Department of Food Science

Sustainable Food Production



GREEN PARTICAPATION, GREEN EUROPE

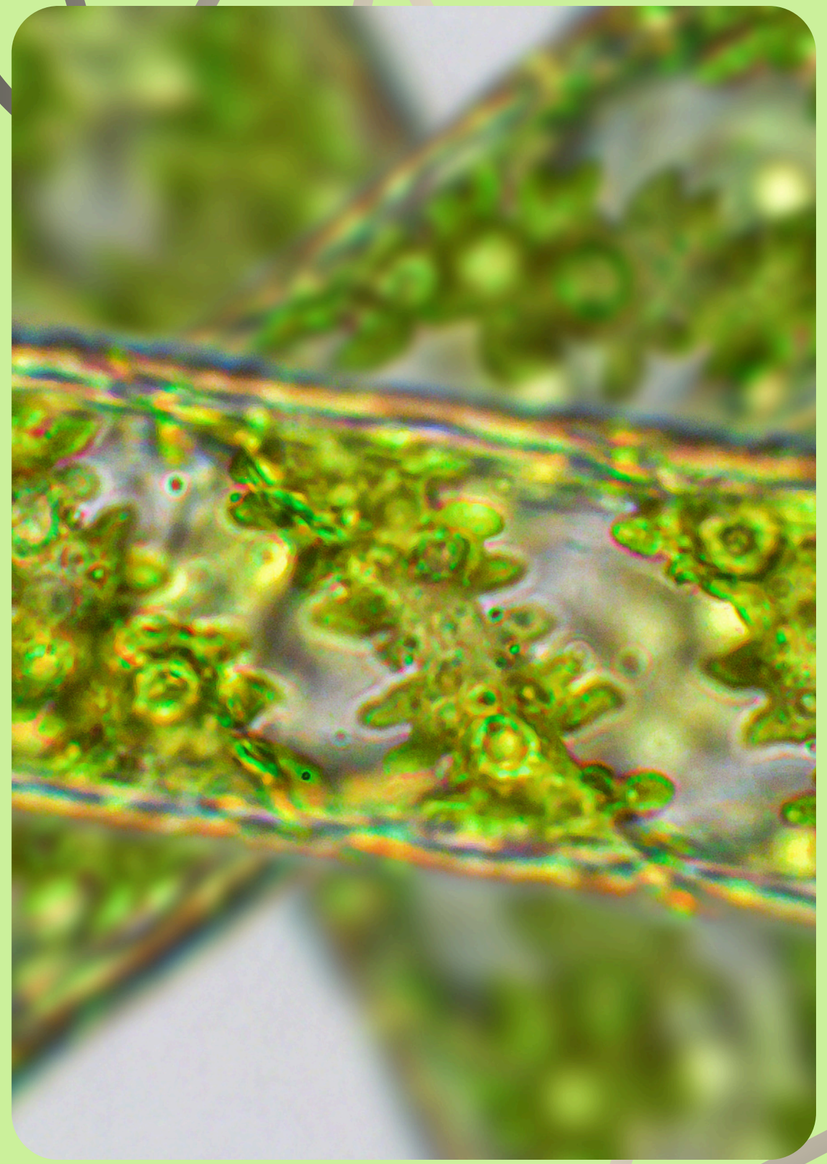
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A11- Potential of microalgae in the fight against climate change

