

Demonstration of Innovative Functional food production systems based on more sustainable value chains of marine and freshwater raw materials for conscientious EU consumers



National Research
Council of Italy

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National Research Council

***ALGAE-BASED INNOVATION FOR SUSTAINABLE PROTEIN
DIVERSIFICATION: SENSORY QUALITY, NUTRITIONAL
VALUE, AND APPLIED RESEARCH PERSPECTIVES***

Rome, April 30, 2026



This project has received funding from the European Union under Grant Agreement N° 101084180.

The Sustainable Protein Imperative

The Global Strain



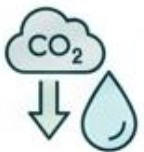
Population Growth

Rising global numbers drive protein consumption



Increased Meat Demand

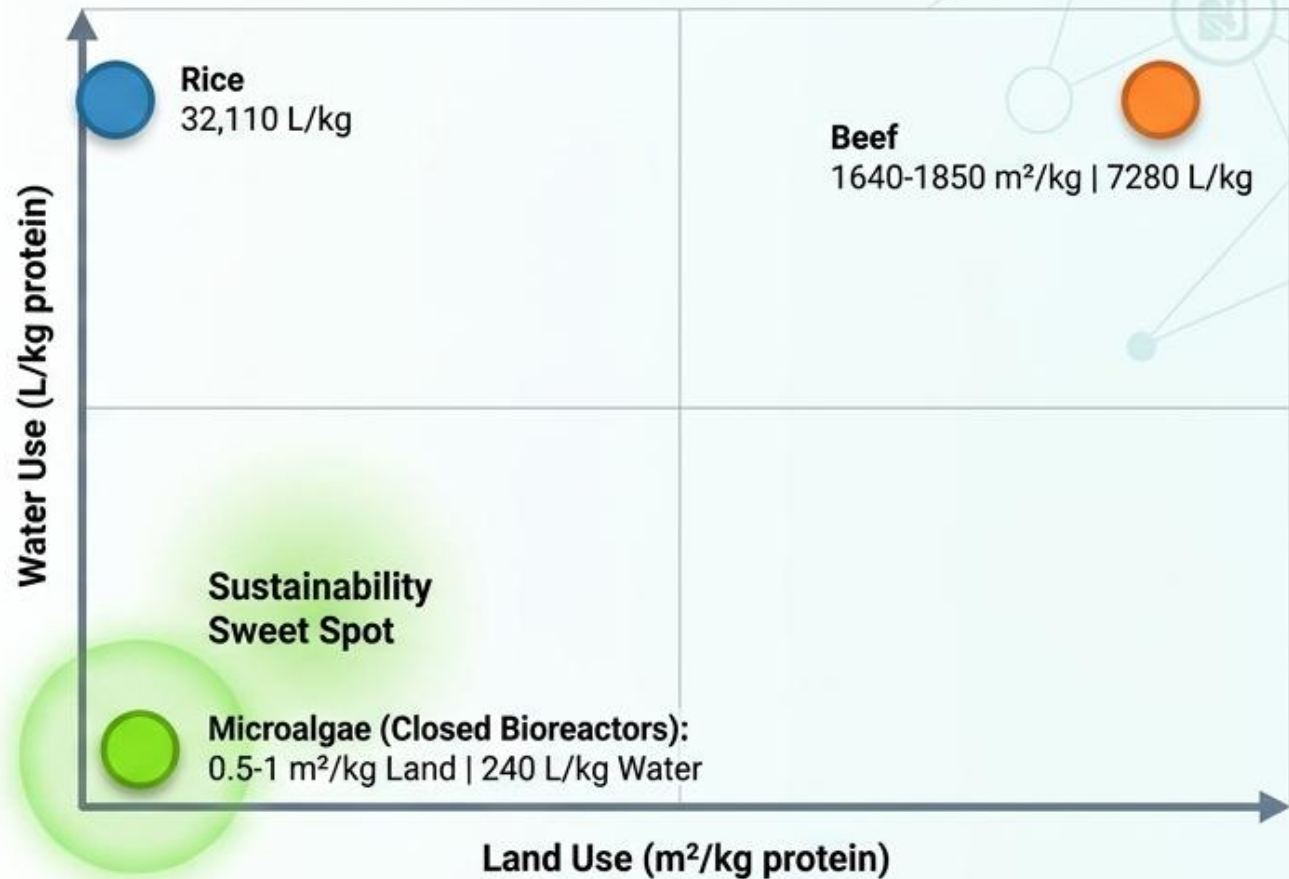
Shift toward animal-based proteins strains resources



Resource Depletion

Greenhouse gases, water scarcity, deforestation risks

Resource Efficiency Matrix

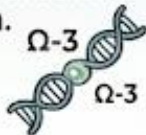


COMPREHENSIVE NUTRITIONAL COMPONENTS OF ALGAE

OMEGA-3 FATTY ACIDS



- High in **EPA & DHA** (essential fatty acids).
- Plant-based, sustainable source.
- Supports heart and brain health.



