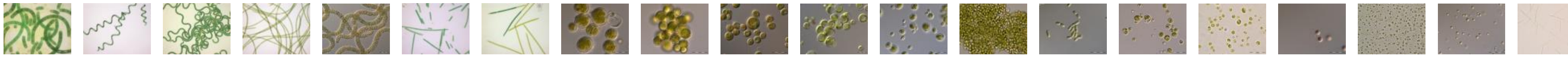
Christian-Albrechts-Universität zu Kiel



Biotechnological screening of microalgal strains for biomass utilization

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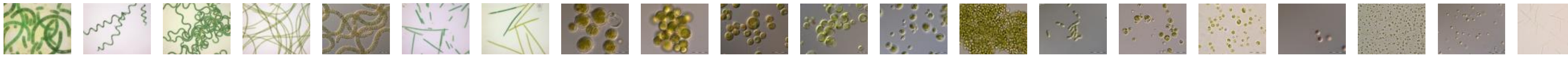
[3] Institute of Geosciences, Department of Organic Geochemistry, University of Kiel

Georg-August-Universität Göttingen

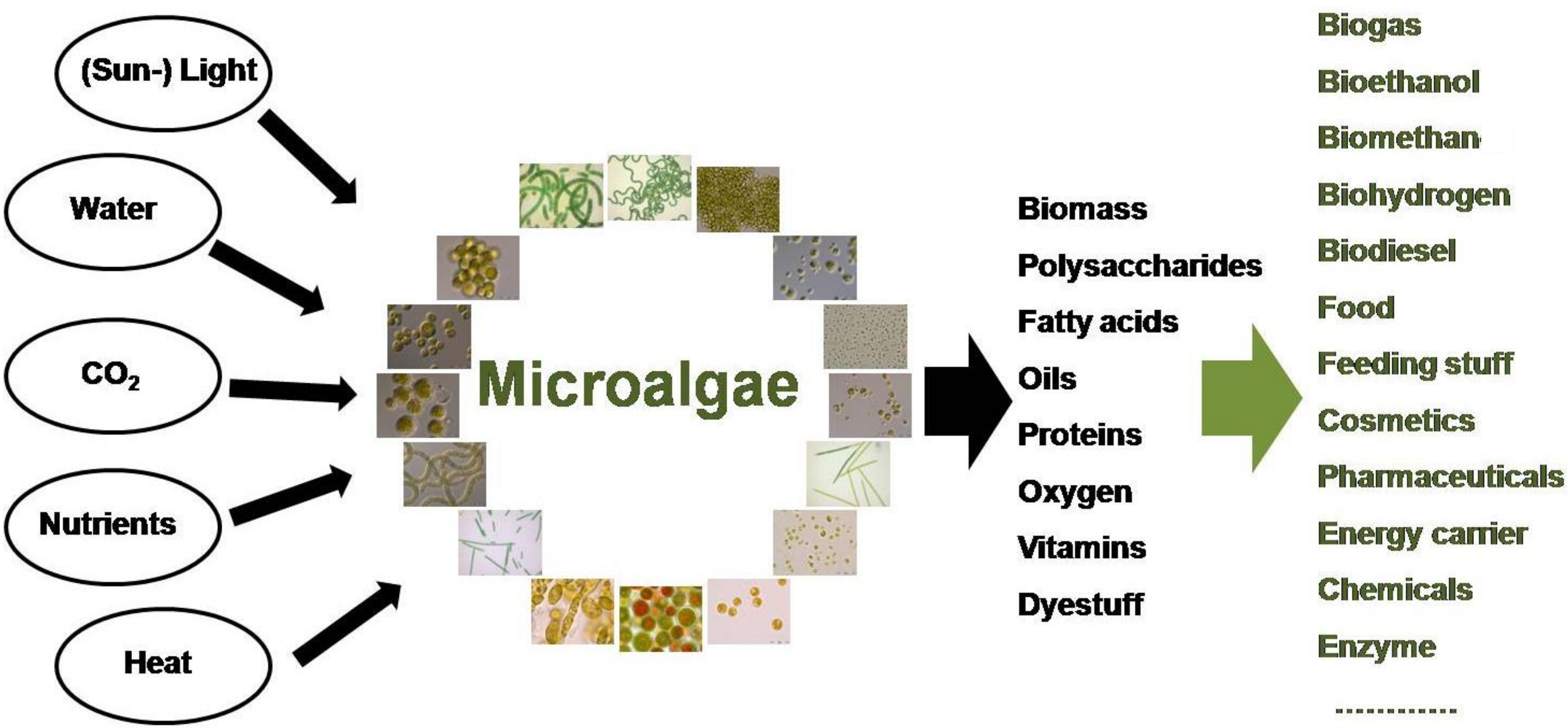
Kompetenzzentrum Biomassenutzung 012

biotechnological use of microalgae

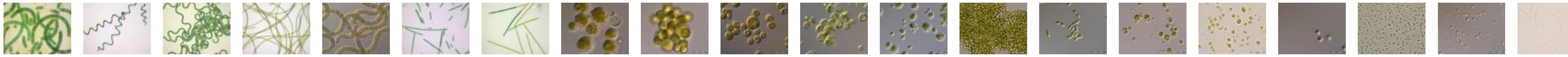


Photosynthesis:

