Status and Perspective of Algal Technology

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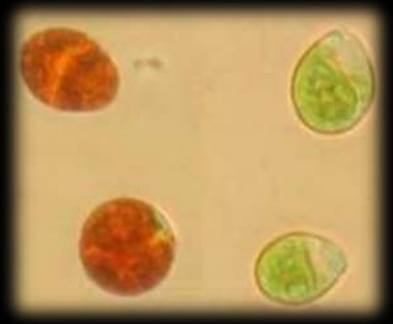
28-Nov-2023

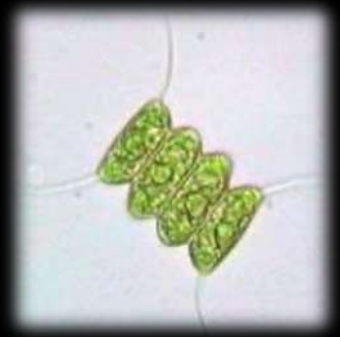
Agenda

- Algae in 3 slides
- Challenges of algal technology
- Algae in agriculture
- Examples

Algae

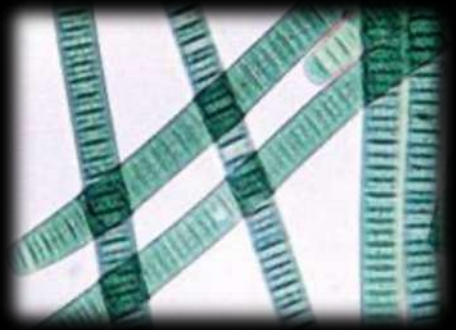
Microalgae





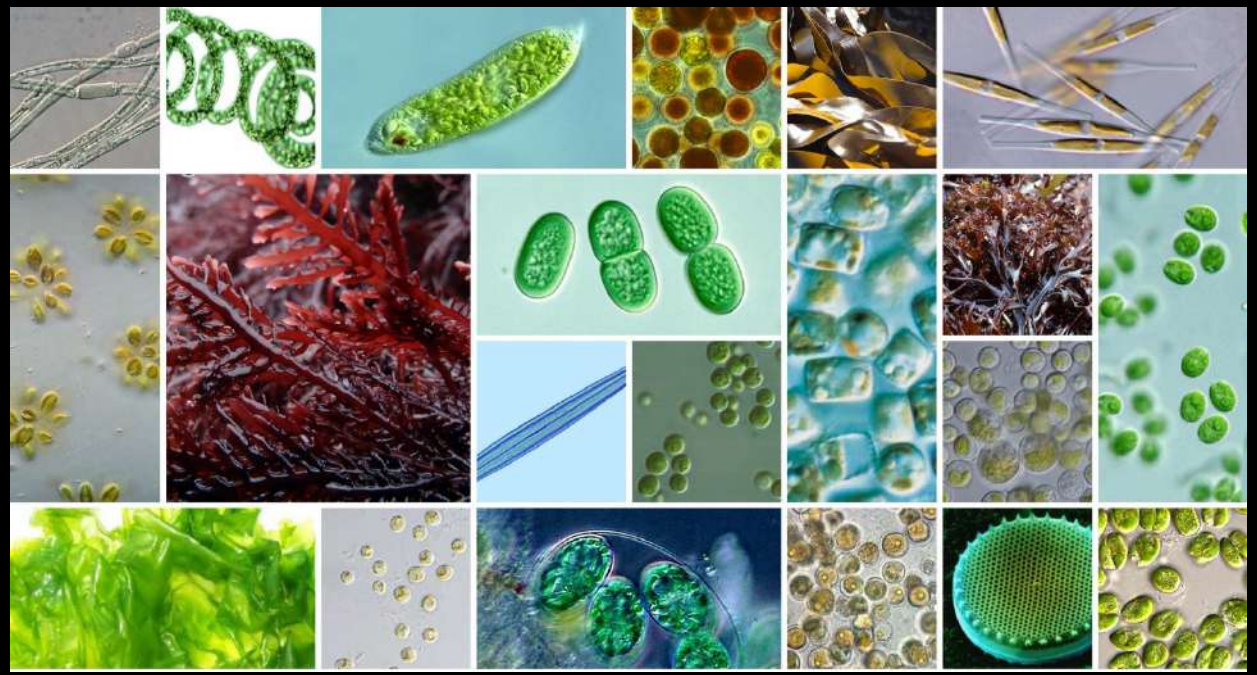
Macroalgae

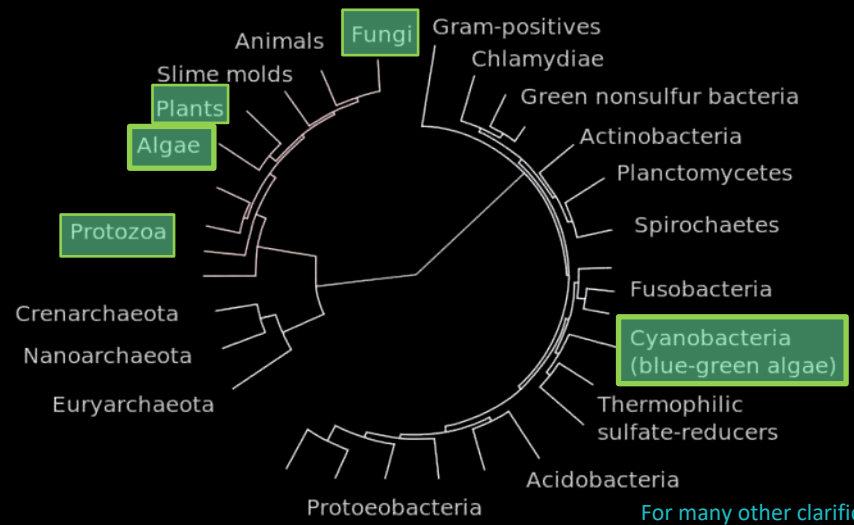
Cyanobacteria



Algae

- Photosynthetic aquatic organisms (exceptions allowed in all 3 words)
- Lacking structure of higher plants (but we would like to adopt some plants, like *Lemnia*)
- Whitepaper *What are algae* https://www.what-are-algae.com/
- Biology vs. Agronomy ⇔ Phycology vs. Algal technology





For many other clarifications:
V. Verdelho, J.P. Cadoret, F. G. Acien,J. Benemann, 2022,
Clarification of Most Relevant Concepts Related to the Microalgae Production Sector, MDPI Process.

Algal products

- Biofuels, biofertilizers, bioplastics
- Biostimulants
- Animal feed (fish, other)
- Food, food additives
- Protein
- Omega-3 fatty acids
- Pigments, antioxidants
- Nutriceuticals

- Oxygen (WWT)

- Biorefinery