VITAMINS



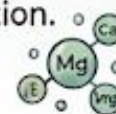
- Rich in **Vitamin B12** (rare in plants).
- Contains **Vitamin A** (as beta-carotene), **C**, and **E**.
- Key for immune system & metabolism.



MINERALS



- Significant source of **Iodine** (species-dependent).
- Contains **Iron**, **Calcium**, and **Magnesium**.
- Essential for thyroid and bone function.



ANTIOXIDANTS



- Contains pigments like **Astaxanthin**, **Phycocyanin**, and **Fucoxanthin**.
- Protects cells from oxidative stress.
- Promotes overall cellular health.



WARNINGS & CONSIDERATIONS



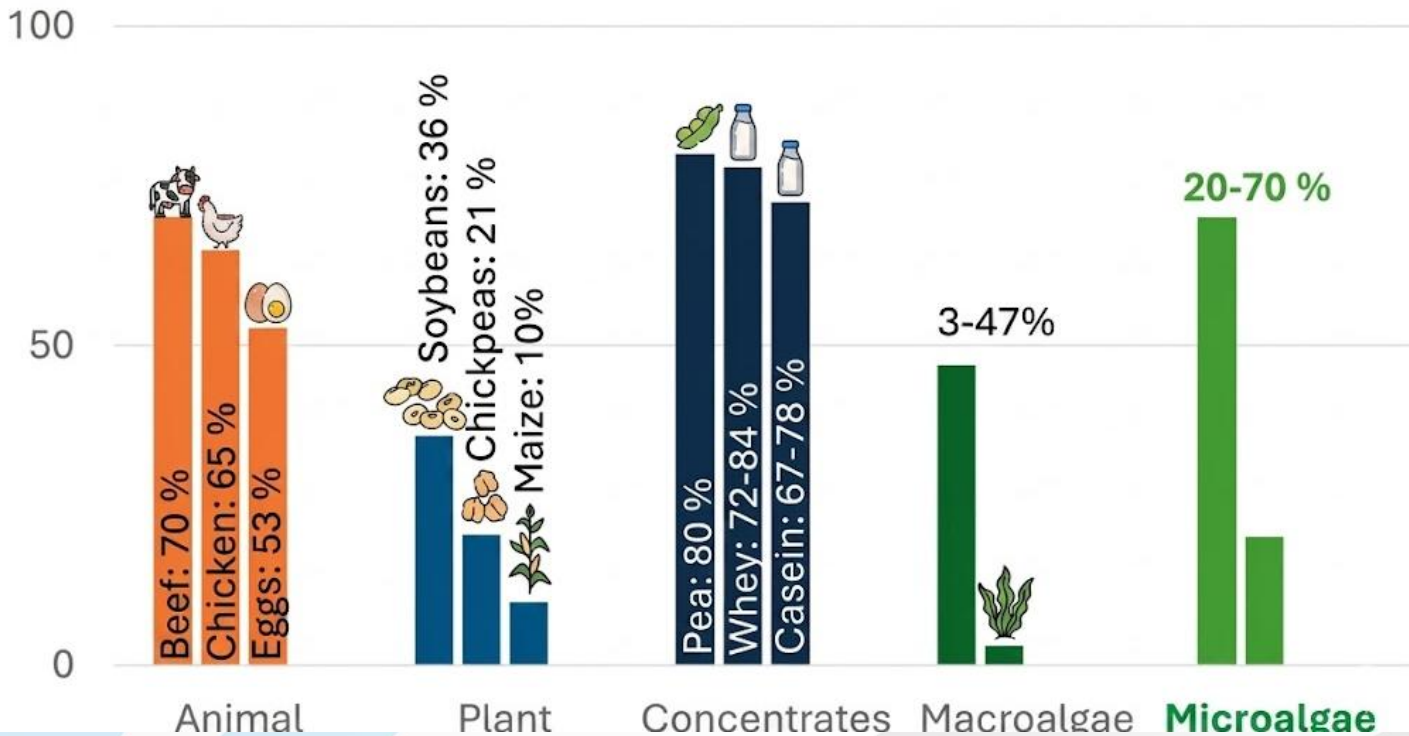
IODINE LEVELS: Can vary greatly by species; consult a doctor.

CONTAMINANTS: Ensure source is clean (e.g., heavy metals, microplastics) – source-dependent risk.



