to 60–70% protein on a dry weight basis, surpassing most plant-based protein sources. These proteins include all essential amino acids, making them particularly valuable for vegetarian and vegan diets.

Fig. 2: Variety of algae-fortified food products for human consumption.

Lipids and Omega-3 Fatty Acids

Algae are the original producers of omega-3 fatty acids in aquatic food chains. Microalgae such as Schizochytrium, Nannochloropsis, and Aurantiochytrium synthesize high levels of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), essential for cardiovascular health, brain development, and immune regulation.

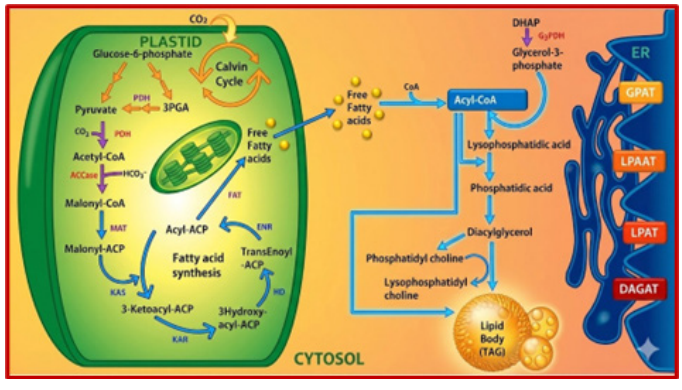

Fig. 3: Overview of the lipid biosynthesis in microalgae

Unlike fish oil, algal omega-3 oils are free from heavy metal contamination and are suitable for vegetarian consumers. Advances in metabolic engineering and photobioreactor technologies have significantly increased omega-3 yields, making algal oils a commercially viable and sustainable alternative.

Polysaccharides and Dietary Fibers

Algal polysaccharides such as alginates, carrageenans, agar, fucoidans, and laminarins play dual roles as functional food ingredients and health-promoting agents. These compounds act as dietary fibers, improving gut health, modulating microbiota, and reducing cholesterol absorption.

Sulfated polysaccharides from algae have demonstrated antiviral, anticoagulant, anti-inflammatory, and immunomodulatory activities. Their unique structural properties, absent in terrestrial plants, make them highly attractive for nutraceutical formulations.

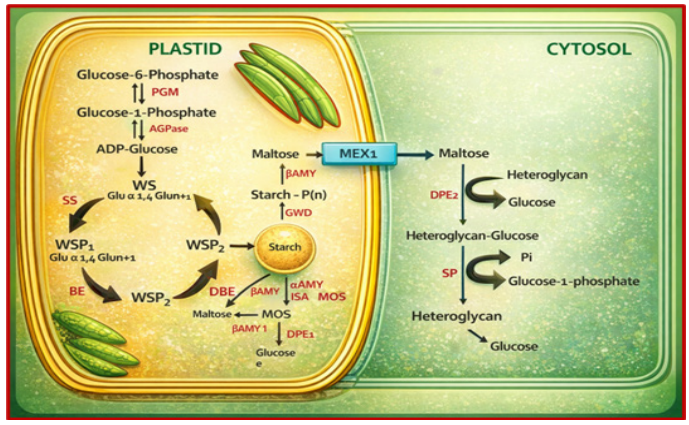

Fig. 4: Starch metabolism in green microalgae.

Polyphenols and Antioxidants

Brown algae are particularly rich in phlorotannins, a class of polyphenols with strong antioxidant activity. These compounds neutralize reactive oxygen species (ROS), thereby reducing oxidative stress associated with chronic diseases such as cancer, cardiovascular disorders, diabetes, and neurodegenerative conditions.

Pigments and Minor Bioactive Compounds

Algae synthesize diverse pigments, including chlorophylls, carotenoids (β-carotene, lutein, zeaxanthin, astaxanthin, fucoxanthin), and phycobiliproteins (phycocyanin, phycoerythrin). These pigments not only impart natural color to food products but also provide significant health benefits:

Astaxanthin: A powerful antioxidant, up to 100 times stronger than vitamin E

Lutein and Zeaxanthin: Support eye health and protect against age-related macular degeneration

Phycocyanin: Exhibits antioxidant, anti-inflammatory, and neuroprotective effects

2. Algae-Fortified Foods in the Modern Marketplace

Algae are increasingly incorporated into everyday food products, improving nutritional value without compromising sensory quality when optimally formulated.

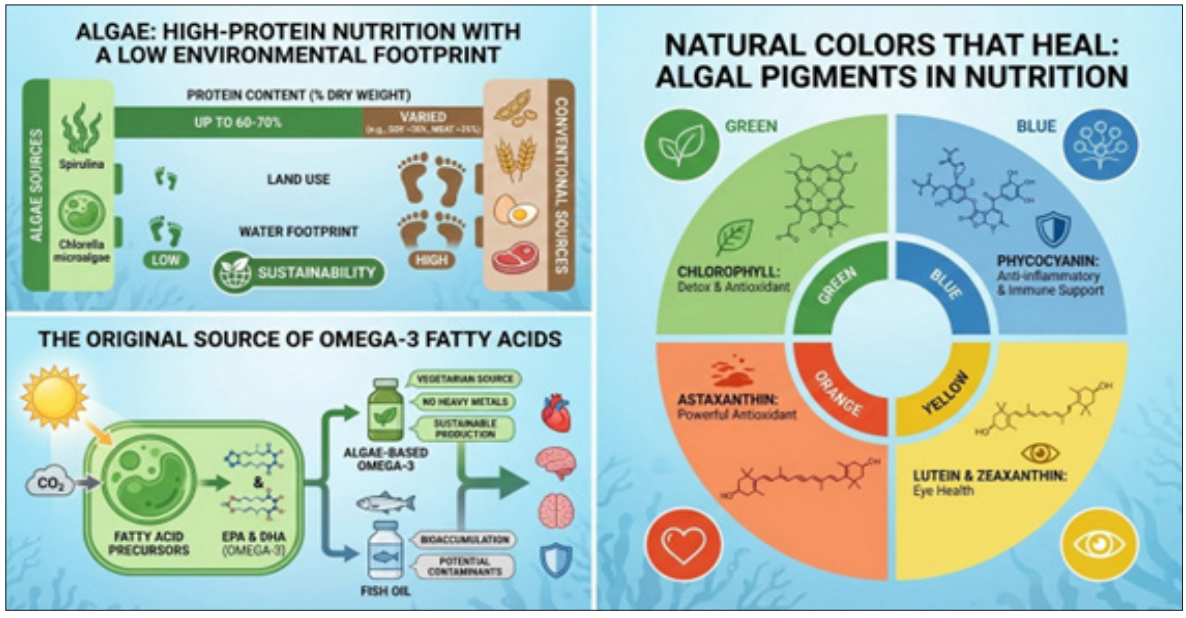

Fig.5 : *Pigments and Minor Bioactive Compounds*

Bakery and Cereal Products

Algal biomass is now used in bread, biscuits, cookies, pasta, and noodles. Studies show that incorporating 1–10% algal powder enhances protein, mineral, and antioxidant content while maintaining acceptable taste, texture, and shelf life. Spirulina-fortified baked goods are particularly popular due to their high protein content and appealing natural color.

Beverages and Functional Drinks

Algae-derived ingredients such as phycocyanin are widely used in smoothies, health drinks, juices, and dairy alternatives. These beverages provide antioxidants, vitamins, and minerals, catering to health-conscious consumers.

Jellies, Puddings, and Dairy Analogues

Algal hydrocolloids like agar and alginate are extensively used as gelling, stabilizing, and thickening agents in desserts, jams, yogurts, and plant-based dairy products.

Snacks and Traditional Foods

From protein-rich snack bars and chips to algae-fortified traditional foods such as chikki and pakoras, algae-based innovations are penetrating diverse cultural food systems.

3. Health-Promoting and Therapeutic Potential

Extensive experimental and clinical evidence supports algae-fortified foods as functional and therapeutic agents.

Antiviral and Immunomodulatory Effects

Sulfated polysaccharides from algae inhibit viral attachment and replication, showing activity against viruses such as HIV, herpes simplex virus, influenza, dengue, and SARS-CoV-2. Algal compounds also enhance immune responses by modulating cytokine production and activating immune cells.

