SCIENCE AND TECHNOLOGY OPPORTUNITIES IN THE ALGAE SECTOR OF INTEREST FOR LARGE COMPANIES

Daniel Twum-Ampofo

Ph.D.

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Contents

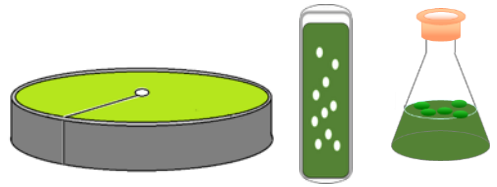
Algae Industry?

The algae industry includes the cultivation and sales of microalgae and macroalgae for a range of industrial and consumer uses [1].

The algae sector is emerging as a critical pillar of the global bioeconomy

Driven by increasing demand for nutritionally rich, sustainable, and bio-based alternatives [2]

Supports resource efficiency, circular economy models, and climate goals [3][4]



Algae Cultivation

Harvesting

Drying, extraction

Processing

Oils, proteins, carbs, biomass

Products

Payment/ Revenue

Sold as

Distributor

Food/Feed: cosmetics, fuel, etc.

Energy companies, health stores, feed companies and cosmetics and biomaterials companies

Or Retail to

Cont'd

- ✓ The algae products market is growing gradually
- ✓ the algae products market is projected to reach USD 8.07 billion by 2030 from USD 5.87 billion in 2025 at a CAGR of 6.6% from 2025 to 2030 MarketsandMarkets(Nov,2025) [5].
- ✓ Large corporations are increasingly recognizing the value of algae and are seeking ways to integrate it into their products and markets
- ✓ However, the algae the industry has not fully yet realized its potential
- ✓ Strengthening industry positioning is essential to deliver scalable solutions and meet growing corporate demand.

Algae: Types, Cultivation, Benefits, Risks, and Environmental Impacts

Algae?

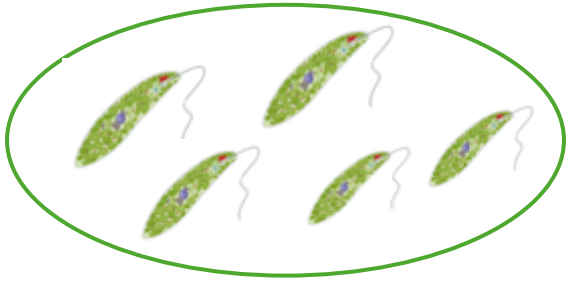
Algae are a diverse group of photosynthetic organisms that include both microalgae and macroalgae. They may be unicellular or multicellular and grow rapidly by using sunlight, carbon dioxide (CO_2), water, and nutrients to produce biomass [6]

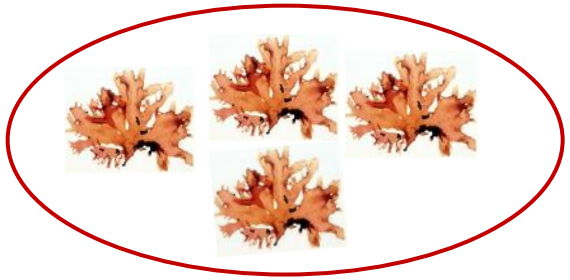
The biomass is useful as

food, feed, biofuels and high-value products [7]

Single-cell microalga

Macroalgae, larger & visible to the naked eye





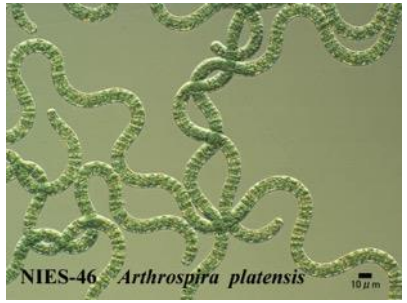
Multiply into many cells

Form a High-value Algal Biomass

High value = high economic, functional, or commercial importance [7]

Types - Microalgae

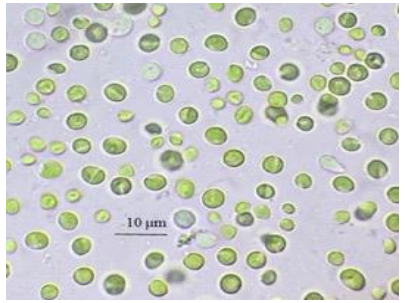
The most prominent species include



[8]

Arthrospira platensis
Spirulina

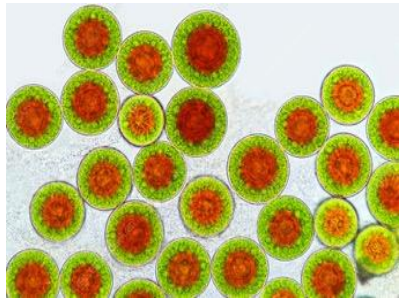
High protein content/food colorant (phycocyanin)



[9]

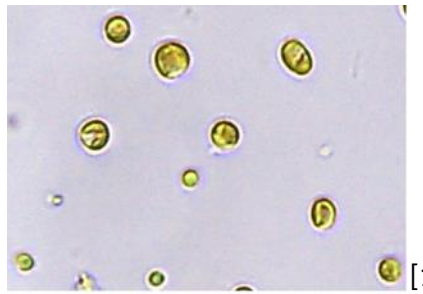
Chlorella vulgaris

Health food/pigments (lutein)


[10]

Haematococcus pluvialis

Source of Astaxanthin


[11]

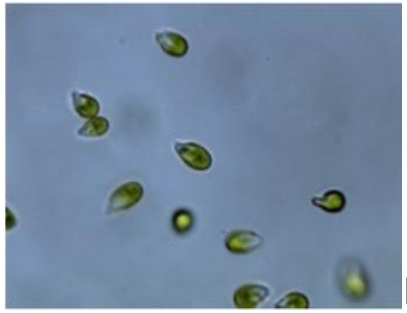
Isochrysis galbana

Fish feed/ omega 3 fatty acids

[8]