Relatively High Protein Content (20-70% DM)

Protein Content of Common Protein Sources
(% dry matter)



Comparable Protein Quality

Amino Acid Score > 1.00	PDCAAS 0.29 – 0.46	DIAAS NIL
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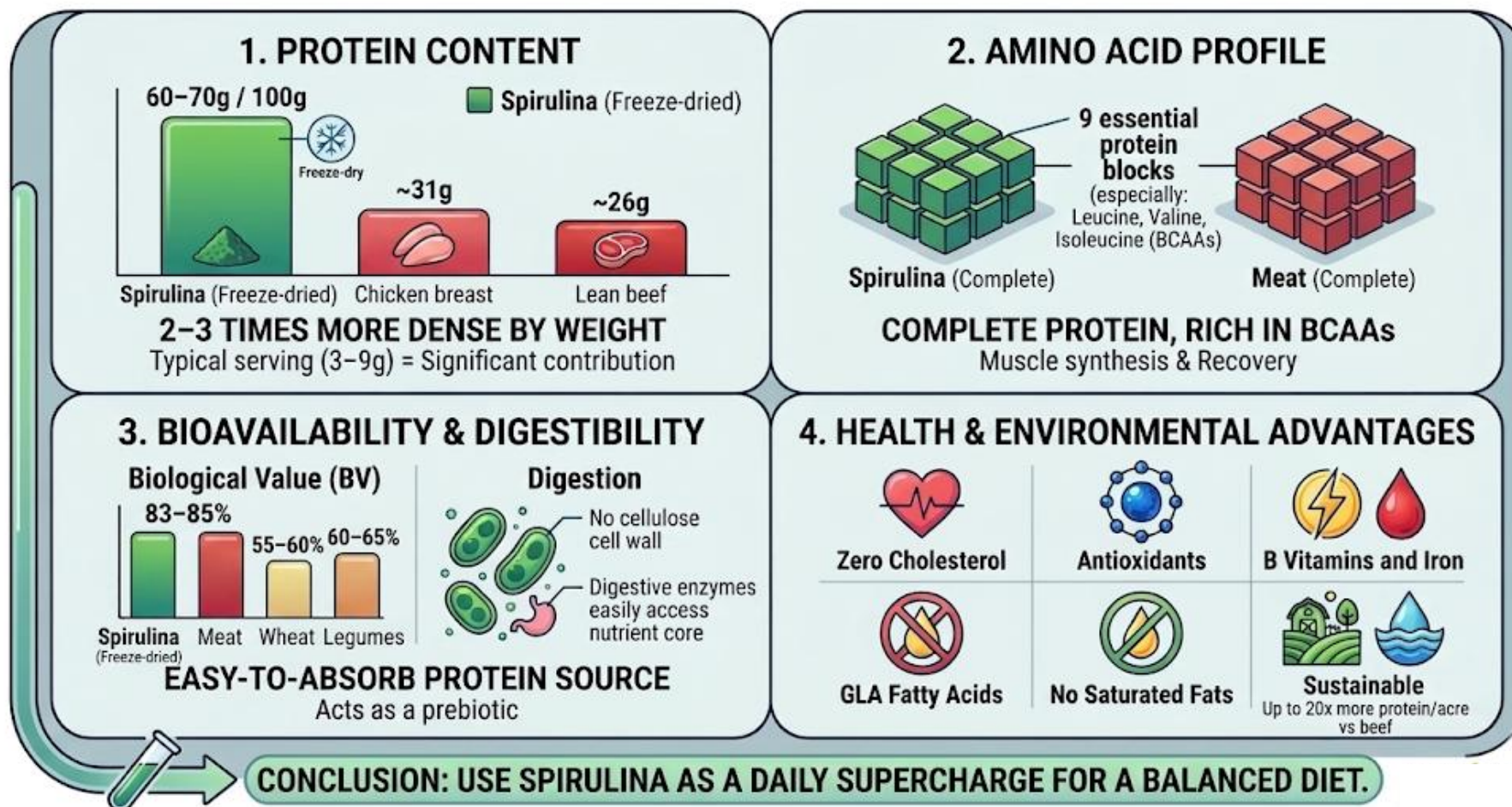
Low protein digestibility and bioaccessibility may be overcome through selecting species with weaker cell walls, or via processing methods

Amino Acid Score: comparison between the essential amino acid content of a protein and a human reference pattern, without considering digestibility

PDCAAS (Protein Digestibility-Corrected Amino Acid Score)

DIAAS (Digestible Indispensable Amino Acid Score)