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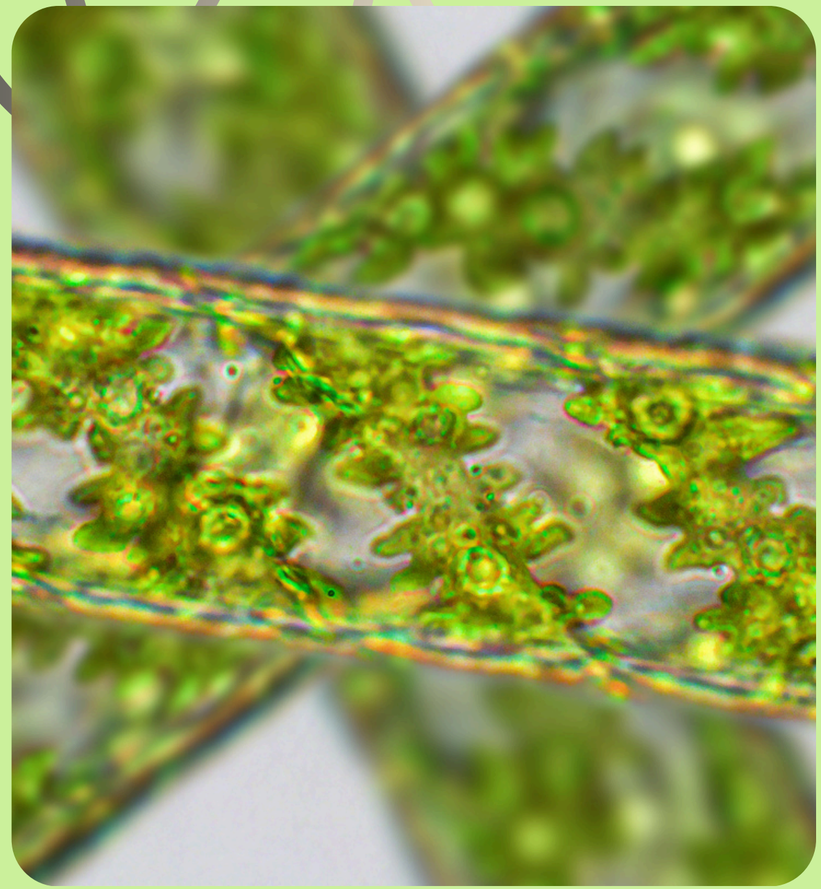
The Sustainable Food Frontier

- Microalgae represent a vast and diverse group of microscopic, predominantly unicellular photosynthetic organisms that inhabit both freshwater and marine environments.
- They are a potential cornerstone for sustainable food systems, recognized as a valuable source of essential nutrients and bioactive compounds crucial for human health.
- Microalgae possess characteristics of both plants (photosynthesis) and microbes (rapid growth potential), offering a unique pathway towards more sustainable nutrient production.



The Nutritional Powerhouse

- **High Protein:** Many species boast high protein content (40-70% of dry weight), comparable or superior to traditional sources like soy or meat, often with a complete essential amino acid profile. Examples: Chlorella vulgaris (51-58%), Arthrospira platensis (Spirulina, 55-70%).
- **Valuable Lipids:** Source of carbohydrates (12-30%) and lipids (20-50%), including beneficial polyunsaturated fatty acids (PUFAs) like EPA and DHA.
- **Vitamins & Minerals:** Contain essential vitamins (B vitamins, E, K, D) and minerals. Some Chlorella species are a bioavailable source of vitamin B12.
- **Bioactive Pigments:** Rich in pigments with potent bioactive properties like carotenoids (beta-carotene, astaxanthin, lutein) and phycobiliproteins (phycocyanin).



The current focus is on integrating microalgae into food systems, aiming to enhance sustainability and nutritional value in our diets.