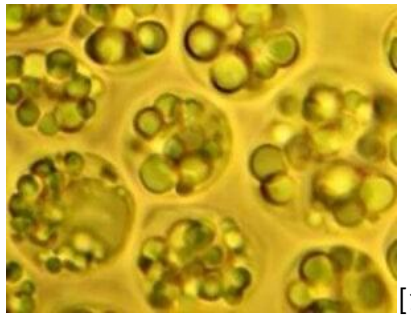
Euglena gracilis

Source of beta-glucans


[12]

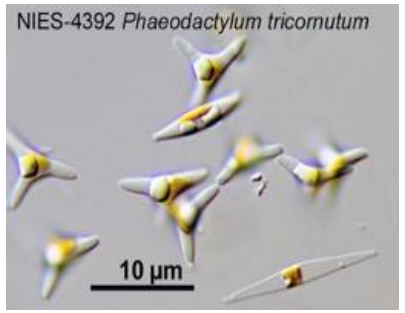
Dunaliella salina

High accumulation of beta-carotene (antioxidant)


[13]

Schizochytrium sp

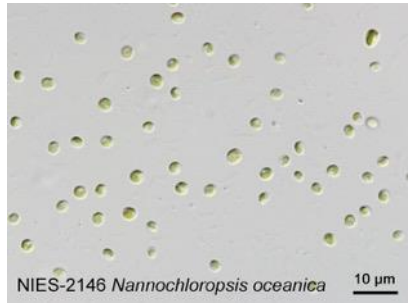
High accumulation of DHA (infant formula)



[8]

Phaeodactylum tricornutum

Source of EPA



[8]

Nannochloropsis oceanica

High accumulation of lipids and omega 3s

[8]

Galderia sulphuraria

High bioremediation ability

Botrycococcus. *Tetraselmis sp.*

Types - Macroalgae

The most prominent species include

Nori (Pyropia/Porphyra sp)

Used as food (sushi) [14]

Giant kelp (Macrocystis pyrifera)

Primary source of alginate [15]

Sea lettuce (Ulva lactuca)

Source of ulvans and good bioremediation potential [16]

Kombu (Saccharina japonica)

Source of food and umami flavor (glutamic acid0 [17]

Wakame (Undaria pinnatifia)

Rich in fiber, minerals and proteins [18]

Irish Moss (Chondrus crispus)

High carrageenan content [19]

Dulse (Palmaria palmata)

Source of proteins and vitamins [20]

Gulfweed (Sargassum spp.)

Largely accumulated in coastal regions [21]

Bladderwrack (Fucus vesiculosus)

Source of iodine and feed [22]

Gracilaria spp. (Gracilaria gracilis)

High agar content [23]

How to grow or cultivate algae

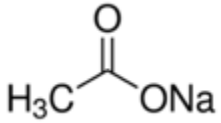
To grow algae, you need:

H_2O Water

light Light source

CO_2 Carbon dioxide

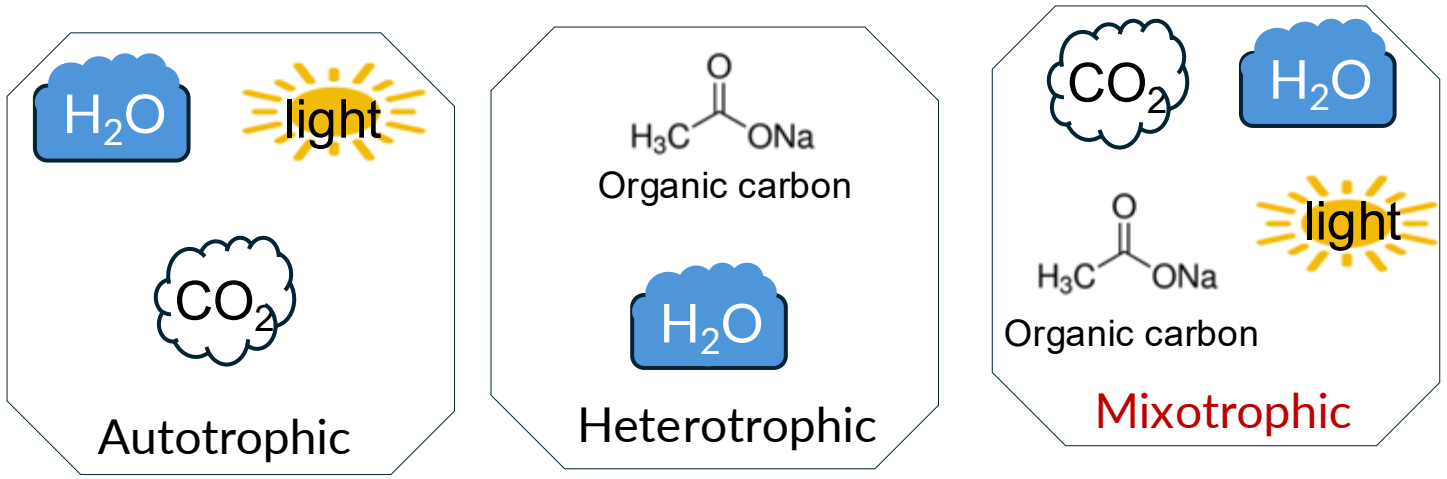
Nutrients Nitrogen, phosphorus, trace metals: Fe, Mn, Zn, Cu, Mo, K, S, Ca



Organic carbon Carbon sources: acetate, glucose, ethanol

Other parameters: pH, temperature, CO_2 concentration

When you combine these conditions;



We get different growth modes

Based on all these **inputs**, several artificial media have been developed for optimal microalgae growth.