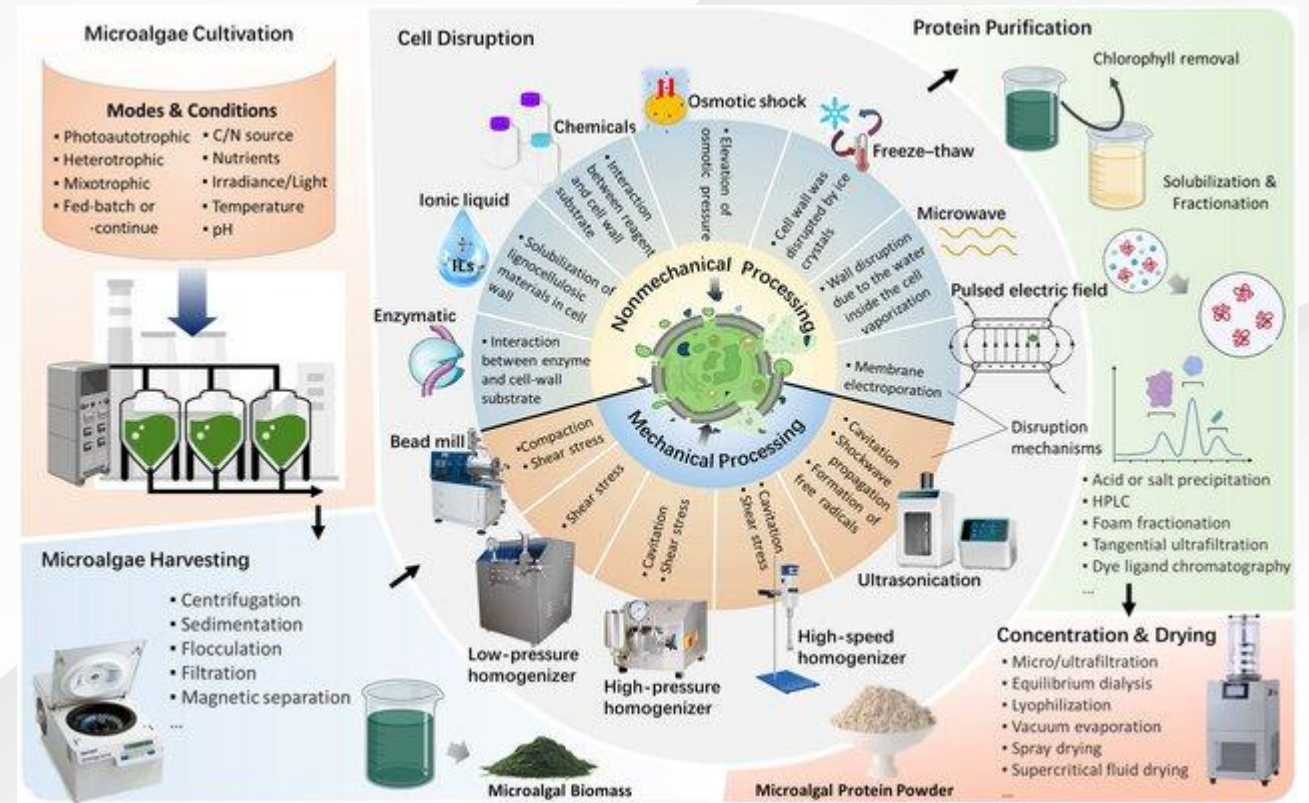
SPIRULINA VS MEAT: PROTEIN AND NUTRITIONAL COMPARISON



STATUS OF MICROALGAE AS NOVEL FOODS: KEY APPLICATIONS AND APPROVALS

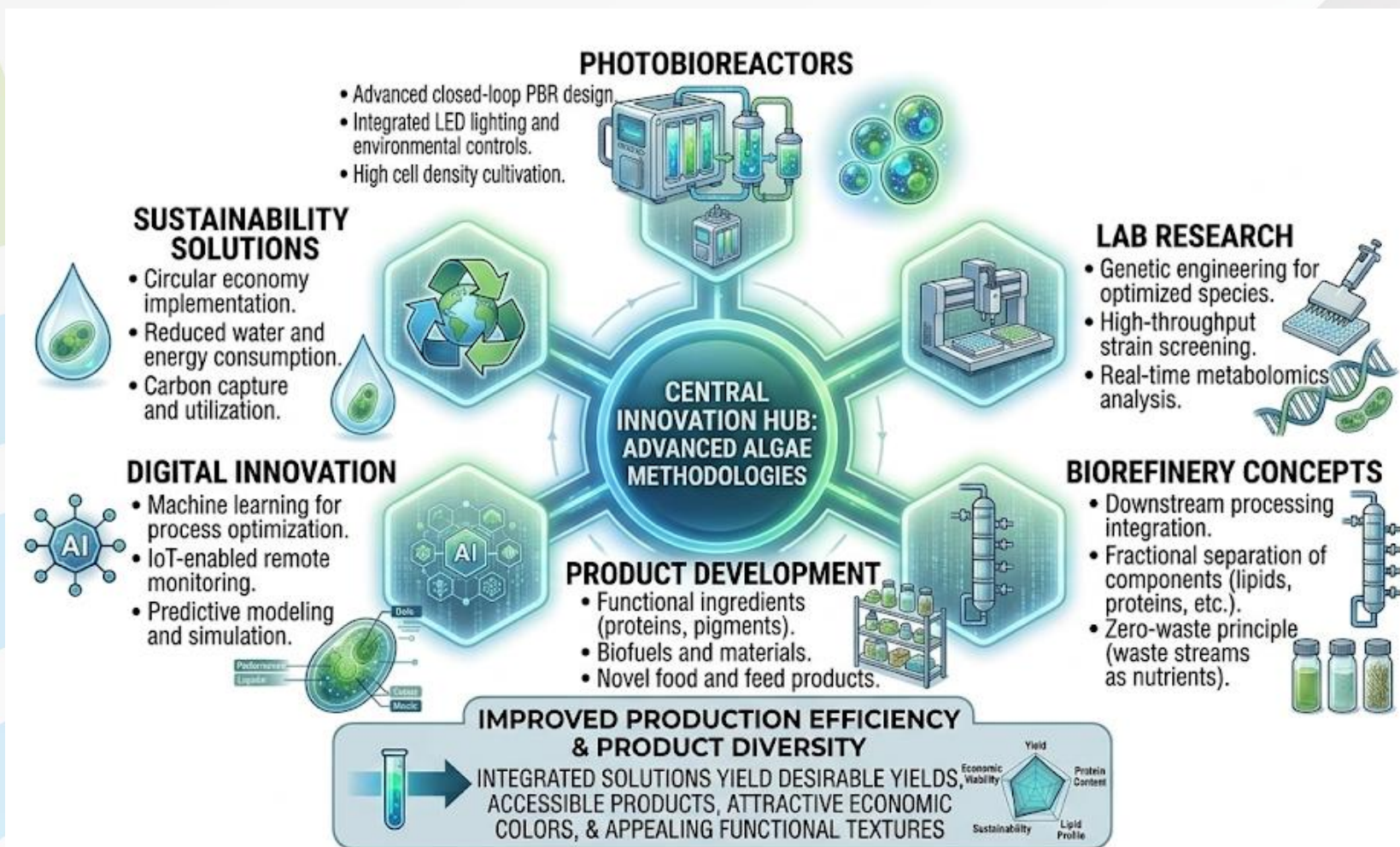
Microalgae Species	Year of Approval	Approved Usage	Examples of Application in Food	Function	References
<i>Chlorella vulgaris</i>	1997	Whole biomass	Cookies, Yogurt, processed cheese, gels	Colouring agent, technofunctional and nutritional	Batista et al., 2017; Falcão et al., 2023
<i>Arthrospira platensis</i> (Spirulina)	1997	Whole biomass	Dairy products, bread, extruded snacks, pasta	Techno-functional and nutritional properties, protein in particular	A. B. García et al., 2021; Casciano et al., 2021; Grahl et al., 2020
<i>Odontella aurita</i>	2002	Food ingredient	N/A	N/A	Mimouni et al., 2015
<i>Tetraselmis chui</i>	2014	Food ingredient	Wheat flour replacement	Increasing bioactivity of gluten-free bread	Qazi et al., 2022
<i>Dunaliella salina</i>	1997	Food Ingredient	Pasta, bread	Techno-functional and nutritional properties	Celente et al., 2022
<i>Haematococcus pluvialis</i>	2019	Food Ingredient	Cookies, Gel, vegetarian food gels, oil/water Emulsions	Techno-functional and nutritional properties, Antioxidant, PUFAs	Celente et al., 2023