Antioxidant and Anti-Inflammatory Properties

Algal antioxidants reduce oxidative stress, inflammation, and lipid peroxidation, thereby lowering the risk of chronic diseases. Omega-3 fatty acids and phytosterols further contribute to cardiovascular protection and metabolic health.

Metabolic and Therapeutic Benefits

Regular consumption of algae-derived nutraceuticals has been associated with improved lipid profiles, better glycemic control, enhanced gut health, and neuroprotection.

List of few algae-fortified foods available in the modern marketplace

4. Techno-Economic and Regulatory Perspectives

The economic viability of algae-based foods has improved significantly due to advances in large-scale cultivation, biorefinery integration, and downstream processing. Expanding production facilities and adopting circular bioeconomy models where residual biomass is converted into biofuels or fertilizers can substantially reduce production costs.

Regulatory frameworks play a critical role in market expansion. Several algal species are approved as GRAS, and nutraceutical regulations in India, Europe, and the United States ensure product safety, quality, and transparent labeling. Clear guidelines on dosage, health claims, and quality control have strengthened consumer confidence.

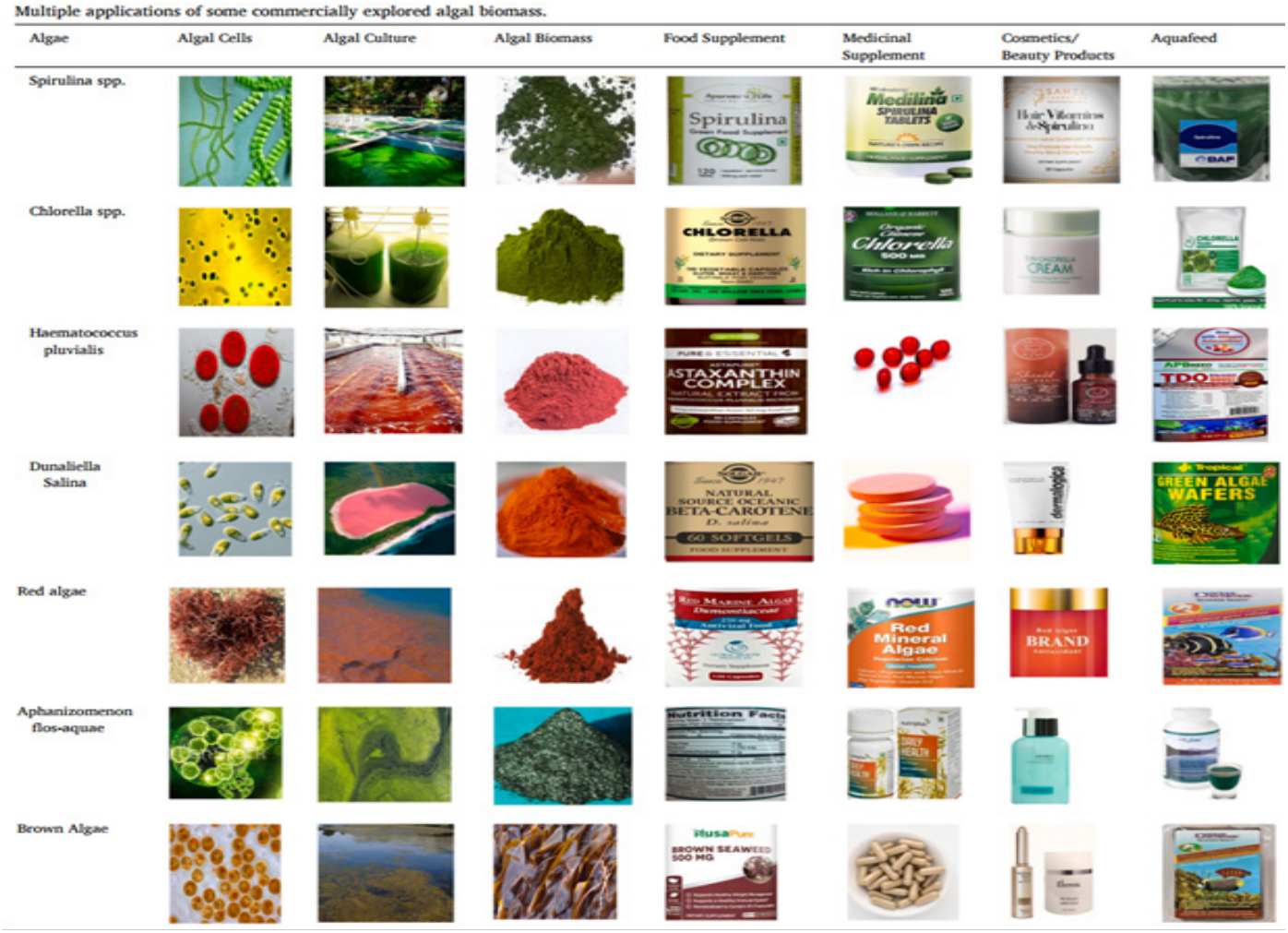

Fig.6: List of few algae-fortified foods available in the modern marketplace

5. Market Potential and Societal Impact

The global algae-based food and nutraceutical market is experiencing rapid growth, driven by rising health awareness, demand for plant-based proteins, and sustainability goals. The microalgae market is projected to reach tens of billions of dollars in the coming decade, with strong contributions from omega-3 oils, protein supplements, natural colorants, and functional foods.Algae-based innovations support multiple United Nations Sustainable Development Goals (SDGs) by promoting food security, reducing environmental impact, and enabling climate-resilient food systems.

Conclusion and Way Forward

Algae-fortified foods represent a transformative opportunity for the global nutraceutical and functional food industries. Their exceptional nutritional profile, proven health benefits, environmental sustainability, and expanding commercial footprint position algae as a key ingredient for future diets. Continued interdisciplinary research, consumer education, technological innovation, and supportive regulatory policies will be essential to mainstream algae-based foods. With strategic investment and public awareness, algae can play a pivotal role in delivering nutritious, affordable, and sustainable food solutions for future generations.

Reference:

Singh M, Mal N, Trivedi D, Krishnamoorthy S, Behera C, Krishnan C, Naik S, Kuppam C, “An overview of the role of algae-fortified foods in nutraceutical industries: Synthesis pathway of value-added bioproducts and co-products,” *Food Bioscience.* 2025 Jan 1;63:105568.

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Department of Pharmaceutical Sciences
Thrust areas of Research

The Department of Pharmaceutical Sciences at VFSTR focuses on advancing drug discovery, improving therapeutic effectiveness, ensuring medication safety, and addressing emerging healthcare challenges. These research activities integrate pharmaceutical sciences, biomedical research, and technological innovations to develop better medicines and healthcare solutions.

Major focus area is drug discovery and development. including identifying new drug molecules from synthetic chemicals, natural products, and biological sources. This includes studying the pharmacological activity, toxicity, and therapeutic potential of compounds for the treatment of diseases such as cancer, infectious diseases, metabolic disorders, and neurological conditions. Preclinical investigations help determine the safety and efficacy of potential drug candidates before they proceed to clinical evaluation.

Another important research domain is pharmaceutical analysis and drug quality assurance. Faculty and students get involved to develop and apply advanced analytical techniques to identify impurities, degradation products, and contaminants in pharmaceutical formulations. Stability studies and quality control assessments ensure that medicines maintain their safety, potency, and effectiveness throughout their shelf life. Such studies are critical for regulatory compliance and patient safety.

Novel drug delivery systems are also a major area of research in VFSTR aiming to design formulations that improve drug targeting, enhance bioavailability, and provide controlled or sustained release of medications. Technologies such as nanoparticles, liposomes, transdermal systems, and targeted delivery platforms are being explored to improve therapeutic outcomes and reduce side effects.

we also focus on nanotechnology and biotechnology-based therapeutics. These approaches enable precise drug delivery, improved stability of medicines, and enhanced treatment of complex diseases such as cancer, viral infections, and genetic disorders. Nanomedicine has particularly shown promise in improving the effectiveness of existing drugs.

Overall, the Department of Pharmaceutical Sciences aims to bridge the gap between scientific discovery and clinical application, contributing to the development of safer, more effective, and accessible medicines for global health.

Core facets of integrated multi-target drug discovery framework for translational and sustainable therapeutic development

When the Body Misses Alcohol: Understanding Alcohol Withdrawal and Natural Support

Dr. Ch. Jithendra, et al.