They include:

C-medium
HUT-medium
AF-6 medium
Bold Basal medium
BG-11 medium
TAP-medium
F/2 medium
Zarrouk's medium

[24] [25]

Algae – Cultivation Systems

Microalgae

Open cultivation systems

Circular pond

Raceway pond

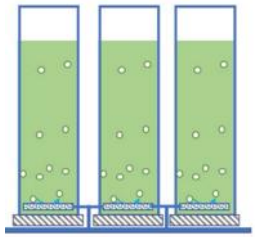
Unstirred pond

[26]

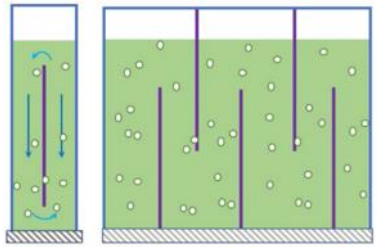
Closed cultivation systems

Photobioreactors

Horizontal tubular

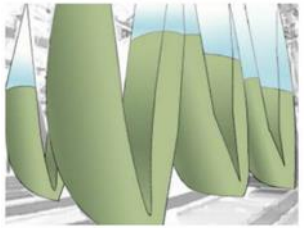


Bubble column



Flat panel

Airlift



Plastic-bag

[27]

Laboratory cultivation systems

Flasks

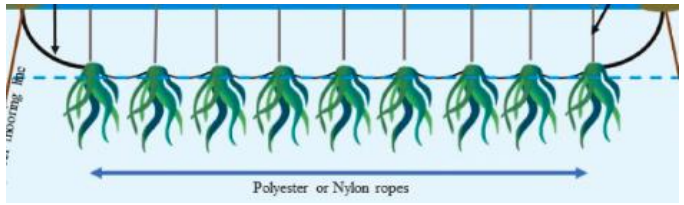
Small reactors

Macroalgae

Seaweed cultivation systems

Hatchery

At Sea cultivation



Long line cultivation

[28]

[29] Seaweed cultivation

Algae – Raw materials

Microalgae

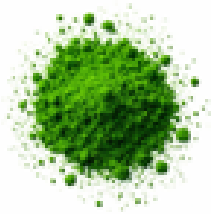
Dried algal powder

Crude lipids

Proteins

Carbohydrates

Pigments



Chlorophyll

Lutein

Astaxanthin

Phycocyanin

β-carotene

Omega 3 oils

Starch, βeta-glucans, vitamins, minerals

Macroalgae (Seaweed)