Innovative Cultivation & Harvesting

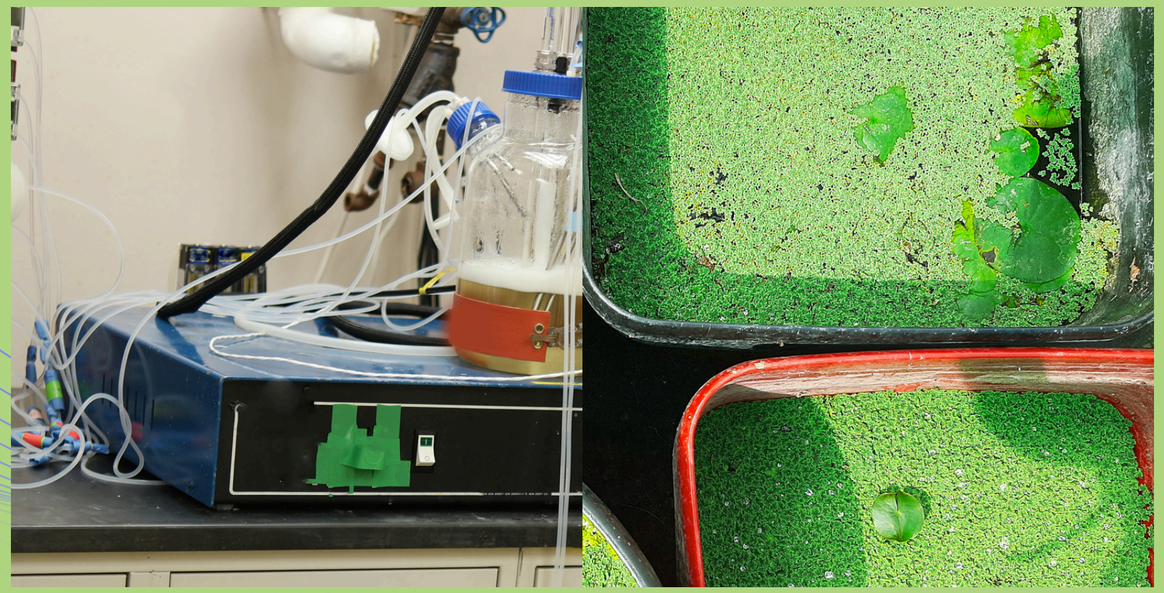




Open Ponds: Lower cost, but susceptible to contamination and harder to control conditions.

Closed Photobioreactors (PBRs): Better control, higher biomass concentrations, but higher capital and operational costs.

Innovative Cultivation & Harvesting



Harvesting Challenges: Separating microscopic cells from large volumes of water is costly and energy-intensive (20-30% of operating costs).

Key Harvesting Techniques for Food:

- **Bio-flocculation:** Uses biologically derived flocculants (e.g., chitosan), suitable for food products.
- **Filtration (Membrane):** Avoids chemical additives, produces high-purity biomass, but can have higher energy/capital costs and membrane fouling.
- **Other methods:** Sedimentation, Centrifugation, Magnetic Nanoparticles

Innovative Processing - From Biomass to Ingredient



Cell Disruption (Lysis): Crucial for breaking robust cell walls to release intracellular components (proteins, lipids, pigments).

Processing Routes:

- **Dry Route:** Biomass is dried, then extraction occurs.
- **Wet Route:** Wet biomass is directly subjected to cell disruption and extraction (often more energy-efficient).

Key Cell Disruption Techniques for Food:

- **Pulsed Electric Field (PEF):** Low energy input, rapid, avoids hazardous substances.
- **Enzymatic Methods:** Gentle conditions, preserves compound integrity, but can be slower/more expensive.
- **Others:** Mechanical: Bead Milling, HPH; Physical: Microwave-assisted, Ultrasonication
- Processing influences functional properties (emulsification, gelation) and nutrient bioavailability.

Integrating into Food Systems - Proteins & Lipids

Applications in food systems

Microalgal Proteins:

- Used as whole biomass, concentrates, isolates, or hydrolysates.
- Exhibit functional properties like emulsifying, water-holding, and gel-forming capabilities for diverse applications (baked goods, dairy, meat analogues).

Microalgal Lipids:

- Primary source of monounsaturated fats and essential omega-3 PUFAs (EPA & DHA) – a direct, vegetarian, and sustainable source.

- Algal oils (e.g., Corbion's AlgaVia™) offer high stability and smoke points for culinary uses, helping reduce saturated fat.

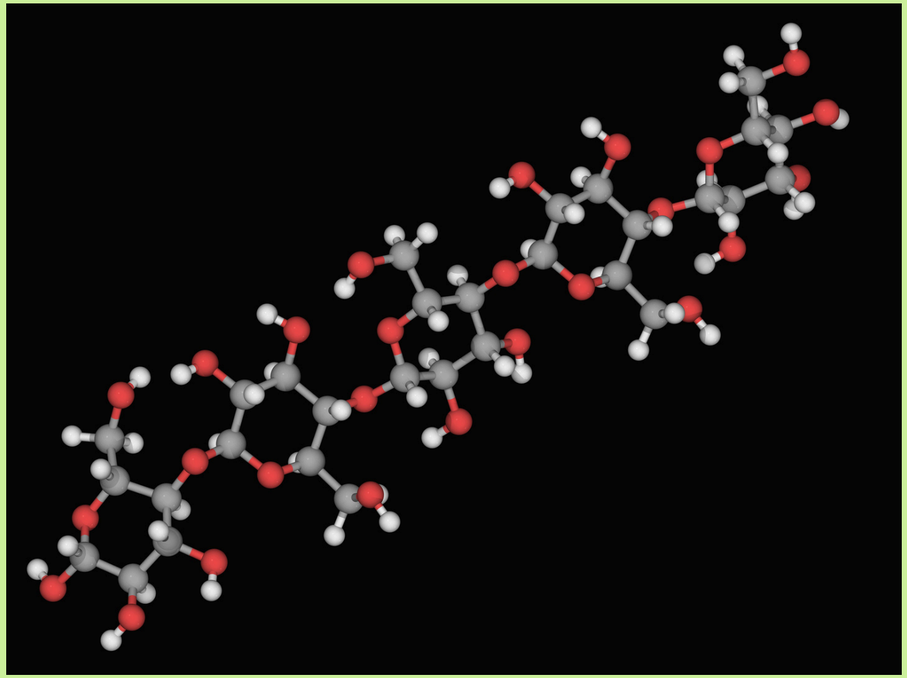
Integrating into Food Systems - Pigments, Antioxidants & Polysaccharides