Alcohol is widely consumed in many societies. For some people it is an occasional drink at celebrations, while for others it becomes a daily habit. When alcohol consumption becomes heavy and regular, the body slowly adapts to its presence. In such individuals, suddenly stopping alcohol can trigger a series of uncomfortable and sometimes dangerous symptoms known as Alcohol Withdrawal Syndrome.

Alcohol withdrawal is an important health issue that families and communities should understand. Recognizing the symptoms early and knowing how to respond can prevent serious complications and help people recover safely.

Why Alcohol Withdrawal Happens

Alcohol affects the brain by altering the balance of chemicals called neurotransmitters, which control mood, relaxation, and alertness.

Two important neurotransmitters involved are:

- Gamma-Aminobutyric Acid (GABA) – a chemical that slows brain activity and promotes calmness
- Glutamate – a chemical that stimulates brain activity

Normally, these two systems remain balanced in the brain. However, when alcohol is consumed regularly for long periods, the brain adjusts to the presence of alcohol.

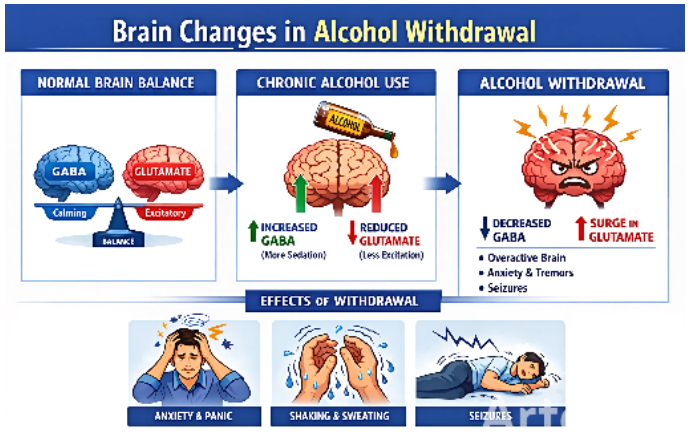

Fig.1: Neurochemical Changes in the brain and Symptoms of Alcohol Withdrawal

Alcohol increases the calming effect of GABA and reduces the excitatory activity of glutamate. Over time, the brain tries to compensate by reducing GABA sensitivity and increasing glutamate activity.

When alcohol is suddenly stopped, the brain becomes overactive, because the calming effect disappears while the excitatory signals remain high. This imbalance leads to the symptoms of alcohol withdrawal.

Common Symptoms of Alcohol Withdrawal

Alcohol withdrawal symptoms can begin within 6–24 hours after the last drink. The severity varies depending on how long and how heavily a person has been drinking.

Table 1 : Symptoms of Alcohol Withdrawal Syndrome

Early Symptoms	Moderate Symptoms	Severe Symptoms
• Anxiety and nervousness	• Increased heart rate	• Seizures
• Restlessness	• Irritability and mood swings	• Hallucinations (seeing or hearing things that are not present)
• Headache	• Fever	• Severe agitation
• Sweating	• Confusion	• Death if untreated
• Nausea or vomiting	• High blood pressure	
• Difficulty sleeping	• Difficulty concentrating	
• Trembling of the hands		

The Early symptoms may appear mild at first but can become more severe if not managed properly, the moderate symptoms requires medical supervision and severe symptoms are the most dangerous leading to Delirium and Tremens, which may cause extreme confusion, shaking, seizures, severe dehydration, rapid heartbeat, and high fever. This condition is a medical emergency and requires immediate hospital treatment, which may also lead to death if untreated

Recognizing Alcohol Withdrawal Syndrome in Family Members

Family members are often the first to notice withdrawal symptoms based on physical Behavioural and psychological observations.

- Physical Signs - Shaking hands, sweating without exercise, Nausea or vomiting, Rapid heartbeat, Poor sleep

- Behavioural Changes - Sudden irritability, Anxiety or panic, Aggressive behaviour, Difficulty focusing
- Psychological Symptoms – Confusion, Fearfulness, Hallucinations

What Should Be Done When Withdrawal Symptoms Appear

Alcohol withdrawal should never be ignored. Proper care and timely medical advice are important, many medicines prescribed by doctors will restore the calmness of mind.

- Rehydration with adequate intake of Water, Electrolyte drinks and soups should be done
- Stress and noise can worsen withdrawal symptoms. A quiet and comfortable environment helps reduce anxiety and agitation.
- Severe symptoms such as seizures may occur suddenly. Continuous monitoring can help prevent complications.

Can Natural Remedies Help?

Modern medicine plays the primary role in treating alcohol withdrawal. However, scientists have also been studying traditional medicinal plants that may support recovery.

One such plant that has attracted attention is Morinda citrifolia, commonly known as Noni, which has flavonoids such as rutin and scopoletin, responsible for the medicinal effects.

Noni is a tropical plant widely used in traditional medicine across the Asia-Pacific region. For centuries, it has been used to treat various health conditions including inflammation, infections, and mood disorders.

Scientific studies suggest that compounds found in Noni fruit may have several beneficial effects on the brain, such as reducing anxiety, depression and stress apart from providing neuroprotection

Natural Compounds in modifying Alcohol withdrawal Syndrome

Recent research has explored whether Noni fruit extract could help reduce symptoms associated with alcohol withdrawal.

In laboratory studies using rats, It is observed that extracts from Morinda citrifolia fruit (Noni) were able to reduce several withdrawal-related behaviours such as anxiety and seizures. by influencing brain systems related to calming neurotransmitters such as Gamma-Aminobutyric Acid and mood-regulating pathways involving serotonin, suggesting that noni could complement existing treatments for alcohol withdrawal.

However, it is important to remember that herbal remedies should never replace medical care, especially in severe cases.

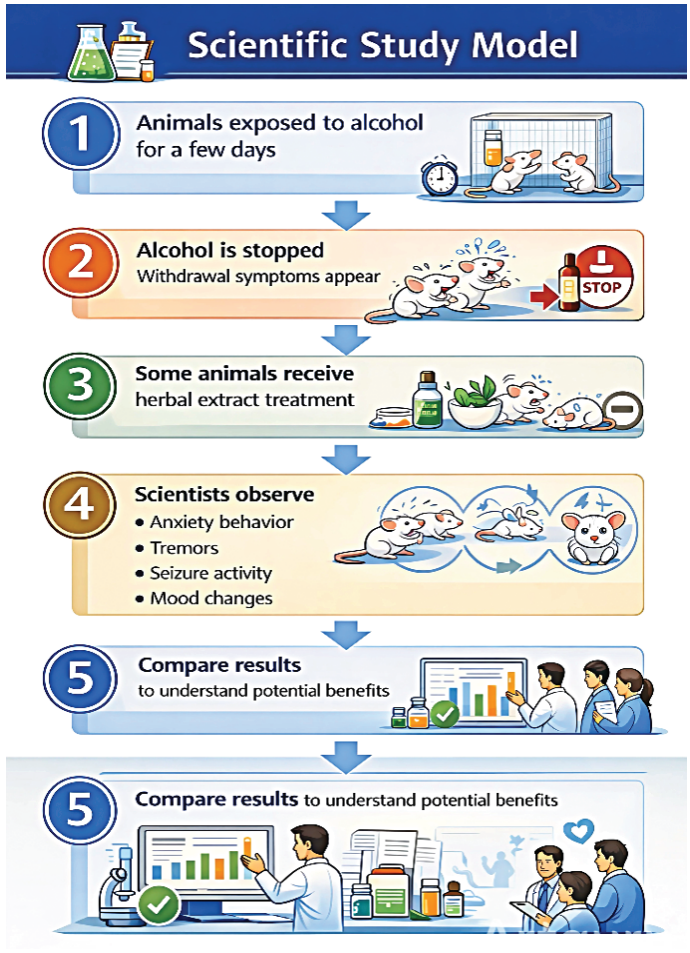

Fig 2: Methodology involved to identify the effects of herbal drugs on the Alcohol Withdrawal Syndrome

How are the effects of Noni on Alcohol Withdrawal studied

Before any treatment is recommended for humans, it is to be carefully tested for its safety and effectiveness in laboratory animals [after obtaining the necessary approval from regulatory bodies], to understand how withdrawal from alcohol affects the brain and how potential treatments might work.