THE TECHNOLOGICAL ROUTES AND THE MAIN USED TECHNIQUES TO PRODUCE MICROALGAL PROTEIN FOR FOOD APPLICATION



Yang et al., Food and Bioprocess Technology, 17(8), 1-33.

INNOVATION IN ALGAE PRODUCTION: NEXT-GEN METHODOLOGIES



Case Study: Phycoerythrin – The Future of Pink/Red Natural Dyes

Commercial Applications



Spirits & Soft Drinks
A clean-label, natural substitute for synthetic dyes in pink gin, tonic waters, and rosé wines.




Dairy
Utilised in yoghurts and fermented milks to visually replicate the appeal of red fruit flavours.




Confectionery
Leverages the psychological association between brilliant red/pink colours and perceived sweetness in sweets and baked goods.


Technical & Process Hurdles



Thermal Sensitivity Rapid protein degradation at temperatures > 30-40°C. Highly incompatible with traditional high-heat industrial pasteurisation.



Light Sensitivity Prone to loss of saturation and colour stability (photodegradation) upon prolonged exposure to UV or direct light.



Purification Costs Requires high expenditure (via ultrafiltration and chromatography) to achieve the analytical purity standards necessary for food-safe usage.

SENSORY CHALLENGES OF ALGAE-BASED FOODS

SMELL (ODOR)



- Intense, **strong**, or **unappealing** marine odor.
- Potential for 'fishy' or 'musty' notes.