$$6\ CO_2 + 12\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$$



Microalgal species with high relevance for biotechnological applications

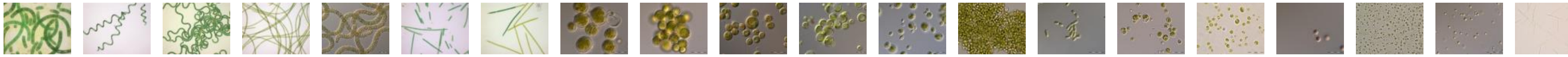


maximal 20 species are economically used

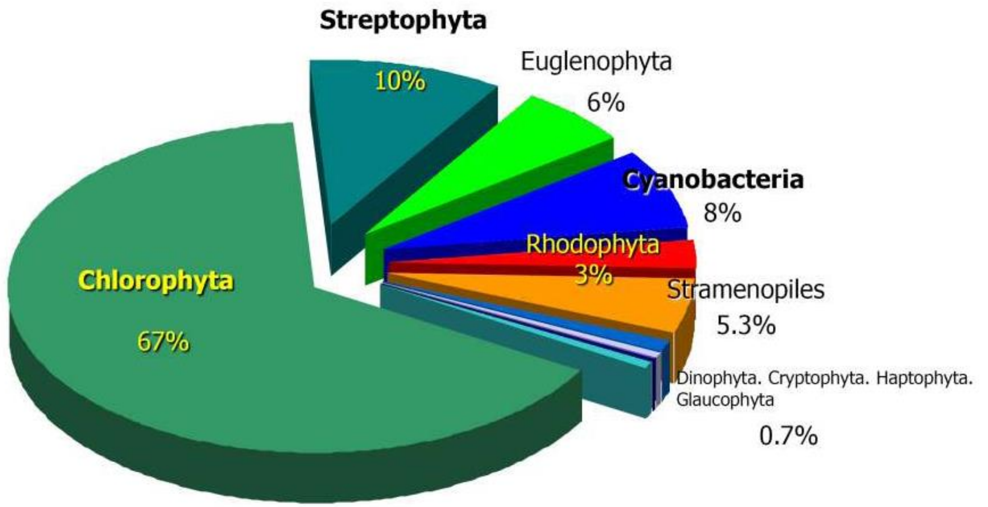
Species/group	Product	Application areas	Basins/reactors
Spirulina platensis/Cyanobacteria	Phycocyanin, biomass	Health food, cosmetics	Open ponds, natural lakes
Chlorella vulgaris/Chlorophyta	Biomass	Health food, food supplement, feed surrogates	Open ponds, basins, glass-tube PBR
Dunaliella salina/Chlorophyta	Carotenoids, β-carotene	Health food, food supplement, feed	Open ponds, lagoons
Haematococcus pluvialis/Chlorophyta	Carotenoids, astaxanthin	Health food, pharmaceuticals, feed additives	Open ponds, PBR
Odontella aurita/Bacillariophyta	Fatty acids	Pharmaceuticals, cosmetics, baby food	Open ponds
Porphyridium cruentum/Rhodophyta	Polysaccharides	Pharmaceuticals, cosmetics, nutrition	Tubular PBR
Isochrysis galbana/Chlorophyta	Fatty acids	Animal nutrition	Open ponds
Phaedactylum tricornutum/Bacillariohyta	Lipids, fatty acids	Nutrition, fuel production	Open ponds, basins
Lyngbya majuscule/Cyanobacteria	Immune modulators	Pharmaceuticals, nutrition	

Pulz and Gross, Appl. Microbiol. Biotechnol. (2004) 65: 635-648

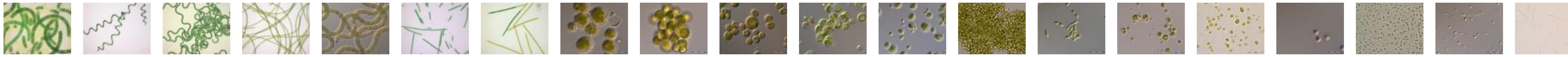
Algal diversity at the Göttingen Culture Collection of Algae (SAG)



Presently, the SAG maintains over 2400 strains of living microalgae incl. cyanobacteria which represent 538 genera and 1424 species.



Algal diversity at the Göttingen Culture Collection of Algae (SAG)



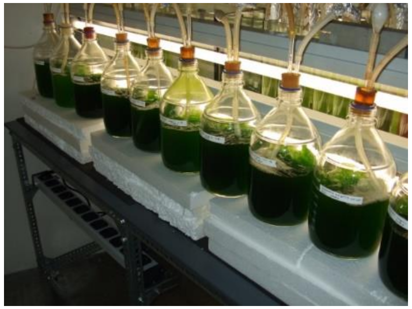
In Göttingen (SAG)

- Over 50 different media
- Five different temperatures and diverse light intensities
- Slant agar and liquid media

For Kiel

- Four different standard media
- two different temperatures and one light intensity
- Liquid media (in 50 ml Erlenmeyer flask)

Cultivation of microalgae in Kiel



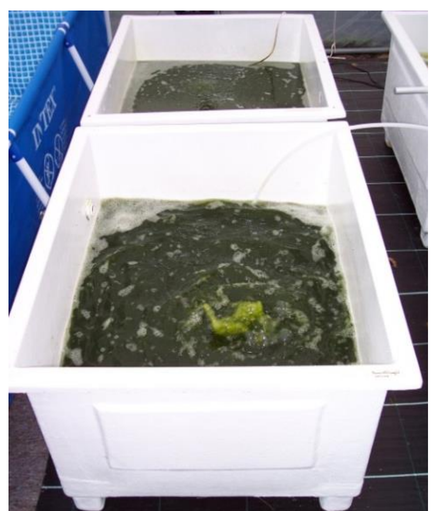
Cultivation in 2 l and 1 l glass bottles

Cultivation in 20 l glass bottles

Cultivation in 400 ml glass tubes

Cultivation in 30 l bioreactors

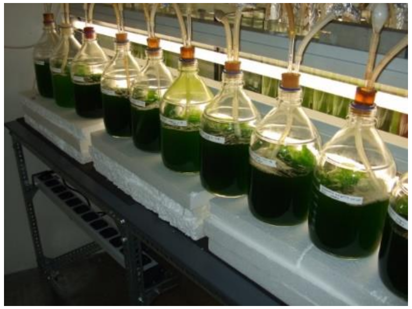
Cultivation in the Kiel fjord



Cultivation in 300 l open ponds

Cultivation in 4000 l open pond

Cultivation of microalgae in Kiel



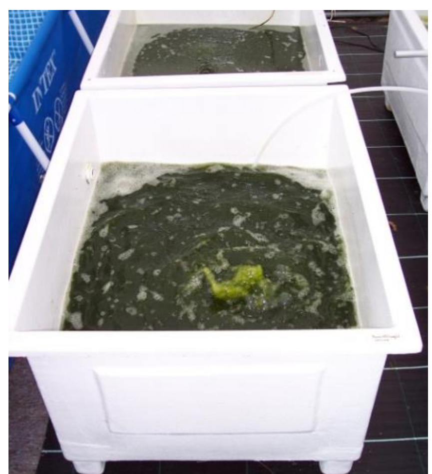
Cultivation in 2 l and 1 l glass bottles