In such studies, animals are exposed to controlled alcohol intake and later observed during the withdrawal phase for behavioural changes such as:

- Tremors
- Anxiety-like behaviour
- Reduced interest in pleasurable activities

What does Noni do to the Brain During Withdrawal

When alcohol is suddenly removed:

- GABA activity decreases
- Glutamate activity increases

This leads to excessive brain stimulation, causing the mild, moderate and severe symptoms. Noni may help reduce some of these effects by protecting brain cells and regulating neurotransmitters.

Fig. 3: Handling the Withdrawal symptoms

Way ahead to overcome Alcohol withdrawal syndrome

The best way to avoid alcohol withdrawal is to prevent alcohol dependence in the first place.

Some helpful strategies include:

- Limiting alcohol consumption
- Seeking help early, if drinking becomes excessive
- Maintaining healthy lifestyle habits such as exercise and balanced nutrition
- Building strong social support systems

Education and awareness are powerful tools in preventing addiction.

Alcohol addiction is not simply a matter of willpower. It is a medical condition that affects the brain and body, which requires support, medical care, and compassion, not judgment.

Families and communities play an important role in helping individuals seek treatment and rebuild their lives.

With proper awareness, timely intervention, and community support, many individuals can successfully overcome alcohol dependence and move toward healthier lives.

Reference:

Begum A, Chimakurthy J, Pandy V, Durgesam R. Noni (Morinda citrifolia Linn.), “Fruit Extract Protects Against Non-precipitated Alcohol Withdrawal Symptoms in Mice,” *Journal of Pharmacology and Pharmacotherapeutics*. 2025 - DOI: 10.1177/0976500X251398613.

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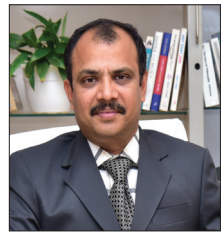

Better Relief from IBS: The Role of Novel Drug Delivery Methods

Dr. Grandhi Srikar et al.

What is Irritable Bowel Syndrome?

Irritable Bowel Syndrome (IBS) is a common chronic gastrointestinal disorder characterized by recurrent abdominal pain, bloating, and irregular bowel habits such as diarrhoea, constipation, or alternating patterns of both. It is considered a functional gastrointestinal disorder, meaning that the symptoms occur without any visible structural damage to the digestive tract. The condition results from disturbances in the interaction between the gut and the brain, abnormal gastrointestinal motility, increased visceral sensitivity, and alterations in gut microbiota.

IBS is typically classified into four major types depending on the predominant bowel pattern:

- IBS with diarrhoea (IBS-D)
- IBS with constipation (IBS-C)
- Mixed IBS (IBS-M)
- Unclassified IBS

Among these, IBS-D is particularly challenging because it involves frequent loose stools, urgency, and abdominal discomfort that significantly affect patients' daily activities and mental well-being. Although IBS is not a life-threatening disease, it significantly reduces the quality of life, leading to stress, anxiety, and depression in many patients. Because the disorder is chronic and requires long-term management, developing effective and patient-friendly treatment approaches is a major goal in pharmaceutical research.

What is the Impact of IBS at National and Global Level?

Irritable Bowel Syndrome is one of the most prevalent gastrointestinal disorders worldwide. Epidemiological studies indicate that IBS affects approximately 4–15% of the global population, making it a major public health concern.

- Global Impact

Globally, IBS contributes to a significant healthcare burden due to:

- Frequent physician visits
- Long-term medication use
- Reduced workplace productivity
- Increased healthcare costs

Patients often experience persistent symptoms that interfere with daily functioning, including work, social interactions, and psychological health.

- Impact in India and National Context

In developing countries such as India, the burden of IBS is increasing due to factors such as:

- Rapid lifestyle changes
- Dietary habits
- Stress and urbanization
- Limited awareness and diagnosis

Many patients remain undiagnosed or undertreated, which leads to worsening symptoms and reduced quality of life. IBS also imposes a considerable economic burden through repeated diagnostic tests, long-term treatments, and indirect costs related to loss of productivity.

Therefore, improving treatment strategies and drug delivery systems for IBS is essential to reduce the disease burden and improve patient outcomes.

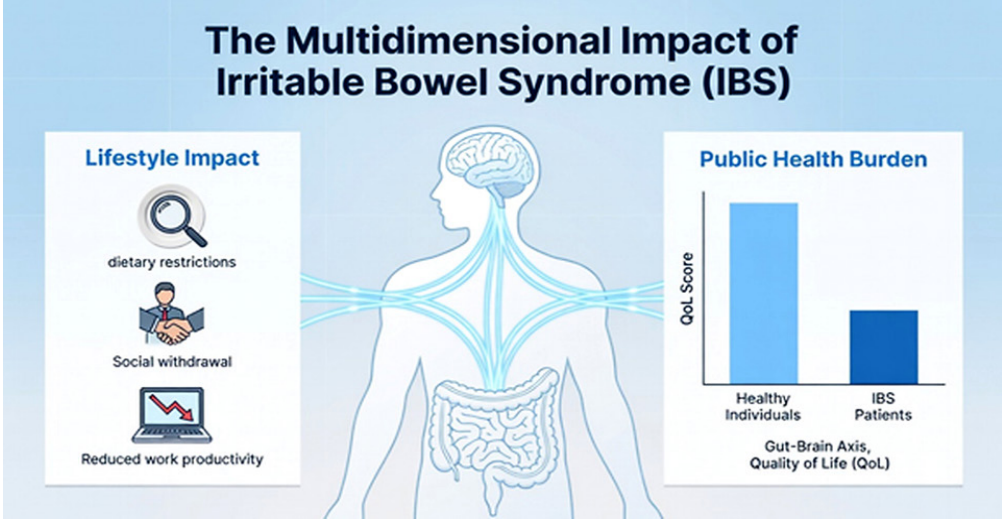

Fig 1: *Impact of IBS on Quality of Life (QoL)*

Existing Treatment Therapies for IBS

Currently, IBS treatment focuses on symptom management, as there is no permanent cure for the condition. Different therapeutic approaches are used depending on the type and severity of IBS.

i. Antispasmodic Drugs: Antispasmodics are commonly used as the first-line therapy for IBS because they relax the smooth muscles of the gastrointestinal tract, reducing spasms and abdominal pain. Examples include: Mebeverine hydrochloride, Alverine citrate, Otilonium bromide, Pinaverium bromide etc. These drugs help restore normal intestinal motility and reduce discomfort associated with IBS.

ii. Laxatives and Antidiarrheal Drugs: Depending on the IBS type, Laxatives are used for IBS-C and Antidiarrheal drugs are used for IBS-D.

iii. Dietary and Lifestyle Modifications: Patients are often advised to increase fiber intake, avoid trigger foods, manage stress and maintain regular physical activity

iv. Limitations of Existing Therapies: Although these treatments help relieve symptoms, they have several limitations such as short half-life of drugs such as Mebeverine, rapid metabolism in the body, need for frequent dosing, variable drug absorption and bioavailability, lack of targeted drug delivery to the colon.

These drawbacks reduce therapeutic effectiveness and patient compliance, creating a need for improved drug delivery systems.

Novel Drug Delivery Systems

Development of novel colon-targeted nanoparticle drug delivery systems for the treatment of IBS is the need of the hour. One of such novel approach is chitosan–xanthan gum based controlled-release nanoparticles containing mebeverine hydrochloride.

Key Components of the Technology

i. Nanoparticle Drug Delivery System: Nanoparticles can be prepared using a polyelectrolyte complexation method, combining two natural polymers, chitosan – a cationic biopolymer with strong mucoadhesive properties, and xanthan gum – an anionic polymer known for high viscosity and stability. These polymers interact to form a stable nanoparticle matrix capable of encapsulating the drug.

ii. Optimization Using Box–Behnken Design: A statistical optimization technique called Box–Behnken design can be used to optimize formulation parameters such as polymer concentration, crosslinker concentration to achieve required particle size and drug entrapment of the nanoparticles. This ensures an efficient and reproducible nanoparticle formulation.

iii. Enteric Coating for Colon Targeting: The optimized nanoparticles are coated with Eudragit S100, an enteric polymer that dissolves only at higher pH levels (around pH 7). This coating followed by the complex polymeric polyelectrolyte complex prevents drug release in the stomach and small intestine respectively and ensures drug release specifically in the colon, where IBS symptoms originate.

iv. Multi-Level Evaluation: The technology is validated through in silico studies (molecular docking with muscarinic receptors), in vitro drug release studies, in vivo studies in IBS-D rat models.