Whole biomass

Proteins

Structural polysaccharides

Alginate

Agar

Carrageenan

Ulvan

Fucoidan

Storage polysaccharides

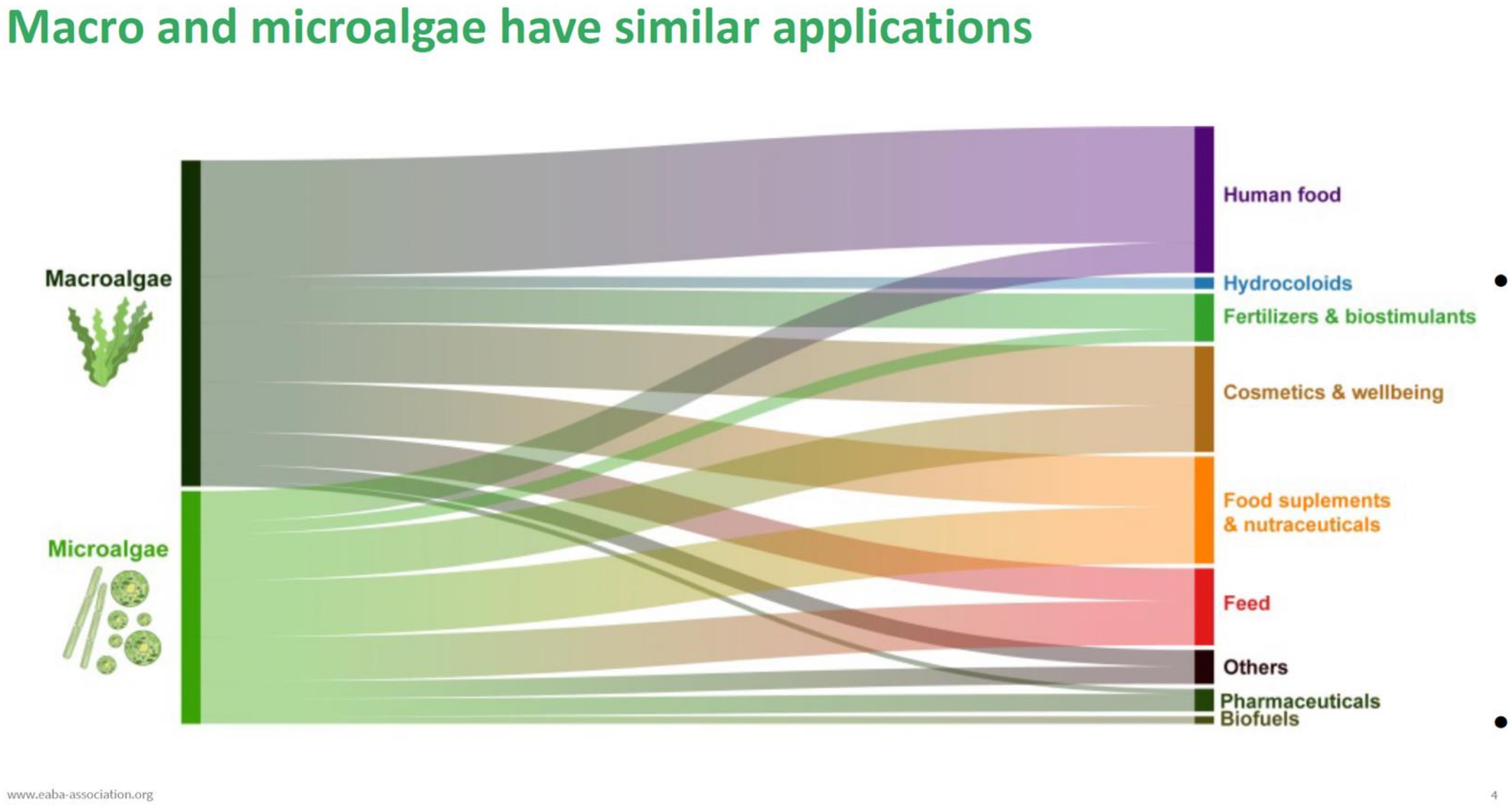
Laminarin

Minerals
Iodine
Potassium
Calcium
Magnesium

Pigments
Fucoxanthin
Phycoerythrin
Chlorophylls

Phenolic compounds
Phlorotannins

Algae - Benefits



Algae - Benefits


WASTEWATER


BIOFUEL

SOIL

HEALTH

FEED

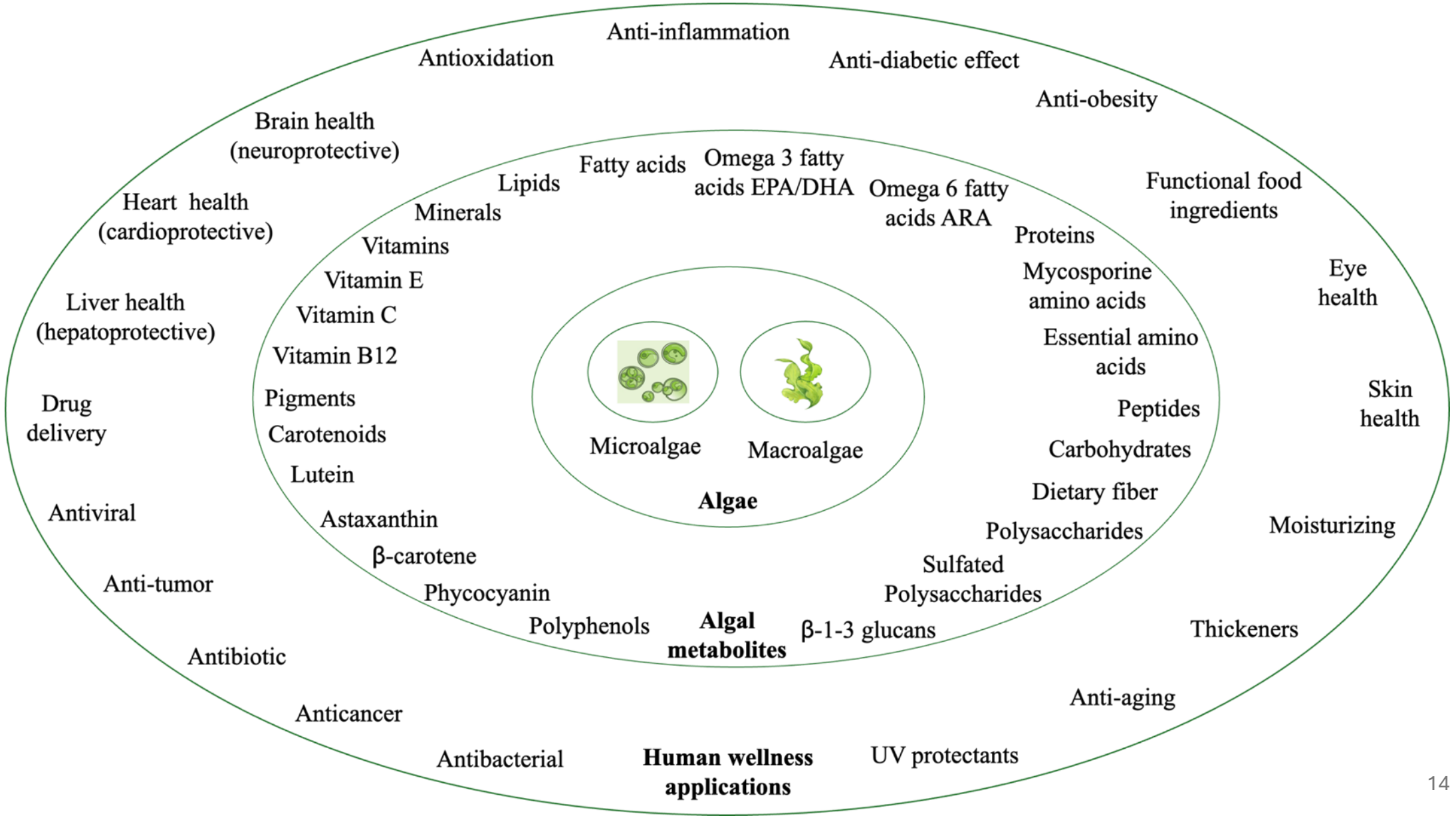
COSMETICS

FOOD

OTHERS

Vitor Verdelho Viera
www.eaba-association.org [10] [11] ユーグレナ Euglena Japan [12]

Algal Metabolites for promoting human health



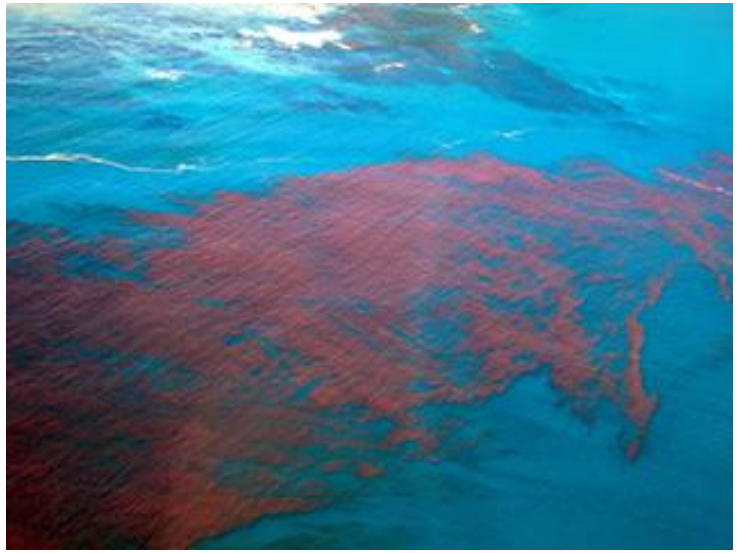
Vitor Verdelho Viera

Algae – Risks and Environmental Impacts

Algae are beneficial to us as food feed, and medicines

However, a few types of algae produce toxins.

When the toxin producing algae grow excessively in a body of water it is called harmful algal bloom



Harmful algal bloom

Sargassum bloom

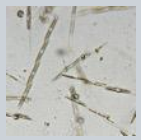
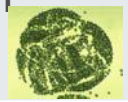
Eutrophication

Harmful algal blooms (HABs) can damage the environment by depleting oxygen in the water, which can kill fish and other living creatures. Some HABs are associated with serious health effects, as explained in the next slide.