Algal pitch

- Faster growth (3 – 15 x)
- Better yields (30 – 150(!) t/ha)
- Continuous harvesting
- More efficient use of fertilizers,
- Reuse/recycle the growth media
- Use of degraded, non-arable land
- No polution, No pesticides…
- No competition with food production
- Fixation of CO_2
- Complete use of whole organisms (no waste, stem, roots,…), no lignin…
- Grown on waste streams – nutrients free or with negative cost

Algae in oceans consume at least 50% of our CO_2 emissions!

Algae have created all fossil fuels in history, why dont we make them create more now?

Algae will save the world!

ALL (ALMOST) TRUE WITH MANY **IFS** AND **BUTS**…

Algae are:

- Omnipotent
- Omnipresent
- Omniscient

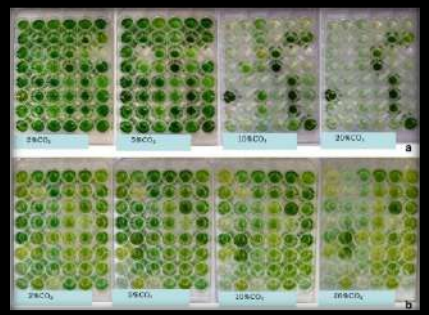
Today we will address a few of those „IFs & BUTs...“

Disclaimers:

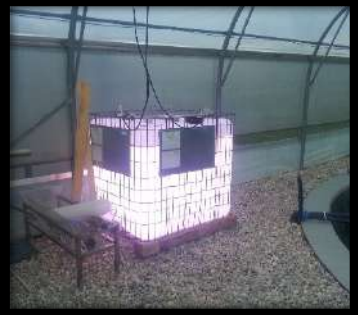
- We will **not** talk about macroalgae/seaweeds
- We will (mostly) **not** talk about economy, supply chain, marketing, market acceptance, regulation...
- Each of those has it‘s own (many) IFs & BUTs...
- We will be slightly biased to **ponds;** in PBR engineering there are more of their own IFs & BUTs...