Scientific Benefits of this Novel Dug Delivery System Over Existing Therapies

This nanoparticle-based drug delivery system offers several advantages compared to conventional IBS treatments.

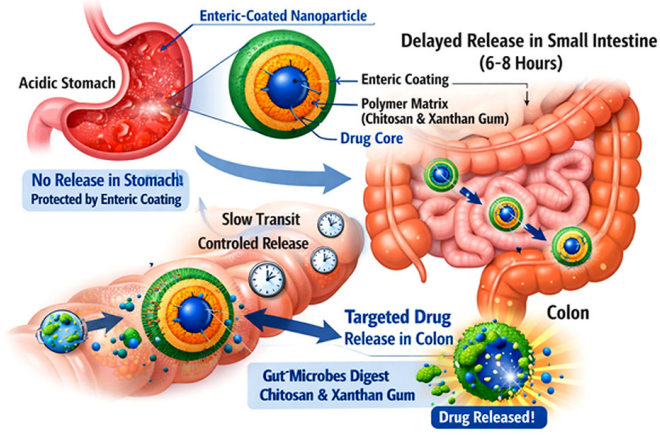

Fig. 2: Colon targeted drug delivery – describing how the drug release is prevented in stomach and small intestine and how the drug is released only in large intestine or colon

i. Colon-Targeted Drug Delivery: Unlike conventional tablets, the enteric-coated nanoparticles release the drug specifically in the colon, ensuring site-specific therapy and improved effectiveness.

ii. Sustained Drug Release: The formulation provides controlled drug release for up to 12 hours, reducing the need for frequent dosing.

iii. Improved Bioavailability: Encapsulation of mebeverine in nanoparticles protects the drug from early degradation and enhances its absorption.

iv. Enhanced Therapeutic Efficacy: In vivo studies demonstrated that the nanoparticle formulation significantly improved visceral sensitivity, intestinal motility, behavioral parameters in IBS models.

v. Better Patient Compliance: Because the formulation provides prolonged drug action and targeted delivery, patients may require lower doses and fewer administrations, improving treatment adherence.

Overall, this technology represents a promising advancement in nanomedicine for gastrointestinal disorders.

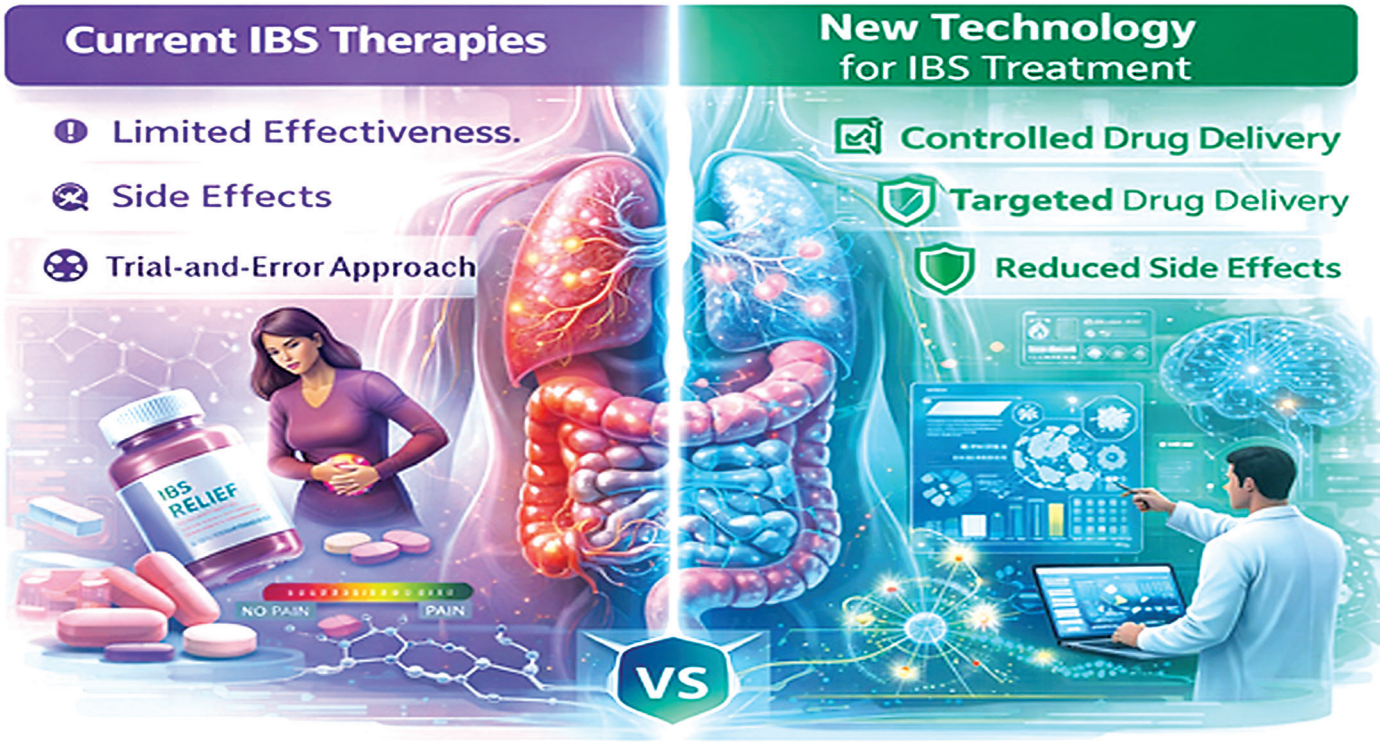

Fig. 3: Illustrating the benefits of the new colon targeted drug delivery technology over current therapies for IBS

Conclusion

Irritable Bowel Syndrome is a widespread digestive disorder that affects millions of people worldwide and can significantly reduce the quality of life. Although several medications are available, many of them provide only temporary relief and often require frequent dosing. However, this new approach using nanotechnology delivers medicine directly to the colon, where IBS symptoms occur. By packaging the drug mebeverine into tiny particles made from natural polymers and protecting them with a special coating, the medicine can travel safely through the stomach and small intestine, and release slowly in the colon. This innovative system allows the drug to work more effectively, for a longer duration, and with potentially fewer side effects. Experimental studies have shown that the new formulation improves symptoms and intestinal function better than conventional treatments. With further development and clinical studies, this technology could lead to more effective, convenient, and patient-friendly treatments for IBS, ultimately helping people live healthier and more comfortable lives.

Reference:

Pushadapu VVSK, Srikar G, “Development and evaluation of chitosan–xanthan gum-based controlled release nanoparticles of mebeverine hydrochloride for targeted IBS therapy: In silico, in vitro, and in vivo investigations,” *DARU J Pharm Sci.,* 2026;34:6. https://doi.org/10.1007/s40199-025-00584-9.

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Detection and Analysis of Degradation impurities in the Drug Voxelotor by Modern analytical method

Dr Shaik Abdul Rahaman et al.

Pharmaceutical analysis is an important field in pharmacy that focuses on the identification, determination and quality evaluation of drugs and pharmaceutical products. It ensures that medicines contain the accurate amount of active ingredient, are free from harmful impurities and meet the required safety and quality standards before reaching patients.

How will you determine the Quality and Quantity of Drugs and Products?

The quality and quantity of drugs are determined using analytical techniques that measure the amount of drug present and check whether it is pure and stable.

In this study, the drug Voxelotor was analyzed to ensure:

- The correct amount of drug is present in the formulation.
- The drug has not degraded or broken down during storage.
- The drug is safe and free from harmful impurities.

Researchers performed forced degradation studies, where the drug was exposed to different stress conditions such as Acid, Base, Heat, Light and oxidation.

This helps determine how stable the drug is and whether any unwanted compounds form during storage.