Cultivation in 20 l

30 l bioreactors

- Investigation for cheap culture media
- Use of sea water as culture media
- Development of a energy efficient harvesting technique in collaboration with:
  - Flensburg University applied sciences
  - Muthesius Academy of Fine Arts and Design
  - Paul Wiener (Botanical Institute, Dept . of Ecophysiology of plants,Prof. Bilger)

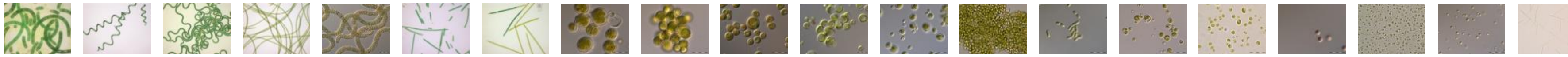
Cultivation in the Kiel fjord



Cultivation in 300 l open ponds

Cultivation in 4000 l open pond

Analyses carried out



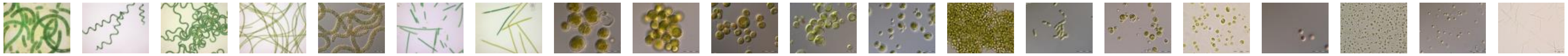
- Preselection of microalgae strains of SAG.

- Optimization of culturing conditions and biomass production.

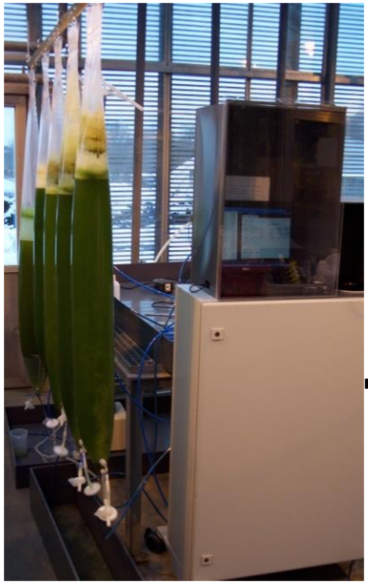
- Analysis of biomass:
  - Biogas yield test (biogas plants)
  - Carbon dioxide absorption capacity
  - Measurement of hydrogenase activities
  - Antioxidants (Carotinoids and Tocopherol (Vitamin E))
  - Screening for compounds with antibacterial effect
  - Determination of total fat content and fatty acid composition

- Development of energy efficient harvesting technique

Biogas yield test from microalgae



Biomass production



Biodiversity

Culture condition

(Heat, light, water, Nutrients and CO2)

Harvesting time

Harvest and conservation of biomass for digestation

Harvest technology

(centrifugation)

Conservation

(at – 20 °C)

Fermentation

Flensburg University applied sciences (AG Prof. Jens Born)

Fermentation technology

Substrate decomposition

(biomass and Sewage sludge, ca. 4 weeks)

environmental conditions

(temperature, PH value)

End products

Biogas

Ca. 70 % Methan

Digestate

Biomass production and biogas yield of microalgae and cyanobacteria strains

- In this work, 45 cyanobacterial and microalgal strains from five different divisions, eight classes and one unclear taxon were also investigated for their potential use in biomass and biogas production.

- All strains were grown under the same culture conditions to allow an interspecies comparison.

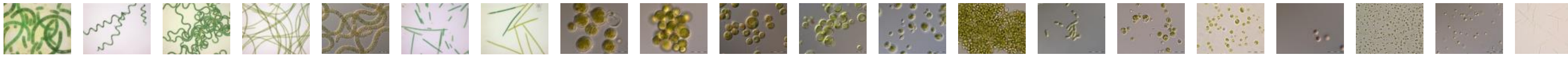
- Our results show that the production of biogas by the investigated microalgal and cyanobacterial strains is highly dependent on both taxonomic division and species.

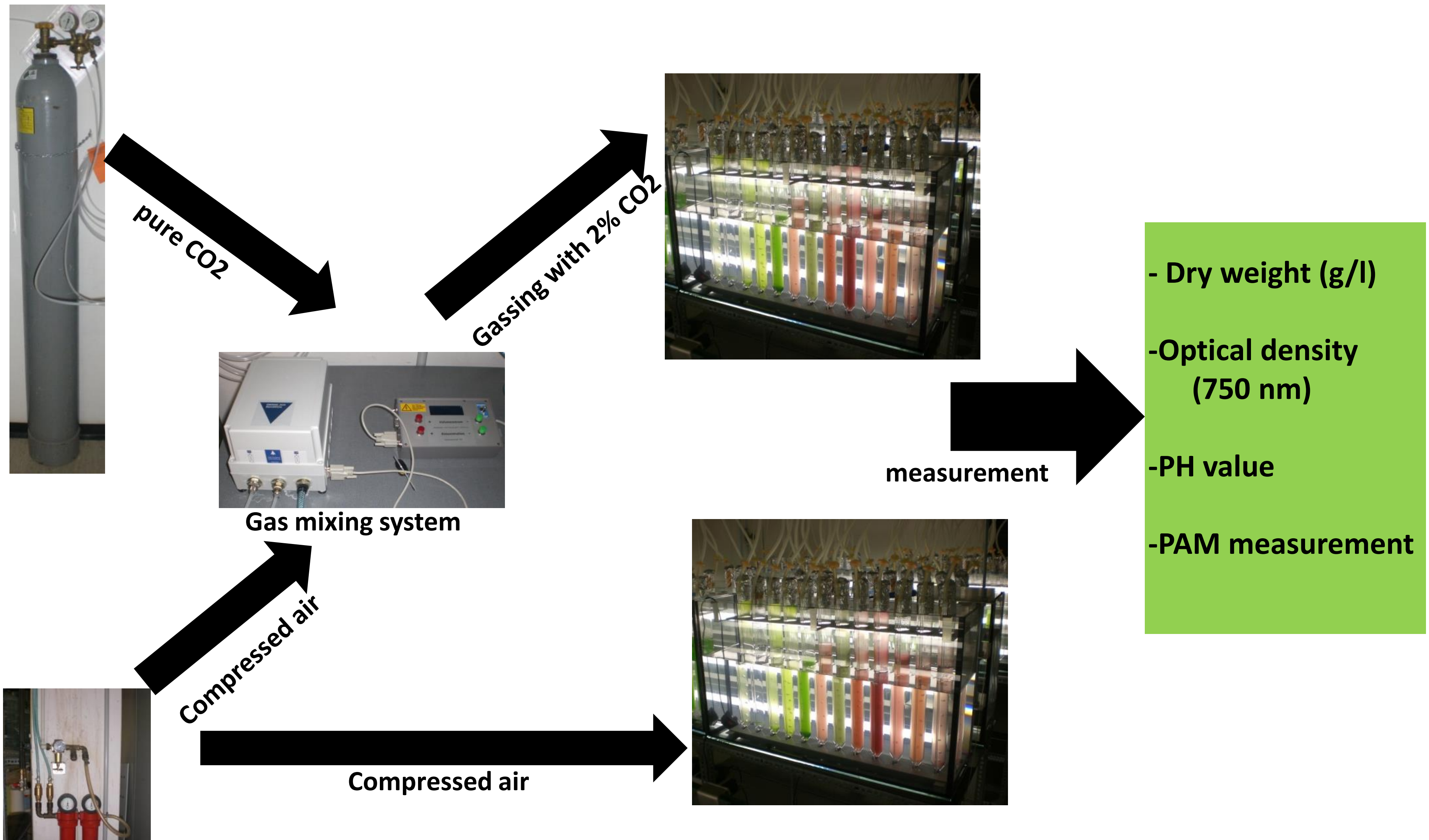
- The division Chlorophyta contained species that had the highest yield of biogas production.