[31]

Algae – Risks and Environmental Impacts

[31]

Organism	Water type	Color	Toxins	Health effects
Alexandrium sp.	Salt 	Red or brown	Saxitoxins	Gastrointestinal (nausea, vomiting), and neurological (a floating sensation, headache, or muscle weakness)
Cyanobacteria (Cylindrospermopsis sp)	Fresh 	Blue-green	Cylindrospermopsin	Nausea, vomiting, diarrhea, abdominal tenderness, pain, or acute liver failure
Gambierdiscus	Salt 	Orange	Ciguatoxins	Nausea, vomiting, diarrhea, or stomach pain
Karenia brevis	Salt 	Red	Brevetoxins	1.Gastrointestinal illness, muscle cramps, seizures, paralysis 2.Respiratory problems, especially for asthmatics
Pseudo-nitzschia	Salt 	Red or brown	Domoic acid	Vomiting, head weaving, nausea, seizures, diarrhea and abdominal cramps, bulging eyes, or headache
Microcystis	Fresh 	Blue-green	Microcystin	Gastrointestinal illness, liver damage

Global Companies Investing in Algal Biomass

Food and Feed related

- Onavita omega-3 algal DHA and Almega EPA
- Food ingredientes with Algenuity
- Food ingredientes with Corbion
- Omega-3 aquafeeds with Veramaris
- Precision fermentation Omega-3 for baby milk
- Nutritional lipids Veramaris Omega-3 for feeds
- Omega-3 from algae Veramaris partnership
- Fucoidan, omega oils and natural beta-carotene
- Red algae-based seaflour and

- Microalgae based cosmetics
- Carrageenan and alginates from seaweed
- Algae control and algae fertilizers
- Beta-glucans for animal feeds
- Seaweed for cow feed aiming methane reduction
- Microalgae cultivation using for next generation biofuels
- Algae cultivation and processing for aviation fuel
- Microalgal bioremediation to clean polluted water

Non-food related

18 examples

Food and Feed related

Omega-3 aquafeeds with Veramaris

Carrageenan and Alginates

Onavita Algal DHA and Almega EPA, the new blends were created in collaboration with Qualitas Health 2019

Omega-3 from algae Veramaris partnership

Food ingredients with Algenuity

red algae-based seaflour and

Seaweed for cow feed methane reduction

Precision fermentation Omega-3 for baby milk

Beta-glucans Animal feeds

Nutritional lipids Veramaris omega-3 for feeds

Food ingredients with Corbion

Fucoidan, omega oils and natural beta-carotene

Non-food related

Microalgae based cosmetics

Algae control and algae fertilizers

microalgae cultivation using for next generation biofuels

microalgal bioremediation to clean polluted water

algae cultivation and processing for aviation fuel

Japanese companies investing in Algal biomass

CHITOSE

DIC Color & Comfort

Eat Well, Live Well.
AJINOMOTO

NEDO New Energy and Industrial Technology Development Organization

ユーグレナ
いきる、たのしむ、サステナブる。

algal bio

galdieria

JST Empowering Science, Inspiring Futures
Japan Science and Technology Agency

National Institute for Environmental Studies, Japan

ICRE

Companies with Algae-Based products generating $100M Annually

Macroalgae

CEAMSA — Algae based carrageenans, pectins, fibres, alginates

syngenta Biologicals — Seaweed extracts as agriculture biostimulans and fertilisers

Pharma Mar — Algae-derived bioactive Compounds with anti-cancer activity

SEPPIC Biotechmarine — Algae based Omega-3 Oils (for human consumption)

FAVINI — Algae based paper

CPKelco A HUBER COMPANY — Red seaweed for carrageenan and other hydrocolloids

GELITA Improving Quality of Life — Gelatin and collagen

Microalgae

FERMENTATION

veramaris A JOINT VENTURE OF DSM AND EVONIK — Algae oil rich in Omega-3 EPA + DHA from natural marine algae to replace fish oil

dic Color & Comfort — Larger spirulina and phycocyanin producers

Fuji Chemical Industries Co., Ltd.

35 YEARS of RESEARCH & INNOVATION AstaReal Be you, Just healthier — Larger astaxanthin producer from microalgae

FERMENTATION

Corbion — Algae-based ingredientes providing nutritional benefits and omega-3 oils for aquafeeds

aqualia — Algae for urban wastewater treatment

HUVEPHARMA HuveNutra — Huve Nutraceuticals for the production of omega-3 algal oils

FERMENTATION

Macroalgae

YSLAB MARINE BIOTECHNOLOGY

SCIENCE & MER PARIS

Cosmetics

PHYTOMER

Cosmetics

Agrimer ALGUES MARINES

ALGEA The Arctic Company

Algaia

Hydrocolloids

North Seaweed

JRS Fibers for Life.

olmix Group

Feed ingredints

Biostimulants

VAL

LESSONIA cosmetics + ingredients

HISPANAGAR

Hydrocolloids

DONEGAL BAY SEAVEG

The Seaweed Company

whole biomass
- food
- feed

Microalgae

5 ansqu'onsème Satmar

Aquafeeds

BLUEBIOTECH

nutrition Solabia group

algalif

Nutraceuticals

Pigments
- astaxanthin

Lonza

Omega-3
- DHA, EPA

Chlostanin 株式会社日健総本社

Pigments
- beta-carotene

Companies with Algae-Based products generating $10M Annually

Macroalgae

DUPONT

FMC An Agricultural Sciences Company

CPKelco A HUBER COMPANY

hydrocolloids

Cargill Helping the world thrive

Acadian Seaplants

algae biomass for food and feed

Microalgae

Reed Mariculture ENSURING HATCHERY SUCCESS™

heliae

FERMENTATION

KEMIN

POWER Organics

KLAMATH ALGAE PRODUCTS – E3live

NEW EARTH

35 YEARS OF RESEARCH INNOVATION AstaReal Be you, Just healthier

Cyanotech

iwi

EARTHRISE a member of the DIC group dic Color & Comfort

Aquafeeds

Agriculture biostimulants

Feed ingredients

Nutraceuticals
• proteins for food

Aphanizomenon

Spirulina

Pigments
• astaxanthin

Nannochlosopsis
• *EPA. proteins*

Spirulina

TRITON ALGAE INNOVATIONS

FERMENTATION

ZIVO BIOSCIENCE

LUMEN BIOSCIENCE

FERMENTATION

Checkerspot®

Oleic-Palmitic-Oleic oil

FERMENTATION

Macroalgae

Collected seaweed for food

Frozen, salted or dried seaweed for food as Wakame and Royal Kombu

Seaweed as a source of vital nutrients for their crops and their livestock

Compounds, extracted from renewable marine and terrestrial resources, to reduce stress in crops, animals and humans