Instruments used to estimate Quality and Quantity of Drugs:

Several laboratory instruments were used in the study:

- HPLC (High Performance Liquid Chromatography)

  Used to separate the drug from impurities and measure its amount.
- LC-HRMS (Liquid Chromatography–High Resolution Mass Spectrometry)
  Analytical weighing balance
  - Ultrasonicator
  - Hot air oven
  - Photostability chamber
  - UV-Visible Spectrophotometer
  - UP-HPLC-QTOF Mass Spectrometer

These instruments help accurately measure and analyze the drug molecules.

Fig. 1: *Analytical Instruments used in the identification of drugs and impurities*

Determination of impurities present in Voxelotor:

Yes. Voxelotor was an oral, once-daily medication approved to treat Sickle cell disease (SCD) in adults and children 4 years of age and older by inhibiting hemoglobin S (HbS) polymerization.

The Analytical techniques like HPLC and LC-MS can detect and identify even very small amounts of impurities.

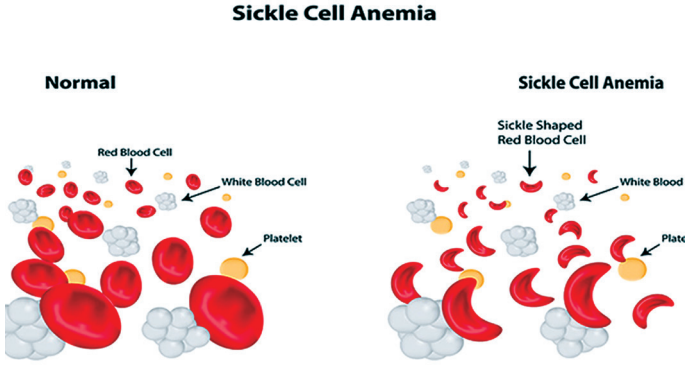

Fig. 2: Morphological difference of the normal and sickle cell type of Red Blood cells

In this research:

- The drug was subjected to degradation studies.
- Two new degradation impurities were detected:
  - V-1
  - V-2

These impurities were formed when the drug was exposed to:

- Acidic conditions
- Oxidative conditions

The study confirmed that the drug remained stable under:

- Light exposure
- Heat
- Neutral conditions.

Role of LC-MS in Pharmacological and Biotechnological Products

LC-MS (Liquid Chromatography-Mass Spectrometry) plays an important role in drug development and biotechnology.

Key Roles

1. **Drug Identification**
   - Determines the exact molecular structure of drugs.
2. **Impurity Detection**
   - Detects trace-level impurities and degradation products.
3. **Drug Metabolism Studies**
   - Helps understand how drugs are broken down in the body.
4. **Quality Control**
   - Ensures pharmaceutical products meet regulatory standards.
5. **Biological Sample Analysis**
   - Used in blood, urine and tissue drug analysis.

In this study LC-HRMS was used to identify the molecular structure of degradation impurities formed from Voxelotor.

How were degradation impurities of Voxelotor separated and identified using LC-MS?

The researchers followed a systematic process:

Step 1: Stress Testing of the Drug

Voxelotor was exposed to stress conditions such as:

- Acid hydrolysis
- Oxidation (hydrogen peroxide)
- Heat
- Light
- Neutral conditions

Step 2: Separation using HPLC

A C18 column with ammonium formate and acetonitrile mobile phase was used to separate the drug and impurities.

Step 3: Detection of Impurities

Two impurities were observed:

- V-1 (m/z 354) – formed due to oxidation of the aldehyde group into a carboxylic acid.
- V-2 (m/z 218) – formed due to hydrolysis of the ether bond.

Step 4: Structural Identification

Using high-resolution mass spectrometry, researchers measured the exact mass and fragmentation pattern of each compound. This helped determine the chemical structure of the degradation impurities.

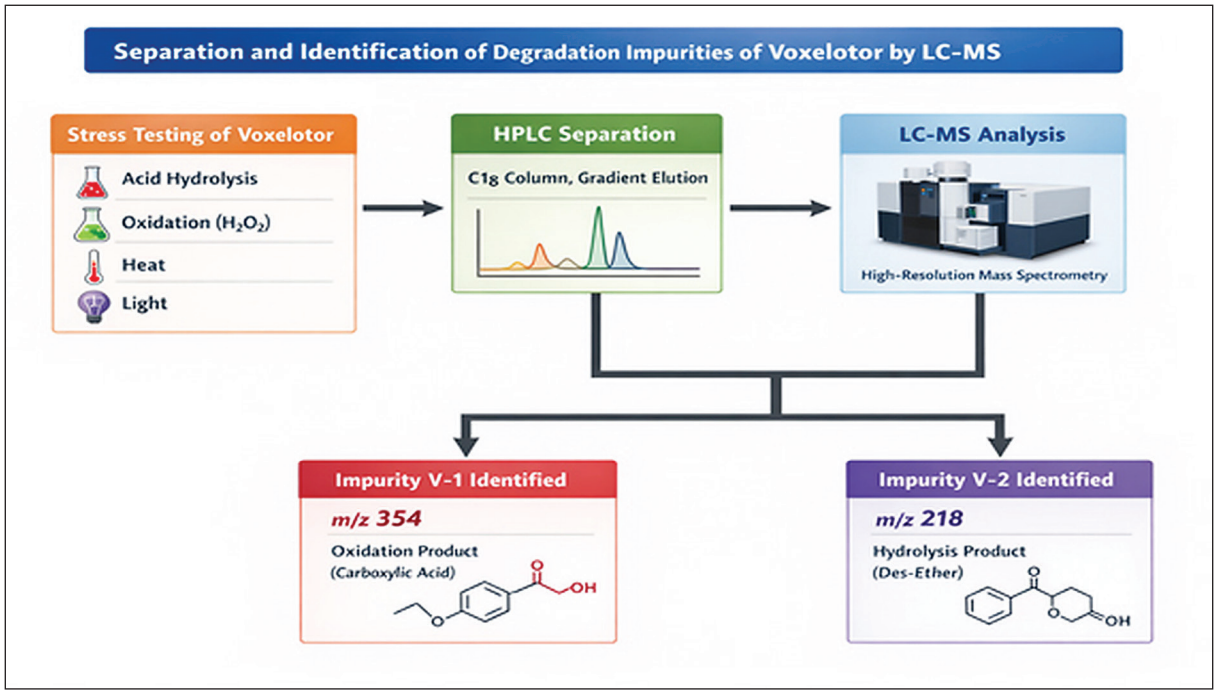

Fig. 3: *Workflow involved in separation and identification of degradation impurities*

Conclusion:

This study focused on evaluating the stability of the drug Voxelotor to ensure its safety and quality. Using advanced analytical techniques such as High-Performance Liquid Chromatography (HPLC) and Liquid Chromatography–High Resolution Mass Spectrometry, researchers successfully separated and identified two previously unknown degradation impurities formed under stress conditions. Identifying these unknown impurities are essential because it helps detect potentially harmful compounds that may form during drug storage or manufacturing. Such analytical investigations play a crucial role in maintaining drug quality, stability and patient safety thereby safeguarding public health.

Reference:

Srisailapu V. S. G. B. Prasad, SK. Abdul Rahaman, Gananadhamu Samanthula, Santhi Priya Lankalapalli, Pushpa Pilli, “Separation and Characterization of Degradation Impurities of Voxelotor by Liquid Chromatography and High Resolution Mass Spectrometry,” *Separation Science Plus,* Wiley Publishers, Volume 9, Issue 2, February 2026.

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Nanotechnology a boon for enhancing the outcomes of HIV Therapy

Dr. M. Prathap et al.,

Human Immunodeficiency Virus (HIV) is a virus that attacks the immune system, which is the body's natural defense against infections and diseases. Specifically, HIV damages a type of white blood cell called CD4 cells, which play a major role in protecting the body from harmful microorganisms. When HIV enters the body, it gradually weakens the immune system. Over time, the body becomes less capable of fighting infections and certain cancers. If HIV is not treated properly, it can progress to a more severe stage called Acquired Immunodeficiency Syndrome (AIDS).