- Different pretreatments of biomass are required to increase the biogas production

Mudimu *et al.* 2014

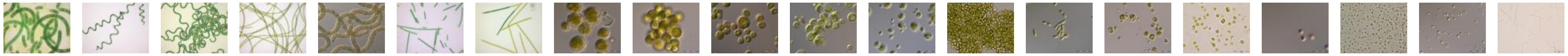
Growth stimulation of microalgae by CO_2 gassing

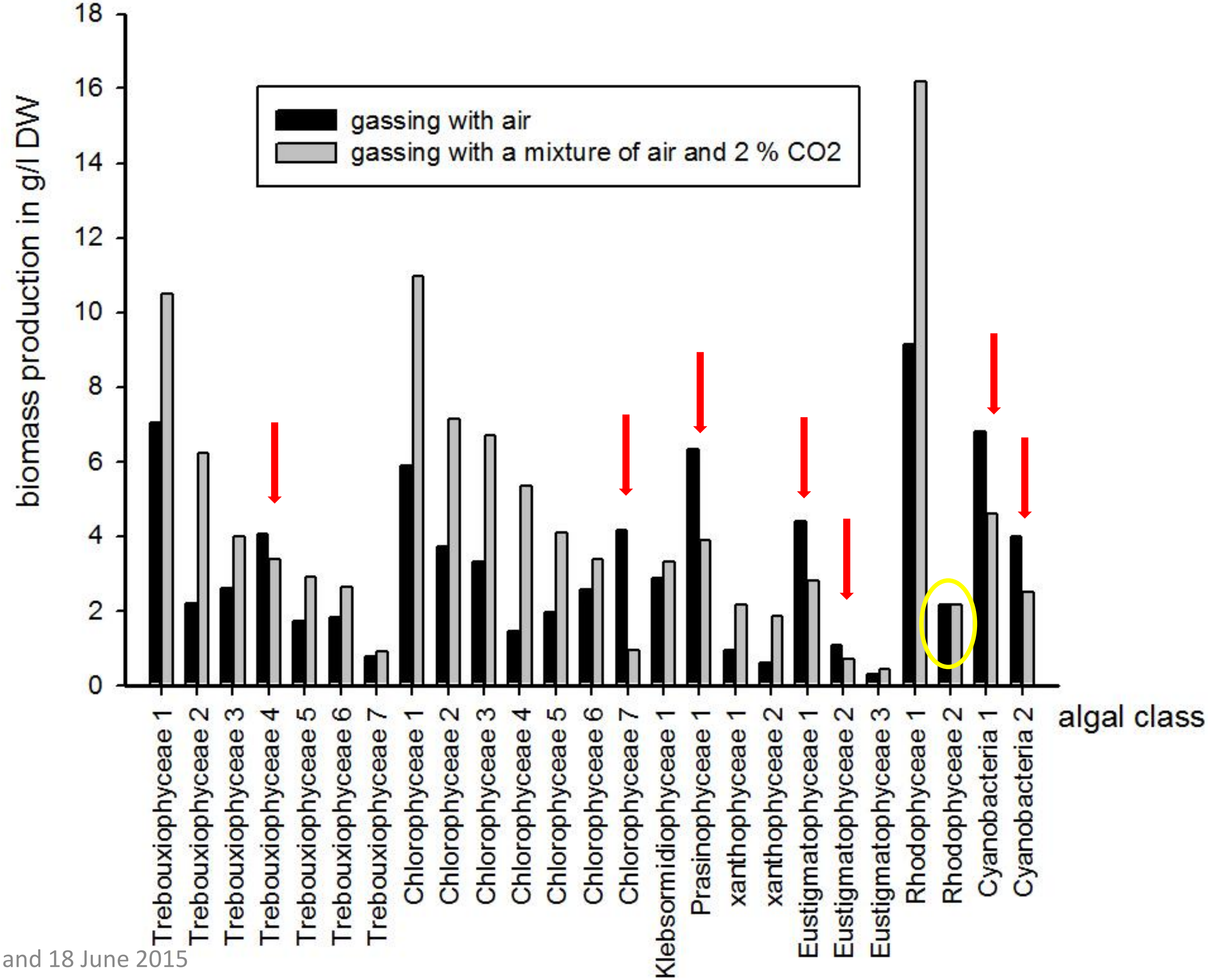




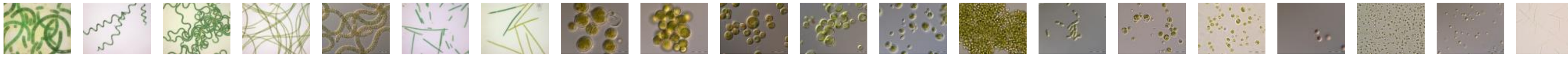
Culture conditions: 23 days, light/dark cycle: 14 h/10 h, 21 °C .