Dried and milled *Ascophyllum* and *Laminaria*

Microalgae

Pigments
- astaxanthin

Phycocyanin

Omega-3

Fucoxanthin

FERMENTATION

Food products that provide inspiration for future innovation in the algae sector

Innovation

Marketing

Adaptation

Strategy

Sustainability

1. Chiquita (Banana Industry):

1. Early market dominance and vertical integration
2. Establishment of a strong brand identity
3. Aggressive global expansion
4. Innovative transportation methods
5. Ability to navigate and influence political landscapes

2. Nestlé (Instant Coffee):

1. Pioneering role in instant coffee technology
2. Effective global branding
3. Diverse product portfolio
4. Strategic partnerships and acquisitions
5. Ability to adapt to local tastes

3. Danone (Yogurt Products):

1. Innovative product development
2. Health and wellness focus
3. Strategic market expansion with local adaptation
4. Sustainable practices
5. Strategic acquisitions and partnerships

4. Unilever (Knorr Brand):

1. Diverse and innovative product range
2. Adaptation to local tastes
3. Prioritizing sustainability
4. Strategic marketing initiatives
5. Globally efficient distribution and supply chain

5. McDonald's (Chicken McNuggets):

1. Innovative product development
2. Consistent quality and standardization
3. Iconic branding and marketing
4. Adaptation to local tastes
5. Efficient supply chain

1. Mondelez (Biscuits and Cookies):

1. Iconic brands and product portfolio
2. Effective global branding and marketing
3. Cultural adaptation
4. Continuous innovation
5. Efficient supply chain with global distribution

2. Nissin (Noodle Industry):

1. Pioneering instant noodle innovation
2. Effective global branding
3. Cultural adaptation
4. Commitment to product diversification
5. Supply chain efficiency

3. Kellogg's (Corn Flakes):

1. Innovative product development
2. Effective branding and marketing
3. Cultural adaptation
4. Robust supply chain
5. Alignment with wellness trends

4. Raízen (Sugar Cane Production):

1. Large-scale integrated supply chain
2. Diversification into ethanol production
3. Commitment to sustainable agriculture
4. Technological innovation
5. Robust global market presence with strategic partnerships

5. Grupo Bimbo (Bread):

1. Strategic acquisitions
2. Diverse brand portfolio with local adaptation
3. Focus on quality and consistency
4. Innovation in product development
5. Commitment to sustainability

Food products that are an interesting inspiration for the future development of the algae sector

Banana - Chiquita

Yoghurt - Danone

Instant Coffee - Nestle

Knorr – Unilever

Corn flakes – Kellogg's

Noodles - Nissin

Sugarcane - Raizen

Nuggets – McDonald's

Biscuits – Mondelez

Bread - Bimbo

Algae sector 4 McDonalds

- algae extracts with film-forming properties could be used as coatings for nuggets,
- algal flours or proteins can be incorporated into batter formulations for coating nuggets
- algal polysaccharides or proteins can serve as natural binding agents in nugget formulation
- extracts containing natural flavors or umami compounds as seasoning blends for nuggets

polysacharides

proteins

Algae sector 4 Unilever

- algae extracts with natural umami compounds can be incorporated into Knorr-type products
- algal polysaccharides and proteins can serve as natural thickeners and stabilizers
- natural pigments from algae, such as spirulina or chlorella, used as clean label natural colors
- algae extracts containing specific flavors and aroma compounds forvseasonings

polysacharides

pigments proteins

Algae sector 4 Nestle

- algae-Infused coffee beverages rich in antioxidants or omega-3 fatty acids
- algae-based fertilizers and soil conditioners can contribute to sustainable coffee
- biodegradable coffee pods with algae-based
- eco-friendly and biodegradable coffee packaging with algae based materials

omega-3

fibers proteins

Algae sector 4 Danone

- omega-3 from microalgae as fortifying agents to enhance the nutritional profile of
- natural pigments from algae as couloring agents (phycocyanin, carotenouds, xanthophylls)
- algal polysaccharides and proteins as plant-based stabilizers, thickeners and emulsifiers
- algae based packaging materials

omega-3

polysacharides pigments

Algae sector 4 Chiquita

- biofertilizers and biostimulants from algae
- algae extracts foor pest control and soil amendment
- biodegradable bioplastics from algae for crop management and packaging
- algaebased wax for banana cosmetic commercial setup

proteins

fibers polysacharides

Algae sector 4 Bimbo
- algae-derived food colors (spirulina or *Chlorella*, produces natural pigments)
- algae-based omega-3 fortification:
- algae-based polysaccharides and proteins as thickeners and emulsifiers
- algae based fibers

polysacharides

pigments omega-3

Algae sector 4 Raizen
- algae based biostimulants
- algae based biofertilizeres
- microalgae based soil ammendment conditioners
- selective wastewater treatment with algae and algae production is sugar wastes

proteins

polysacharides

Algae sector 4 Nissin
- algae-based fortifiers, such as omega-3 fatty acids
- algae-derived colors: Natural pigments from algae, like spirulina or chlorella
- algae-based Thickeners and Stabilizers: Algal polysaccharides and proteins
- infused seasonings to enhance flavor as algal compounds with umami or savory characteristics

omega-3 proteins

fibers pigments

Algae sector 4 Kelloggss
- algae-based fortifiers such as omega-3 fatty acids
- algae-derived colors as natural pigments from algae, like spirulina or chlorella
- algae-based polysaccharides and proteins as thickeners and stabilizers
- algae-based sustainable biodegradable packaging materials

omega-3

pigments polysacharides

Algae sector 4 Mondelezs
- algae-based fortifiers such as omega-3 fatty acids
- algae-derived colors as natural pigments from algae, like spirulina or *Chlorella*
- algae-based polysaccharides and proteins as thickeners and stabilizers
- algae-based sustainable biodegradable packaging materials