Pigments & Antioxidants:

- Natural food colorants (replacing synthetic dyes): Phycocyanin (blue from Spirulina), chlorophylls (green), carotenoids (yellow/orange/red).
- Potent bioactive compounds with antioxidant and anti-inflammatory properties (e.g., Astaxanthin from H. pluvialis).

Polysaccharides:

- Unique polysaccharides like beta-glucans (e.g., Paramylon from Euglena gracilis) show immunomodulatory effects for functional foods.



Current Applications & Industry Spotlights



- **Dietary Supplements:** Whole biomass (Spirulina, Chlorella), extracts (astaxanthin, omega-3 oils).
- **Enriched Foods:** Added to pasta, bread, cookies to boost protein, fiber, antioxidants.
- **Dairy & Alternatives:** Fortified yogurts, kefir, vegan kefir, vegan ice cream, algae-based butter spreads.
- **Meat & Fish Analogues:** High protein and texturization potential (e.g., SimpliiGood's spirulina-based salmon/chicken; Algama's Chlorella-based egg replacers).
- **Beverages:** Health drinks, smoothies.
- **Industry Examples:** Corbion (AlgaVia™ oils, AlgaPrime™ DHA), Algama (Tamalga® egg substitutes), SimpliiGood (spirulina-based meat/fish analogues

Future Trends - Enhancing Strains



Advanced Biotechnology (Genetic Engineering, CRISPR-Cas9):

- **Enhanced Productivity:** Increasing biomass yield or specific high-value compounds (proteins, lipids, pigments).
- **Improved Nutritional Value:** Optimizing essential amino acids or beneficial fatty acids.
- **Optimized Processability:** Engineering weaker cell walls for easier disruption or natural flocculation for easier harvesting.
- **Increased Stress Tolerance** & **Modified Sensory Properties**.

Challenges: Genetic complexity, developing tools for commercial strains, regulatory approval, and consumer acceptance of GMOs.

Future Trends - Market Growth & Advanced Applications



- **Market Growth:** Global market projected to grow significantly (e.g., USD 783 million in 2024 to USD 1.38 billion by 2032). Driven by demand for sustainable proteins, plant-based foods, and natural ingredients.
- **Functional Foods & Nutraceuticals:** Targeting specific health outcomes (immune support with beta-glucans, cardiovascular health with omega-3s, anti-inflammatory with astaxanthin).
- **Personalized Nutrition:** Potential for tailoring microalgal ingredients to individual nutritional needs – microalgae as customizable "bio-factories."
- **Advanced Health Applications:** Exploring use as biocompatible carriers for drug delivery.

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Overcoming Hurdles for Mainstream Adoption



- **Economics of Scale:** High production costs ($5-15/kg for protein vs. soy $1-2/kg) remain a barrier. Strategies include biorefinery integration, waste stream utilization, technological innovation, and strain improvement.

- **v**Strong flavors/odors ("fishy," "grassy") and intense colors can be unappealing. Lack of familiarity is an issue. Strategies include product formulation, processing to mitigate off-flavors, and consumer education.

- Regulatory Maze: Navigating Novel Food regulations (EU) and GRAS notifications (US) is essential but can be complex and costly.

Conclusion - Charting a Sustainable Course



- Microalgae offer a compelling solution for enhancing sustainability and nutrition in global food systems due to efficient photosynthesis, rapid growth, and rich biochemical profiles.
- Significant advantages in resource efficiency (lower land/water use) and CO2 mitigation.
- Realizing full potential requires overcoming hurdles in cost, sensory aspects, and regulation through continued innovation, strategic integration into circular economies, and market development.
- Microalgae are well-positioned to play an increasingly important role in a sustainable, resilient, and nutritious global food future.

Thank you!

What role do you see for microalgae in your field of study or future career?

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