Growth stimulation of microalgae by CO_2 gassing





Conversion of power plant CO_2 to Biomass



Photosynthesis:

$$6\ CO_2 + 12\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$$

(Sun-) Light →

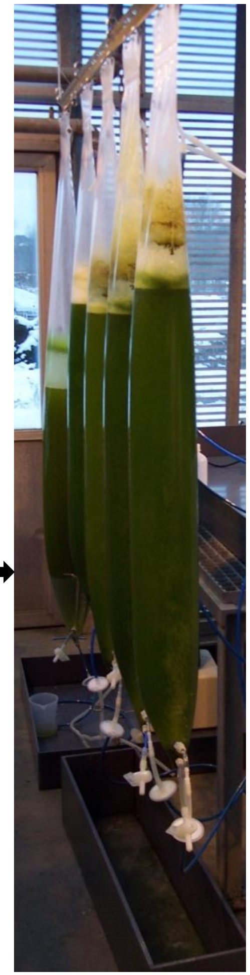
Power plant

→ CO_2 (ca. 20 %) →

→ Heat (winter) →

Nutrients →

Water →

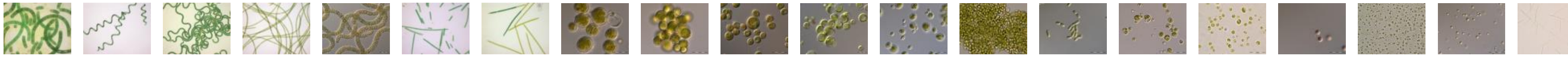


Cultivation of microalgae in bioreactors

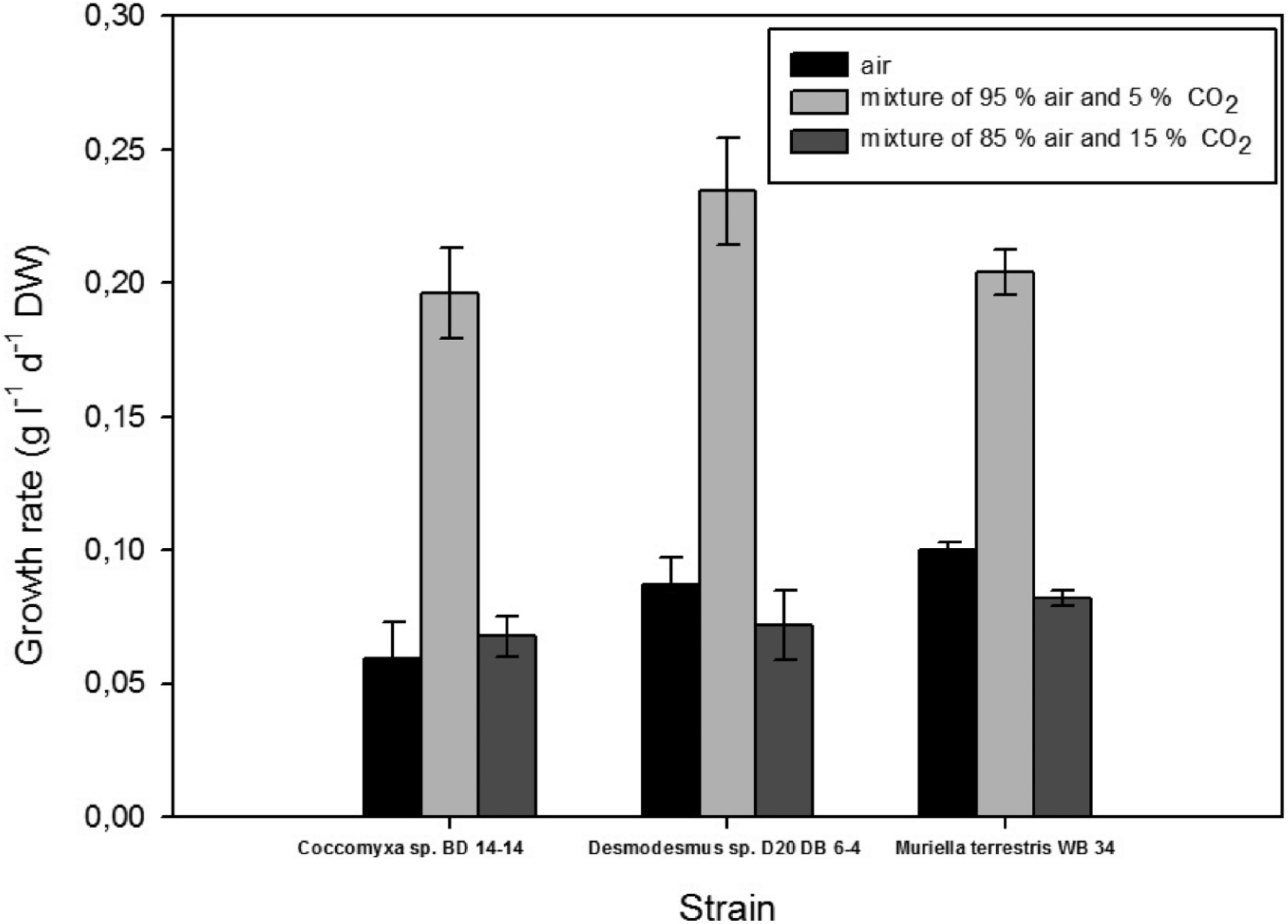
→ **Biomass** →

Energy
- Biogas
- Biodiesel
- Bioethanol
- Biomethan
- Biohydrogen

Carbon dioxide absorption capacity of microalgae

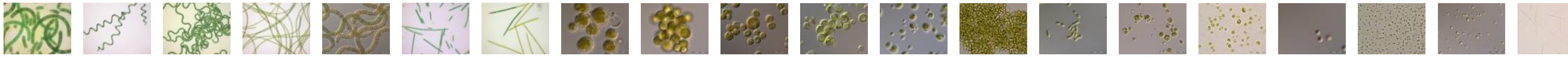


Growth rates (g $l^{-1}d^{-1}$ DW) of microalgae strains grown by gassing with air or mixtures of 95% air and 5% CO_2 as well as 85% air and 15% CO_2, respectively.