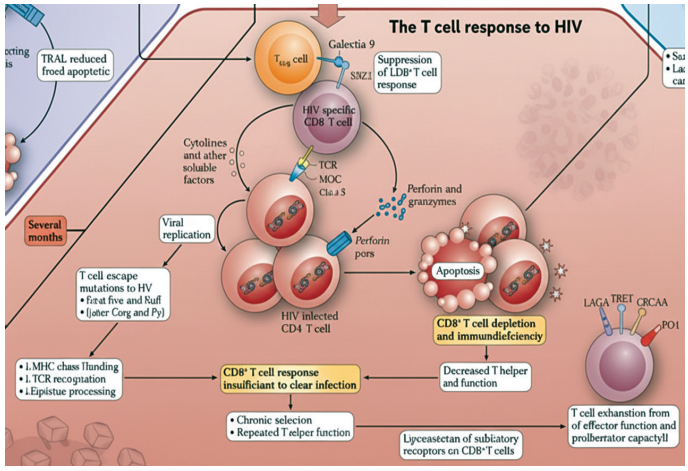

Fig.1 : Structure of Human Immunodeficiency Virus

Global Impact

Across the world, millions of people are living with HIV. Despite significant medical advances, the disease continues to affect many countries, especially developing regions. HIV not only affects the health of individuals but also impacts families, healthcare systems, and economic productivity.

Key global concerns include:

- Large numbers of people still becoming infected each year
- Lifelong treatment requirements
- High healthcare costs
- Social stigma and discrimination faced by patients.

Impact in India

India has made significant progress in HIV prevention and treatment through government programs such as the National AIDS Control Programme (NACP). However, HIV still affects many individuals, especially in high-risk populations.

Major challenges include:

- Continuous need for medication
- Limited access to advanced treatment technologies
- Drug resistance and side effects in some patients

Because HIV treatment must be taken regularly and for life, improving drug effectiveness and reducing dosing frequency are important goals in pharmaceutical research.

Existing Therapies for HIV

Currently, HIV is treated using Antiretroviral Therapy (ART). These medicines work by preventing the virus from multiplying inside the body. When taken regularly, ART can reduce the viral load to very low levels, helping patients live normal lives.

One important drug used in HIV therapy is Ritonavir, an antiviral medication that helps block the enzymes required for viral replication.

However, conventional HIV drugs have several limitations:

- **Low Bioavailability**

  Some drugs, including Ritonavir, are not easily absorbed by the body when taken orally.

- **Frequent Dosing**

  Patients often need to take medicines daily for many years.

- **Side Effects**

  Long-term drug use can lead to unwanted side effects.

- **Drug Resistance**

  If drugs are not taken properly, the virus may develop resistance.

Because of these challenges, researchers are working to develop better drug delivery systems that can improve drug absorption and effectiveness.

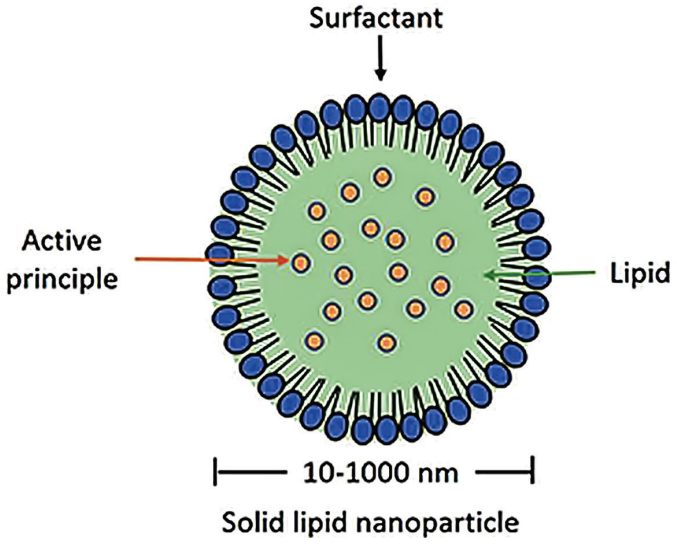

Fig. 2 : Structure of Solid Lipid Nanoparticle

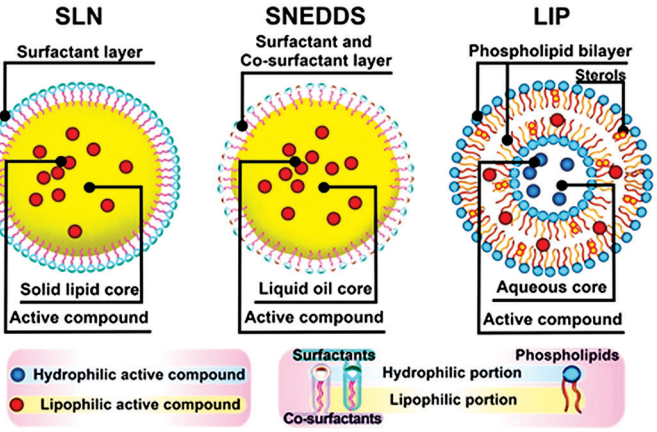

Fig.3 : Process involved in formulation of SLNP

Solid Lipid Nanoparticles, the real change makers

Solid Lipid Nanoparticles are extremely tiny particles made from biocompatible lipids (fats) that can carry drugs inside them. These nanoparticles are measured in nanometers, which means they are thousands of times smaller than the width of a human hair.

Nanotechnology helps drugs perform better by:

- Protecting the drug from degradation
- Improving absorption in the body
- Providing controlled drug release
- Enhancing drug stability

The nanoparticles will be prepared using an ultrasonication technique. Leading to incorporation of Ritonavir into solid lipid nanoparticles, the best formulation could be obtained using Box–Behnken design. Properties of nanoparticles such as Particle size, entrapment efficiency, Drug release behavior, structural analysis and characterization and ex vivo evaluation

Characteristics of Nanoparticle formulations

The optimized nanoparticle formulation exhibited:

- Particle size: approximately 270 nm
- High drug entrapment efficiency: about 94%
- Controlled drug release: about 67% release over time
- Stable nanoparticle structure
- Uniform spherical shape

One of the most important findings was that the drug permeability increased significantly.

The nanoparticle formulation allowed Ritonavir to permeate approximately 3.5 times faster than the conventional drug suspension. This means the drug can be absorbed more effectively by the body.

Applicability in Clinical setup

Solid Lipid Nanoparticles can serve as an effective drug delivery system for Ritonavir, a key drug used in HIV therapy. The optimized nanoparticle formulation significantly improves drug permeability and entrapment along with controlled release properties.

Overall, the potential of nanotechnology in improving HIV treatment was evident. With further development and clinical studies, such advanced delivery systems may contribute to more effective therapies, better patient outcomes, and improved quality of life for people living with HIV.

Reference:

Guptha PM, Palei NN, Vanangamudi M, Vijayaraj S, Mohanta BC, “Formulation, Optimization, and Ex vivo Permeation Study of Ritonavir-loaded Solid Lipid Nanoparticles,” *Current Pharmaceutical Design*. 2025 Jul;31(26):2105-16.

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Plant-Derived Phenolic Acids inhibit the Release of Inflammatory Mediators

Rudrapal et al.

Many common diseases such as heart disease, diabetes, cMany common diseases such as heart disease, diabetes, cancer, brain disorders, and autoimmune conditions are linked to long-term inflammation and oxidative stress in the body.

- Inflammation is the body's defense response, but when it continues for too long, it can damage tissues.
- Oxidative stress happens when harmful molecules called free radicals build up and damage cells.

These two processes fuel each other, creating a harmful cycle that worsens disease.

Synthetic Drugs act specifically on one target, but instead of targeting just one pathway, these plant compounds may:

- Reduce inflammation
- Reduce oxidative stress
- Break the harmful cycle between them
- Potentially help in chronic diseases like heart disease, diabetes, and neurodegenerative disorders

as they are derived from plants, they have a good safety profile than many synthetic drugs.

22 plant-based natural compounds called phenolic acids found in many fruits, vegetables, and herbs were investigated for their effect on three important enzymes in the body that cause inflammation and oxidative damage:

- COX – produces inflammatory chemicals
- LOX – increases inflammatory reactions
- NOX – produces harmful free radicals

Most drugs block only one of these. That can limit their effectiveness and sometimes cause side effects. Natural plant compounds could block all three at the same time.