Scale matters

- Lab scale
  - model organisms
  - physiology, genetic, metabolomic, ... research
- Pilot scale
- Large production scale









Aqualia, Chiclana


Parry Nutriceuticals, India


Cheng Hai, China


Cyanotech, Hawaii


Earthrise, CA

Images: Liu, Zhang, Chen, 2013, High throughput screening of CO2-tolerating microalgae using GasPak bags, Aquatic Biosystems 9(1):23
Algen , Google Maps

Energy source

- Heterotrophic cultivation (fermentation)
- Autotrophic cultivation (photoautotrophic)
  - Sunlight
  - Artificial light
- Mixotrophic

Images: Fermentalg, Libourne, Algen EKOJanez, Galdieria, WUR

Open / closed

- Closed or semi-closed: Photobioreactors
- Open or covered: Ponds
- Biofilms, ...





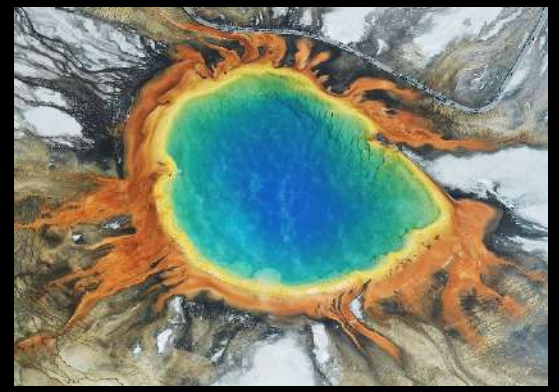


Images: BenGurion University,
Algen - project Water2Return, Archimede Ricerche,
Gross-Wen Technologies - Terrence J. O'Brien Water Reclamation Plant in Skokie IL, project AlgaDisk, Archimede Ricerche - project Saltgae, Algen - EkoJanez

Large scale & open

- We cultivate ~ 10 species out of >50000 known
- Extremophiles
  - Arthrospira platensis (Spirulina)
  - Dunaliella
  - Galdieria
- Fast growers
  - Chlorella
  - Scenedesmus

- Wastewater microbial communities



Large scale challenges

- Light: penetration(density), photoinhibition
- Area: vertical, horizontal, area of the shadow
- Temperature: thermal capacity – buffering, cooling, heating
- Nutrients: contamination, cost, LCA
- CO_2 (inorganic carbon), purity, solvability
- O_2 toxicity
- Contaminants in nutrients
- Birds, rodents, insects, lizards, amfibia, ...
- Grazers: amoeboids, rotiferae, ciliates, zoosporic parasites, ...
- Foreign species, possibly toxic
- Sediments
- Cleanliness (dust, precipitates, foreign objects, foam & waves biofilms)

Harvesting

- 1 kg algal biomass <-> 1 ton water
- Small, possibly fragile cells
- Neutral buoyancy
- Energy demanding processes

- Combination of:
  - Sedimentation
  - Flotation
  - Combined with flocculation or electrocoagulation
  - Filtering
  - Centrifuge, decanter, ...

Dewatering, drying

- Growth media is protecting
- Biological contaminants present in ponds
- Additional contamination during process
- Low T
- Fast process

- Freezing
- Pressing
- Spray drying (fast, high T)
- Solar drying (slow, uncontrolled)
- Clean air drying, low T

Result

- Wildly variable quality
  - Foreign biomass: 0-15%
  - Heavy metals
  - PAH
  - Bacterial contamination
  - Cyanotoxins
- High cost
  - 2 €/kg, 8 €/kg, 150 €/kg
    (10 – 100 times commodity crops)
  - Crops are subsidized, algae are not
  - Uncontrolled competition
- LCA?
- Algae & wastewater (high value?)