Mudimu *et al.* 2015

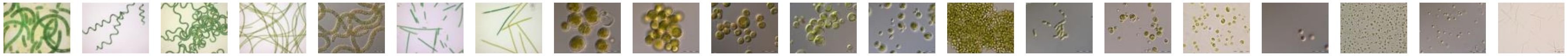
Carbon dioxide absorption capacity of microalgae



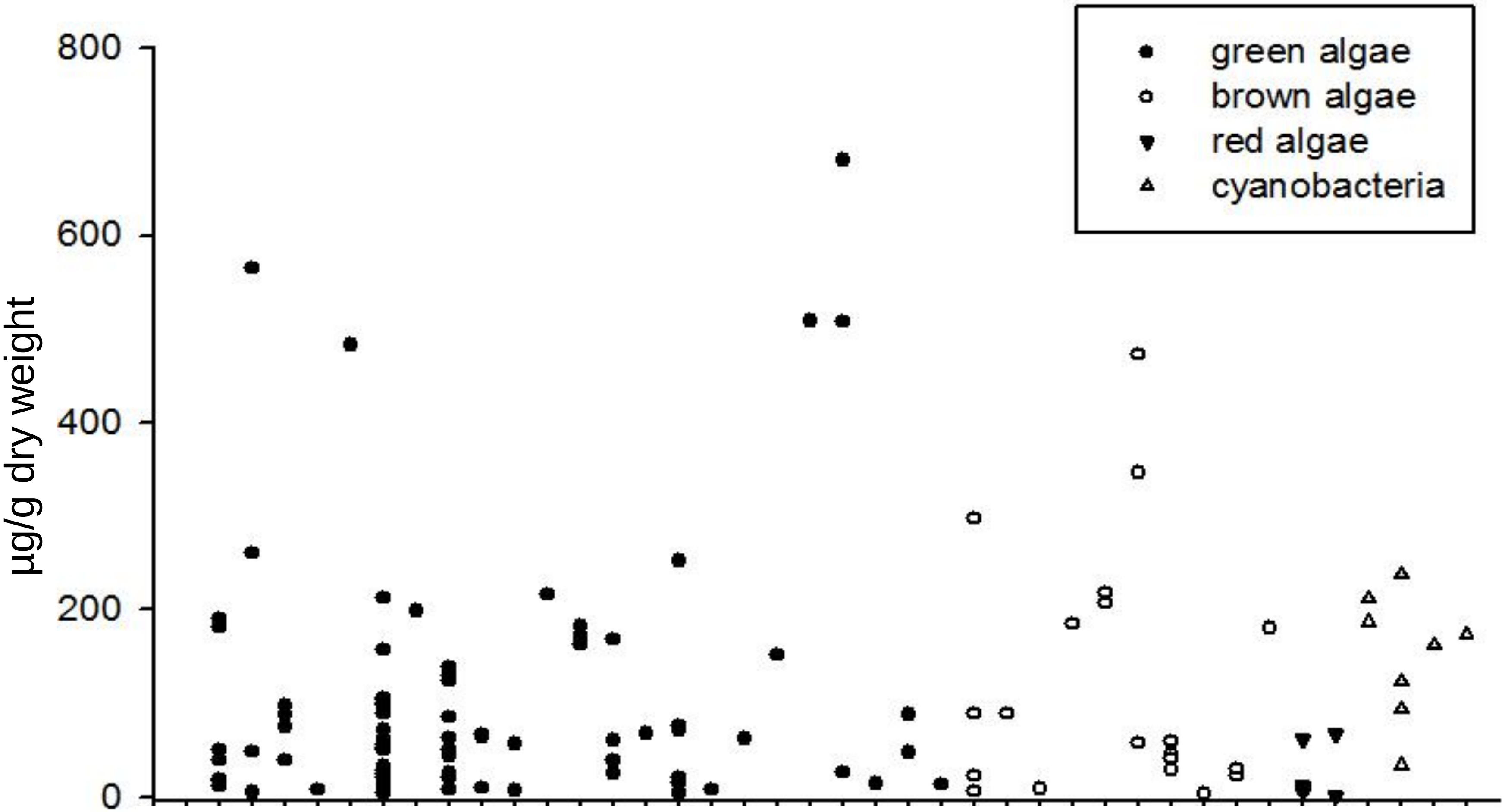
Xanthonema debile SAG 22.89   15% CO_2

Desmodesmus sp D20DB6-4   15% CO_2

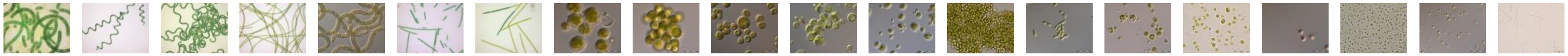
α tocopherol content of microalgae



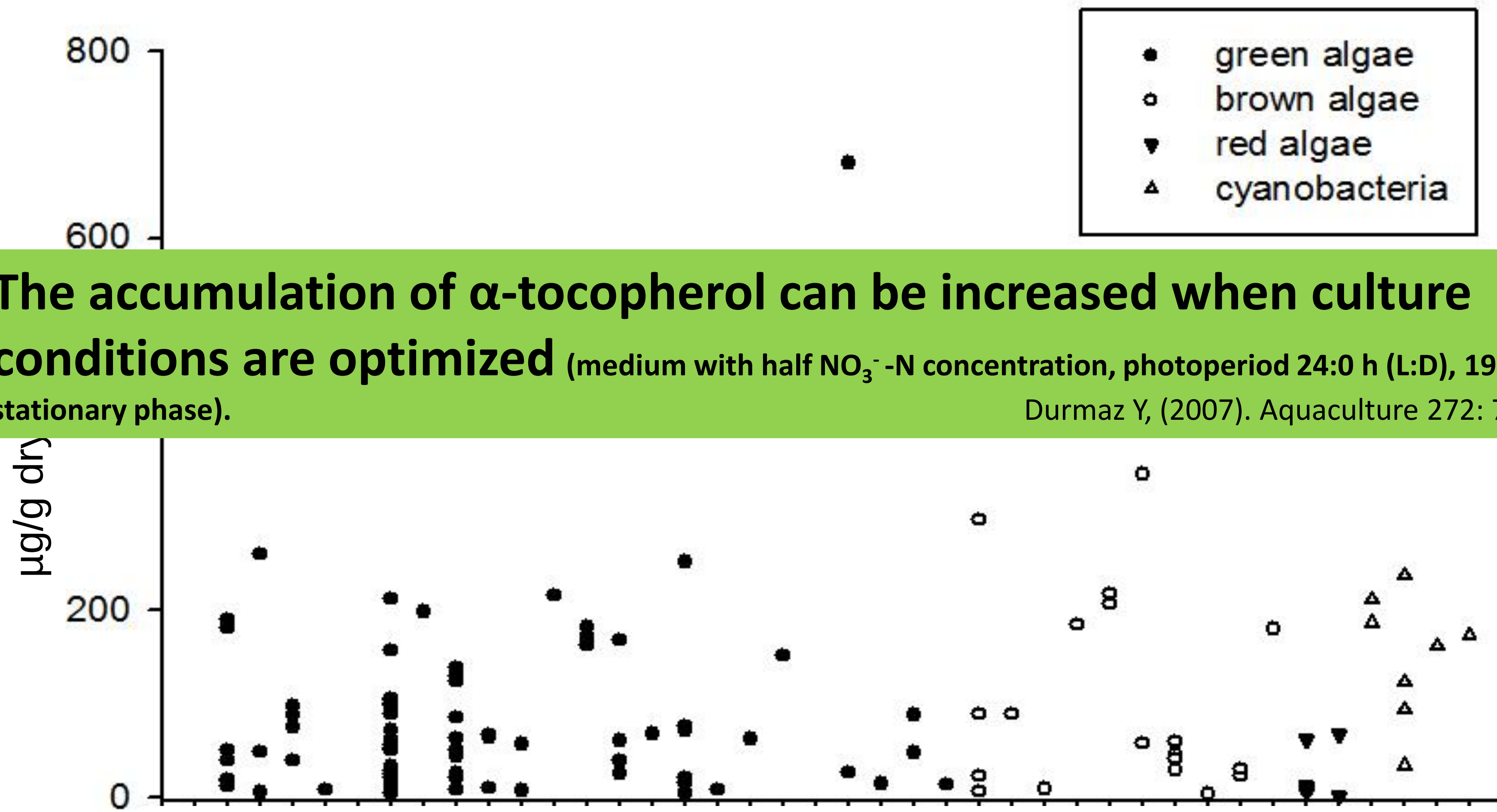
microalgae grown on standard conditions (standard medium, photoperiod 14:10 h (L:D), 21°C, early stationary phase)