Using advanced computer simulations, it was tested how well these compounds could:

- Bind to the three harmful enzymes
- Act as antioxidants (neutralize harmful free radicals)
- Show safe and drug-like properties

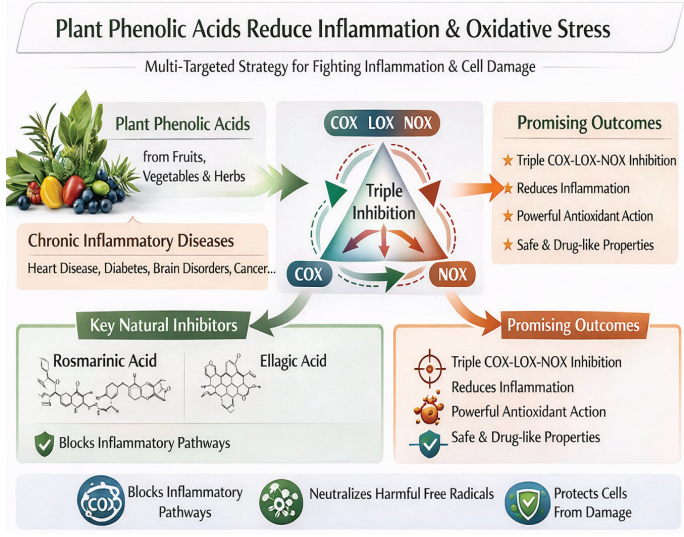

Fig.1 : Plant phenolic acids reduce inflammation and oxidative stress, depicting multi-targeted approach for fighting inflammation and cell damage.

What did we find?

Two natural plant compounds - rosmarinic acid and ellagic acid - show strong potential to fight inflammation and oxidative stress by targeting multiple harmful enzymes at once.

These compounds:

- Strongly blocked all three enzymes (COX, LOX, and NOX)
- Remained stable in long computer simulations
- Showed powerful antioxidant ability
- Had good predicted safety and drug-like properties

Among them, rosmarinic acid performed the best overall.

Overall significance

This study is important because it moves beyond the traditional "one drug-one target" approach. Most current anti-inflammatory drugs block only a single pathway, which may reduce effectiveness in complex chronic diseases.

Certain plant compounds - especially rosmarinic acid and ellagic acid as triple inhibitors - may help fight inflammation and cell damage by blocking three key harmful enzymes at the same time. While these results are based on computer studies, they provide strong support for future laboratory and clinical research to develop safer, multi-target natural medicines.

By simultaneously inhibiting these inflammation- and free radical–producing enzymes, the compounds demonstrated strong antioxidant capacity, stable enzyme binding, and favorable predicted safety profiles. Overall, the study suggests that plant phenolic acids may serve as promising multi-target natural candidates for managing chronic inflammatory and oxidative stress–related diseases.

Future perspectives

The paradigm of modern drug discovery is shifting from the traditional "one drug-one target" approach toward multi-target therapeutic strategies, driven by the complex and interconnected molecular basis of contemporary diseases. Conditions such as diabetes, neurodegeneration, chronic inflammation, cancer, and multidrug-resistant (MDR) infections arise from overlapping pathways/ targets involving oxidative stress, inflammation, metabolic imbalance, and adaptive resistance mechanisms. Consequently, therapeutics capable of modulating multiple biological targets simultaneously are increasingly recognized as more effective and sustainable interventions.

Fig.2 : *Multi-target therapeutic strategies at the interface of phytopharmacology, computational design and medicinal chemistry and core facets of integrated multi-target drug discovery framework for translational and sustainable therapeutic development by repurposing natural molecules and utilizing traditional medicinal knowledge and resources*

The integration of phytopharmacology, computational drug design, and medicinal chemistry, helps to identify, validate, and advance multi-target bioactive agents. Medicinal plants emerge as a natural starting point due to their chemically diverse phytoconstituents that inherently act on multiple molecular targets.

Beyond bioactive extracts, computational repurposing of defined plant-derived molecules enables precision-guided multi-target lead identification. Phenolic acids such as rosmarinic acid and ellagic acid were identified as triple inhibitors of COX, LOX, and NOX-key regulators of inflammation and oxidative stress. Molecular docking, dynamics simulations, DFT calculations, and in silico pharmacokinetic profiling collectively demonstrated their promising binding affinity, antioxidant potential and drug-like behavior.

In conclusion, such studies converge on a unified research trajectory: complex diseases require multi-target solutions, best achieved through the convergence of identification of bioactive natural products as functional leads by advanced computational modeling and subsequently rigorous experimental validation. This integrated drug discovery and development framework offers a forward-looking blueprint for next-generation therapeutics, emphasizing efficacy, safety, and translational relevance to tackle some of the most pressing and emerging human diseases.

Reference

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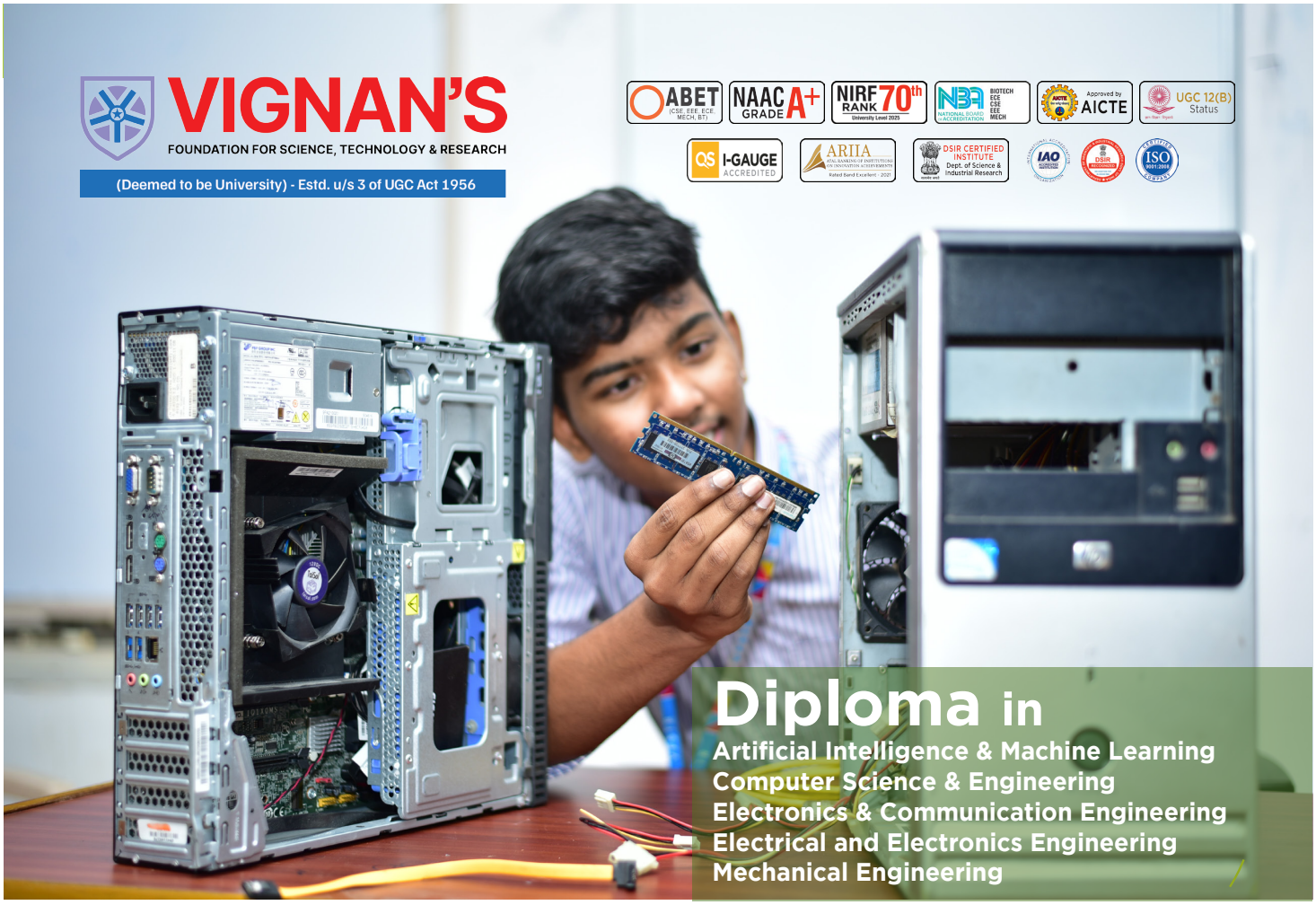

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