TASTE (SENSE)



- Acquired or **overly saline** taste.
- Bitterness or astringency in certain species.



COLOR (APPEARANCE)



- Unusual, **deep green/blue-green** hue.
- Can be unappetizing or unexpected in Western diets.



TEXTURE (MOUTHFEEL)



- Potentially **slimy, tough, or gritty** mouthfeel.
- Varies by species and processing.



FINDINGS FROM SCIENTIFIC STUDIES



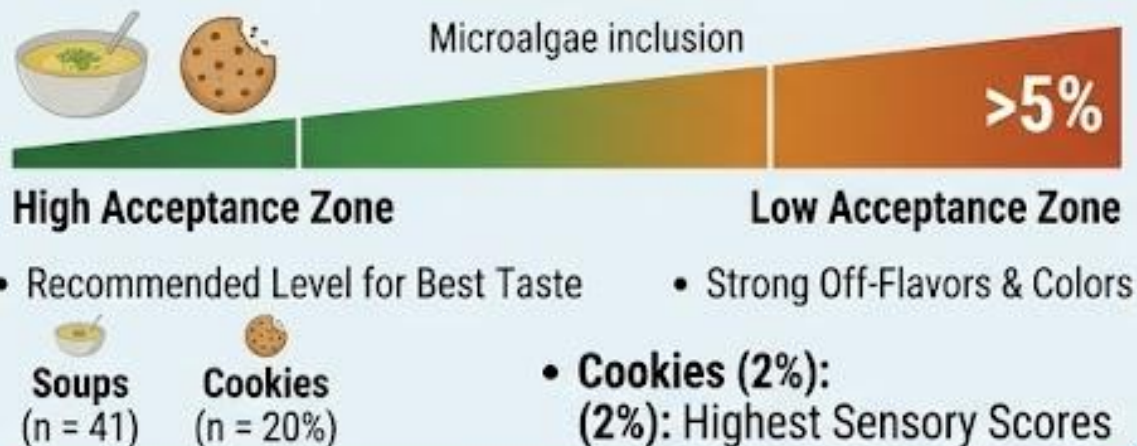
Studies show that sensory quality is a major factor in Western consumer acceptance.



INNOVATION IN FUNCTIONAL FOOD: MICROALGAE ACCEPTANCE & STRATEGIES IN THE EU



1. OPTIMISING SENSORY ACCEPTANCE



2. PRODUCT-SPECIFIC SUITABILITY

HIGH ACCEPTANCE
(BAKED GOODS)



- Bread, Pasta, and Crackers perform well

LOWER ACCEPTANCE
(DAIRY & FRESH)



- Challenges with Cagliate and Cream Cheese

3. CONSUMER PERSPECTIVE & AWARENESS

FAMILIAR & CONSCIOUS



- Interest in Health & Sustainability
- Higher Acceptance Cluster

UNAWARE
(MAJOR BARRIER)



- Lack of awareness is a major barrier (n < MA30)

4. STRATEGIES FOR IMPROVEMENT

Step 1.