Overcoming the barriers

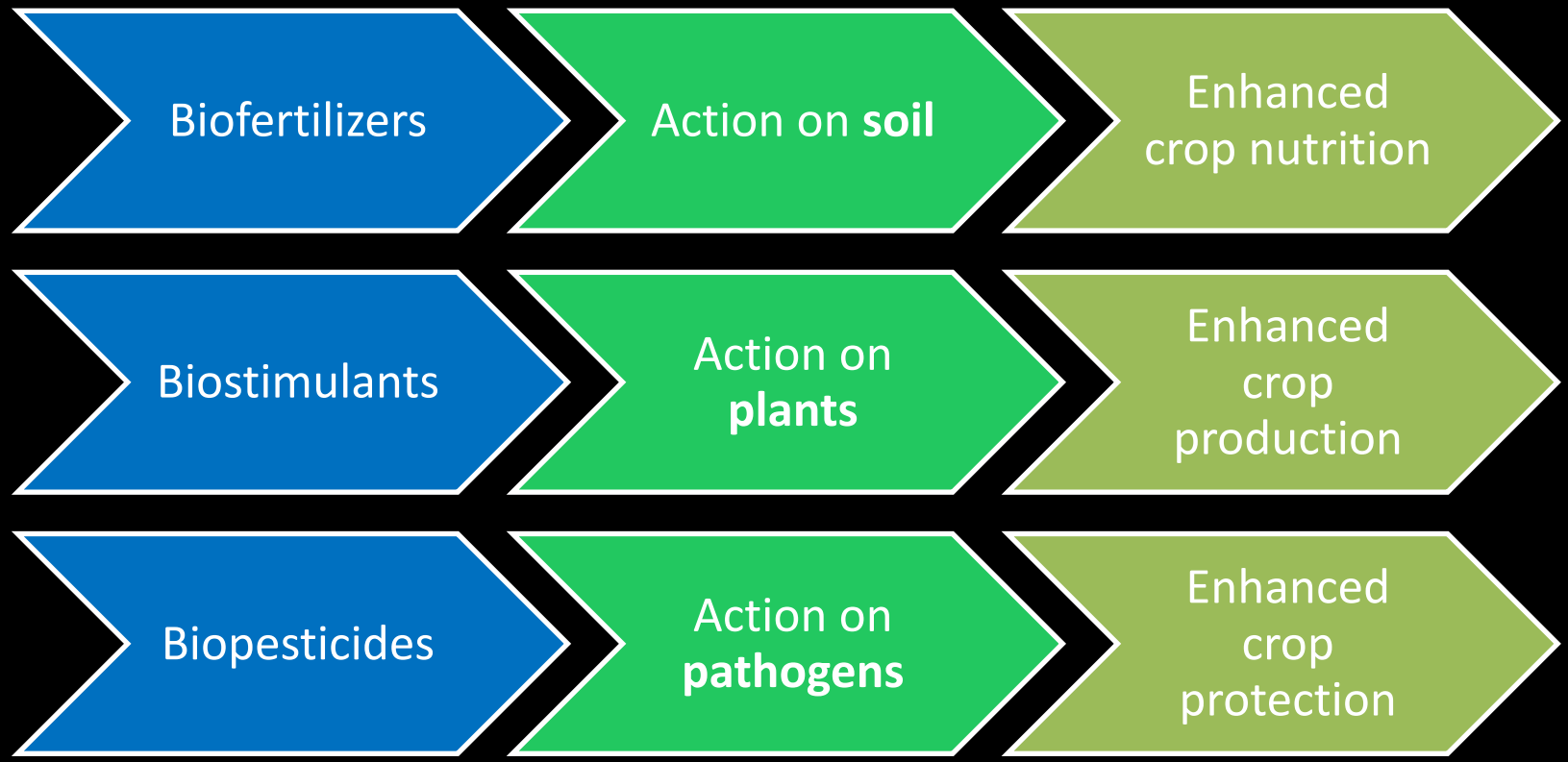
- Economy of scale with non-naive approach
- Subsidies as for agriculture: for food, feed, fish-feed
- Marketing: high-end products, organic labelling, locally produced, quality branding
- R & D, standardization,
- Good side-streams for nutrients
- Good CO_2 streams
- Biorefinery (use all)

Algae and agriculture

- Macroalgae are used in agriculture for millenia
- Macroalgal agricultural products are popular in last decades
- Microalgae agricultural products are entering the market

https://www.globalseafood.org/advocate/seaweed-aquaculture-provides-diversified-products-key-ecosystem-functions-part-1/
https://www.biorizon.es/en/bioenhancers/trietech-https://www.biorizon.es/en/bioenhancers/trietech-eco-technology/eco-technology/

Activity of algal & cyanobacterial biomass in crop production



Produce algae for agriculture

- Produced on wastewater
- Produced on non-arable land
- Recycle nutrients
- Recycle, reuse CO_2
- Water treatment:
  - Reduced treatment cost
  - Improved treatment quality
  - Remove pathogens, odours

Benefits

- N-fixation (?)
- Increase soil organic content
- Improve soil physicochemical properties
- Improve soil stability, binding effect
- Reduce nutrient loss and leaching

Thank you

Questions?