omega-3 polysacharides

pigments

Conclusions

Conclusions

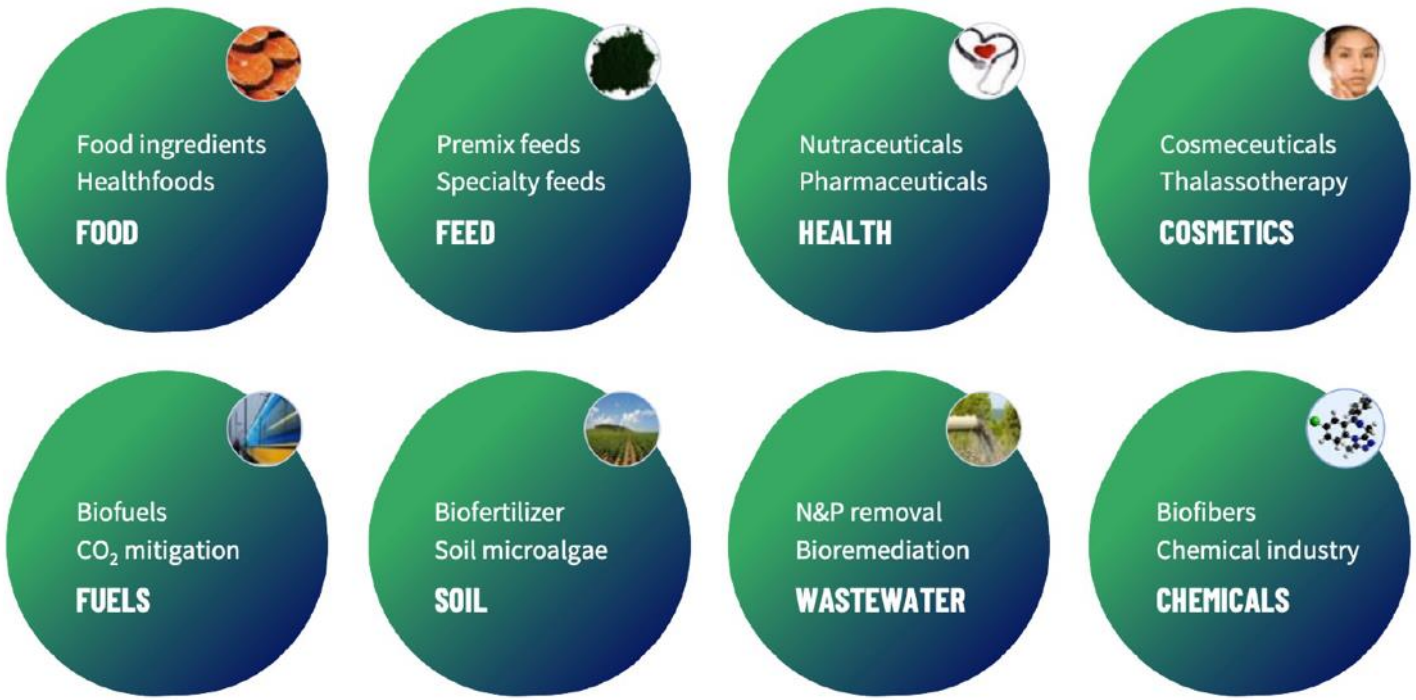
Microalgae

- **Whole biomass**
- Pigments (phycocyanin, astaxanthin)
- Omega-3 (DHA, EPA)
- Beta-glucans
- Proteins (specific aminoacids)

Macroalgae

- **Whole biomass**
- Hydrocoloids / Polysacharides
- Foods
- Feed
- Fertilizeres ad Biostimulants

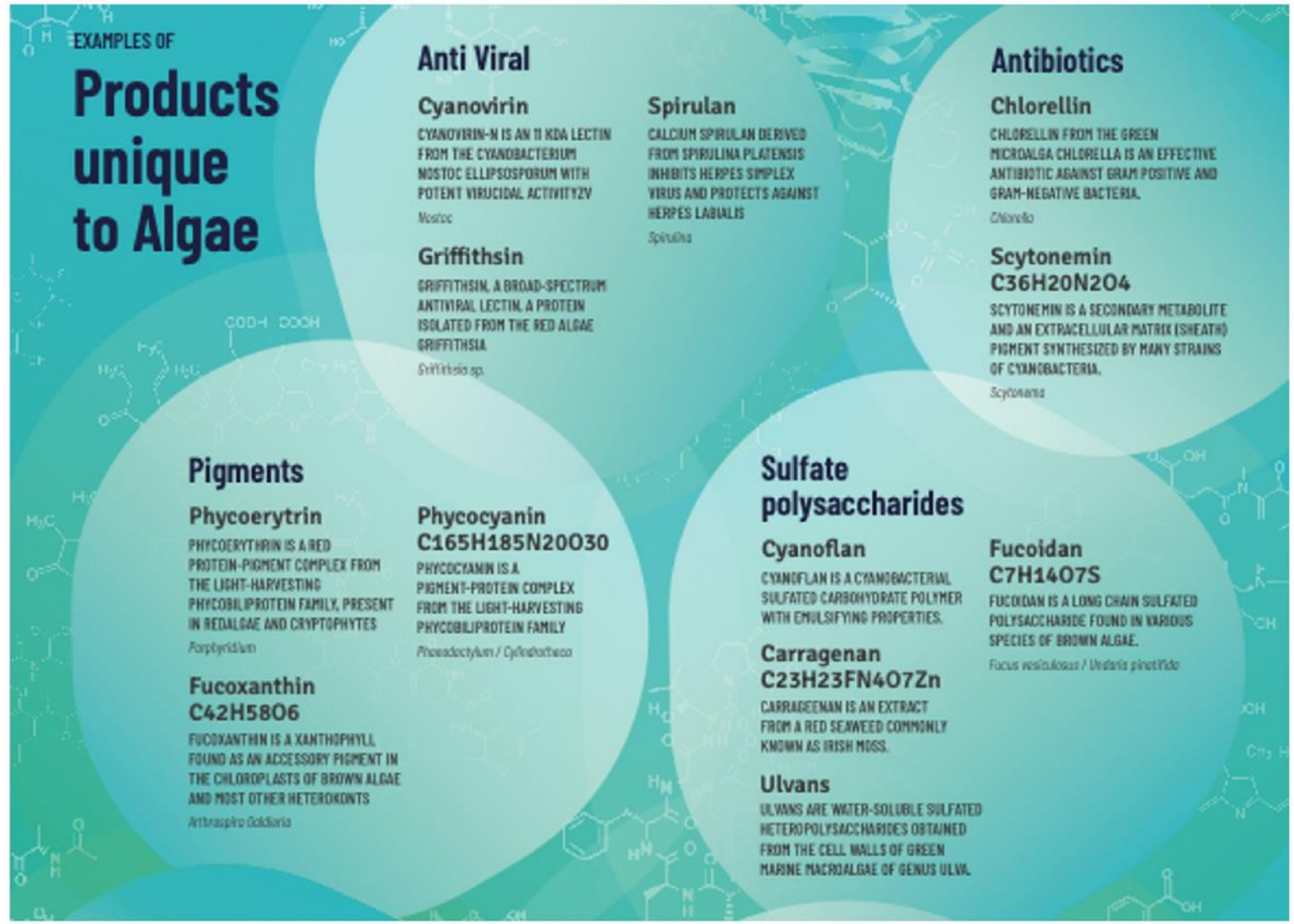
What they do...