α tocopherol content of microalgae



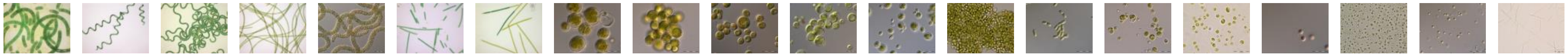
microalgae grown on standard conditions (standard medium, photoperiod 14:10 h (L:D), 21°C, early stationary phase)

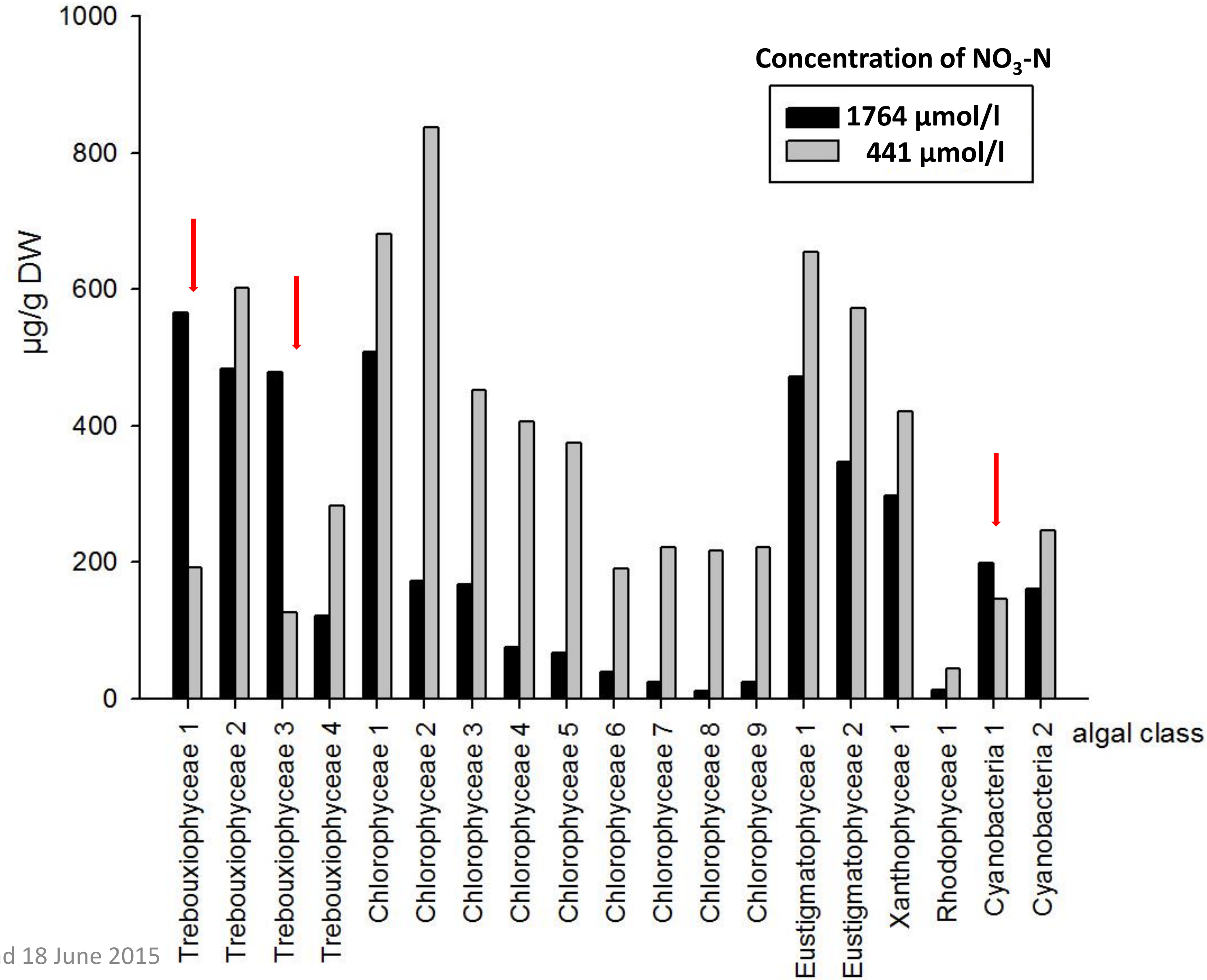


The accumulation of α-tocopherol can be increased when culture conditions are optimized **(medium with half NO_3^--N concentration, photoperiod 24:0 h (L:D), 19°C, late stationary phase).**

Durmaz Y, (2007). Aquaculture 272: 717-722.