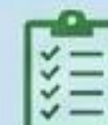
COMPETITIVE PRICING

Step 2



CLEAR COMMUNICATION

Step 3

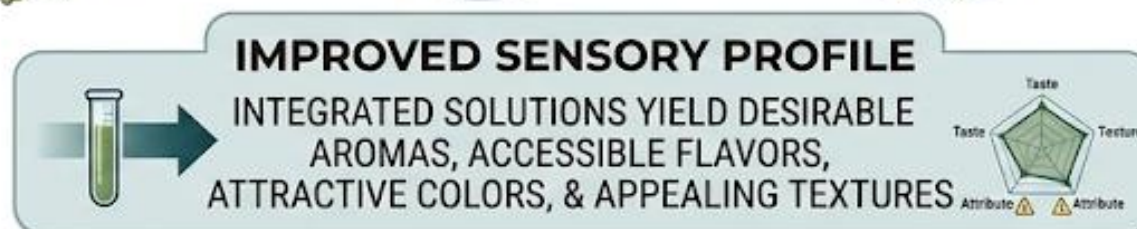
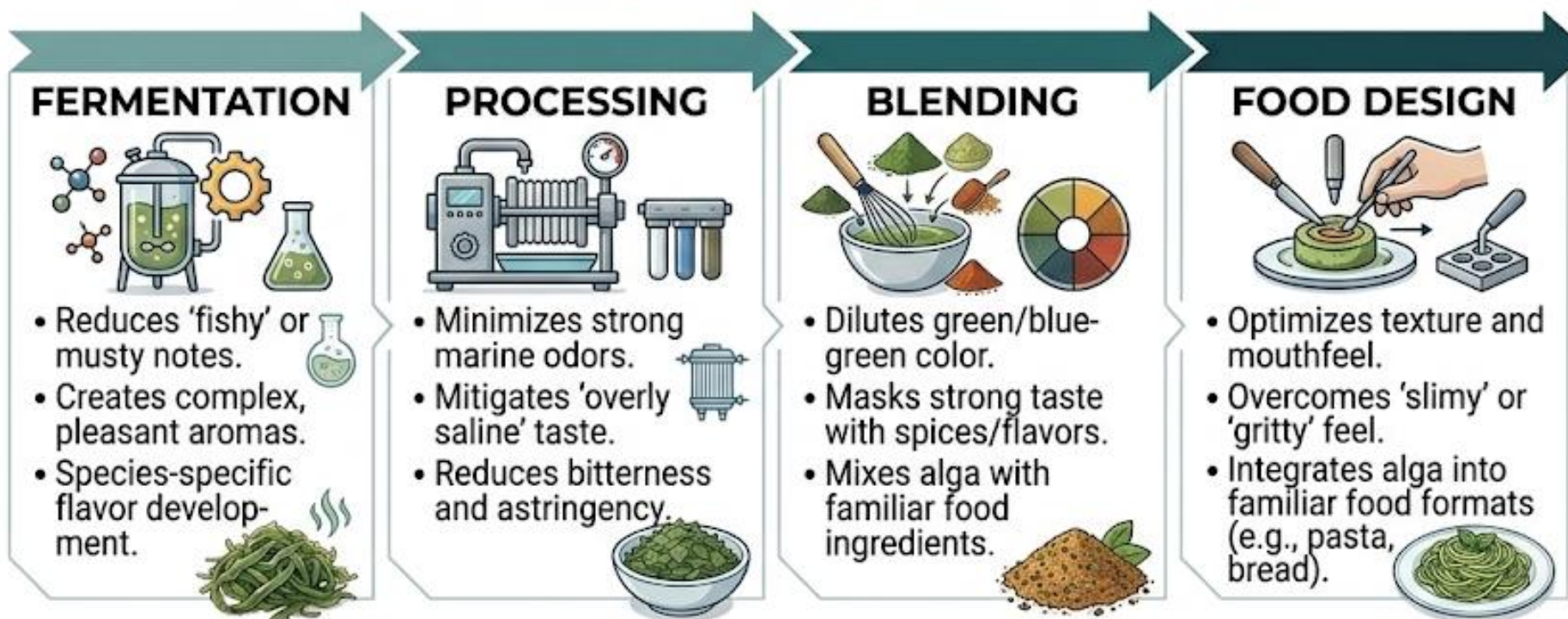


FRONT-OF-PACK LABELS

INCREASED WILLINGNESS TO PAY

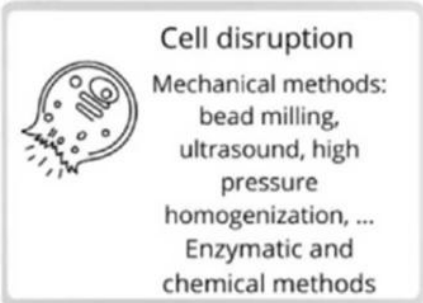
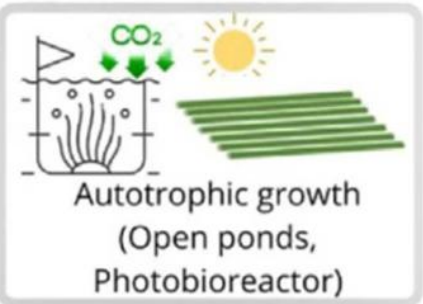


IMPROVING ALGAE SENSORY QUALITY: PATHWAYS TO ACCEPTANCE





LAB RESEARCH



Random DNA alteration and Controlled DNA manipulation

Adjustment of cultivation conditions
(Growth system & media optimization)

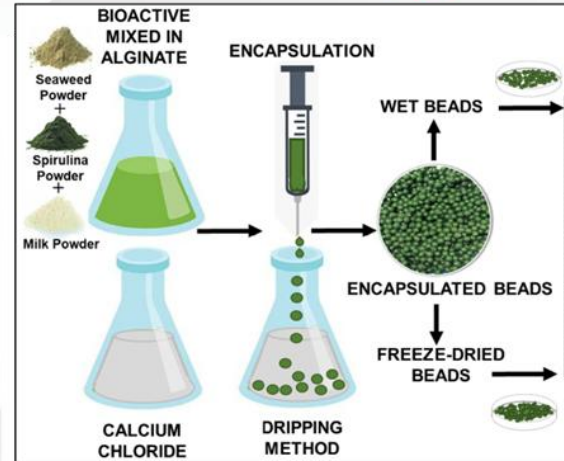
Downstream processing
(Cell disruption, drying & storage)

Extraction
(mechanical methods, solvents)

Bioprocessing
(enzymatic treatment)

Microencapsulation

Deodorization & decolorization



Abraham et al., (2021). *International journal of biological macromolecules*, 170, 540-548.