What they could also do...

Sulfated polysacharides
- carragenan
- fucoidan
- ulvans

Pigments
- phycocyanin
- phycoerytrin
- fucoxanthin



What they could also do...

Specific carbohydrates
- alginates
- agar-agar
- laminarin

Toxins
- nodularin
- saxitoxin
- microcystin
- scytonemin
- cylindrospermopsin

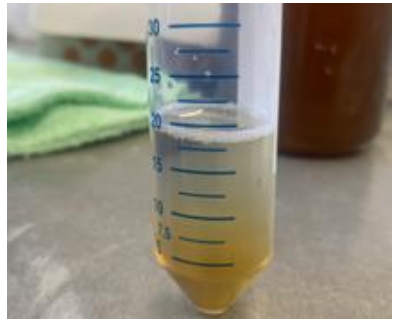
Algal toxins are also valuable for biomedical research, biotech applications, and potential drug development

What they could also do

Low cost mediums

Food waste mediums

Algal biomass



Treated effluent

✓ Using food waste and wastewater to reduce cost of production

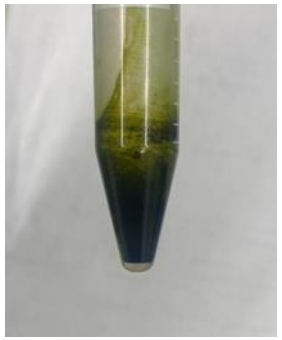
What they could also do

Biorefinery/multiproduct approach

Similar to traditional refinery → Crude oil → gasoline → diesel → jet fuel → asphalt

For a biorefinery

This time our starting material is algae biomass



lipids

proteins

carbohydrates

or

Biogas & Biofertilizer

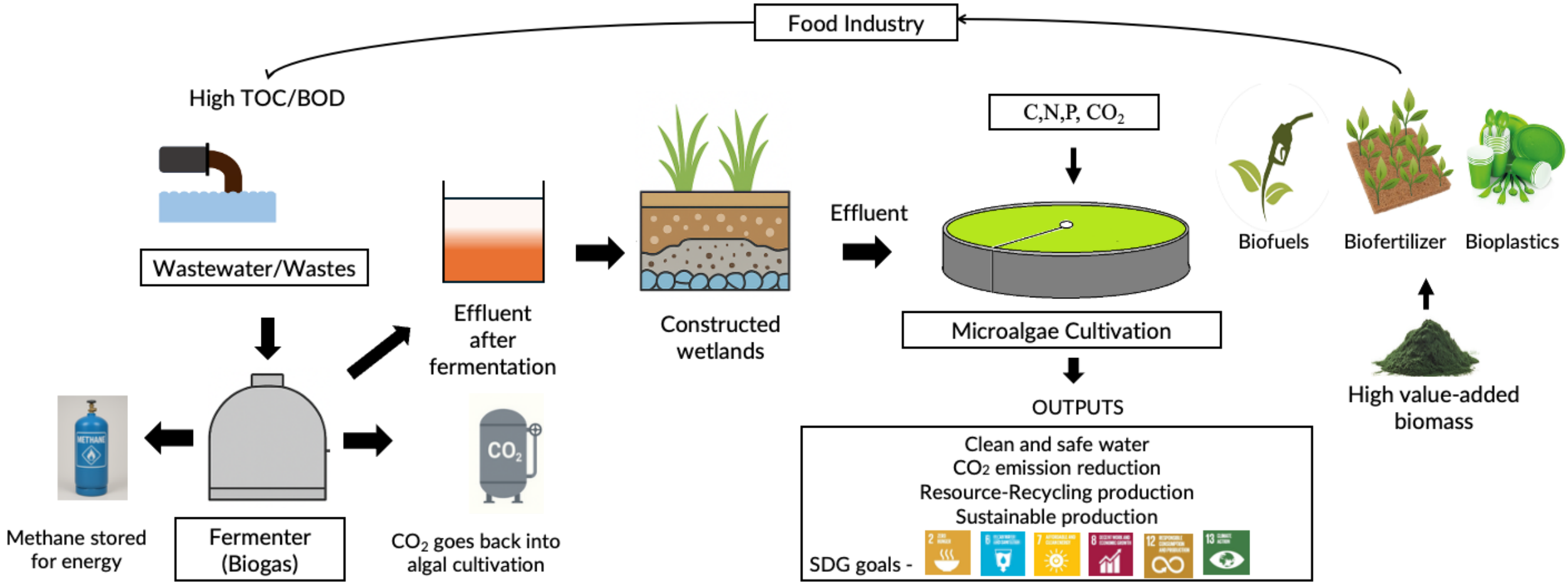
or

Lipids & Biochar

Multiple uses of the biomass will further maximize the commercial value of algae

What they could also do

Combination /Circular economy approach



Integrated Food Industry waste, Wastewater Treatment and Resource Recovery through Microalgae Cultivation

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THANK YOU VERY MUCH FOR LISTENING

Name : Daniel Twum-Ampofo (Ph.D)

Email: dtwumampofo001@gmail.com