Schüler et al., *Front Bioeng Biotechnol* , 8 (2020)

Microalgae in healthy, sustainable and tasty food!

Nunes et al., (2023). *Current Opinion in Food Science*, 51, 101040.



ALGAE PROTEINS: MODERN FOOD APPLICATIONS

PLANT-BASED BURGERS

- Meat alternative with rich flavor profile.
- High protein content, mimicking meat.
- Lower environmental footprint.



ALGAE-BASED PASTA

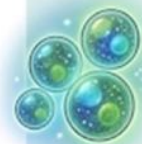
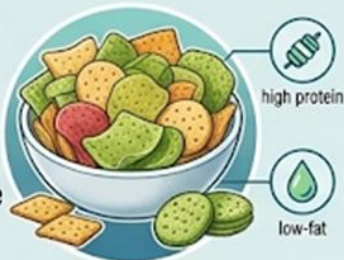
- Natural green color and high fiber.
- Nutrient-dense carbohydrate substitute.
- Boosted protein content for pasta meals.



Grahl et al., (2020). Food Quality and Preference, 84, 103933.

PROTEIN SNACKS

- Convenient, high-protein snack bars.
- Tasty protein chips and crackers.
- Sustainable alternative to conventional snacks.



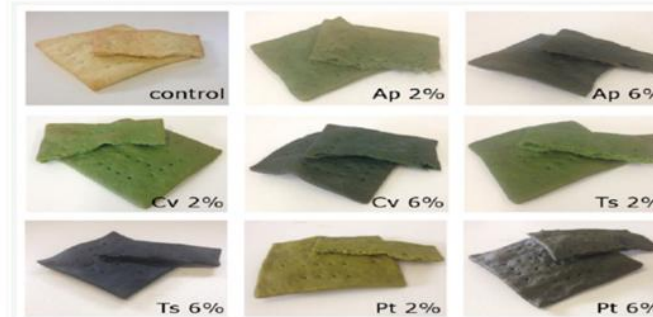
FUNCTIONAL FOODS

- Enriched beverages and meal replacements.
- High-protein bread and baked goods.
- Source of valuable antioxidants and minerals.



IMPROVED NUTRITIONAL VALUE & PRODUCT DIVERSITY

INTEGRATED SOLUTIONS YIELD DESIRABLE AROMAS, ACCESSIBLE PRODUCTS, ATTRACTIVE ECONOMIC COLORS, & APPEALING FUNCTIONAL TEXTURES



Ampofo & Abbey (2022) Foods, 11(12), 1744.

CHALLENGES IN ALGAE ADOPTION

PRODUCTION COST

- High initial capital and operating expenses.
- Specialized cultivation required.
- Process optimization needed.



REGULATORY FRAMEWORKS

- Stringent safety and novel food rules.
- Lengthy approval processes.
- Harmonization across regions.



SCALABILITY

- Commercial-scale production is limited.
- Significant tech transfer hurdles.
- Yield consistency at scale.



CONSUMER ACCEPTANCE

- Cultural and flavor barriers.
- Misperception of algae products.
- Need for desirable food formats.



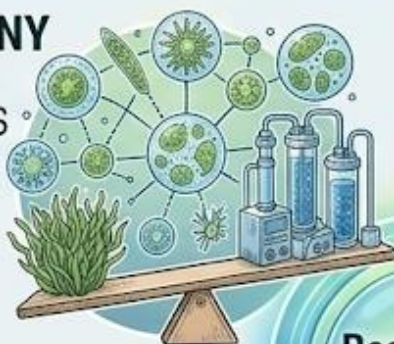
OVERCOMING KEY HURDLES
TO REALIZE THE POTENTIAL
OF ALGAE-BASED FOODS



ALGAE: KEY TO A SUSTAINABLE & RESILIENT FOOD FUTURE

ECOSYSTEM HARMONY

- RESTORING HEALTHY MARINE ECOSYSTEMS
- ENHANCING BIODIVERSITY
- INTEGRATING CULTIVATION



CIRCULAR ECONOMY

- MINIMIZING RESOURCE WASTE
- VALORIZING BYPRODUCTS
- ACHIEVING A CLOSED-LOOP SYSTEM



Resilience Platform

SEA TO FORK

- ENSURING GLOBAL FOOD SECURITY
- FOSTERING CONSUMER RESILIENCE
- DEVELOPING DESIRABLE FOODS



FUTURE INNOVATION

- DRIVING TECHNOLOGICAL ADVANCES
- ACCELERATING NOVEL FOOD DEVELOPMENT
- SECURING CONSUMER ACCEPTANCE



A BALANCED APPROACH FOR LONG-TERM SUSTAINABILITY





Thank you very much for your attention!

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