α tocopherol content of microalgae





Antibacterial and antifungal effects

- We investigated 97 microalgae and cyanobacteria for antibacterial and antifungal effects against:

  - *Bacillus subtilis* DSM 10
  - *Escherichia coli* DSM 18039
  - *Pseudomonas fluorescens* DSM 50090
  - *Candida albicans* DSM 1386
  - *Saccharomyces. cerevisiae* S 150–2b ATCC 96686

- The highest bioactive effect obtained was inhibition of 70 % against the gram-positive bacterium *B. subtilis*. The second highest bioactive effect detected was inhibition of 60 % against the gram-negative bacterium *E. coli*.

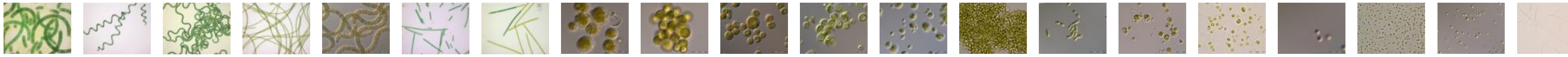
- bioactive effects have been obtained by compounds extracted with methanol.

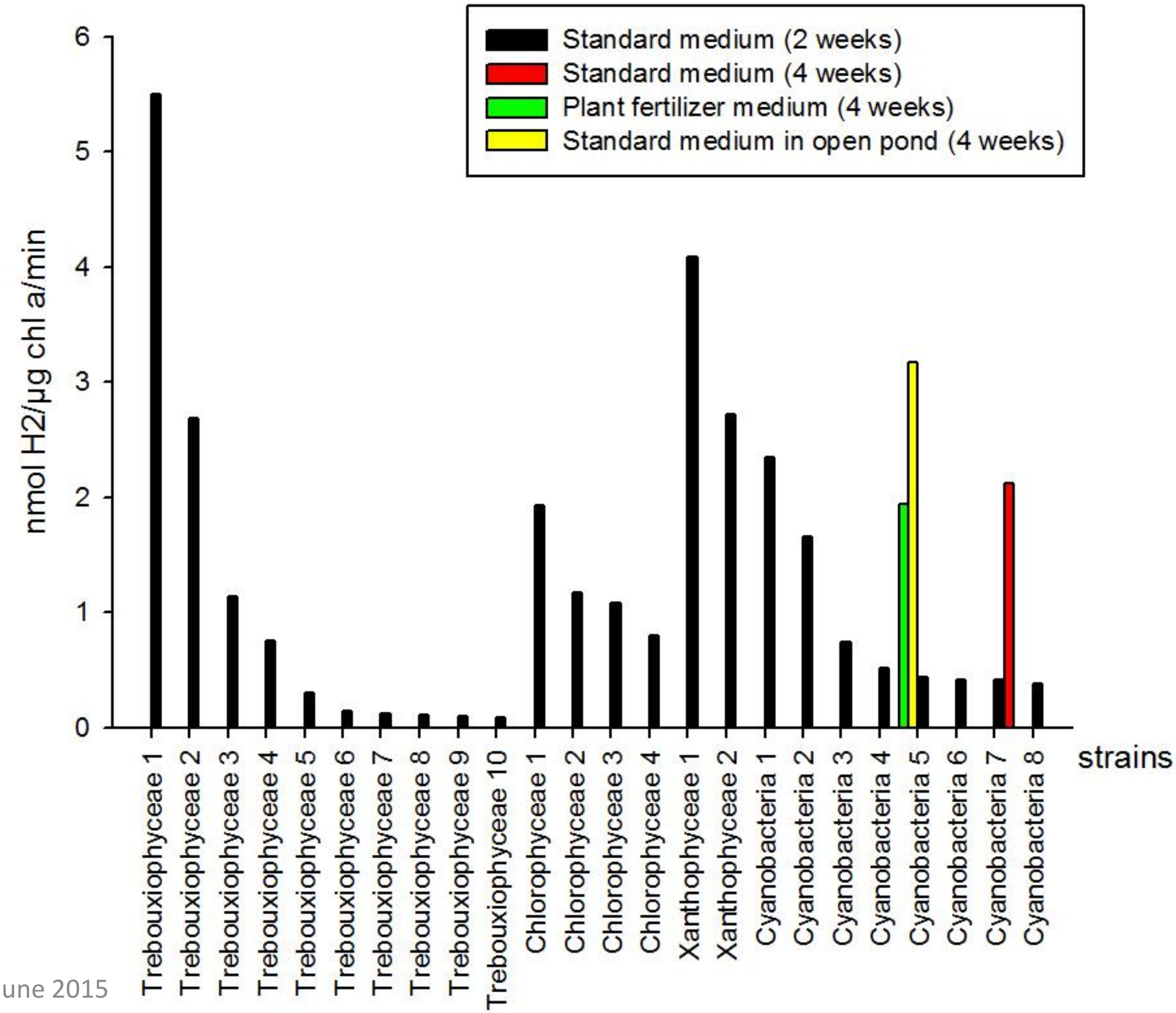
- These results reveal that a better part of the bioactive compounds in microalgae and cyanobacteria is hydrophobic and can better be extracted with organic solvents.

- The majority of strains are considered as good candidates for further biochemical and biotechnological analyses in order to characterize and purify novel antimicrobial compounds.

Mudimu *et al.* 2014

Measurement of hydrogenase activities





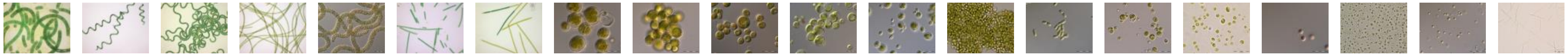
- **Fatty acid composition of microalgae and cyanobacteria**

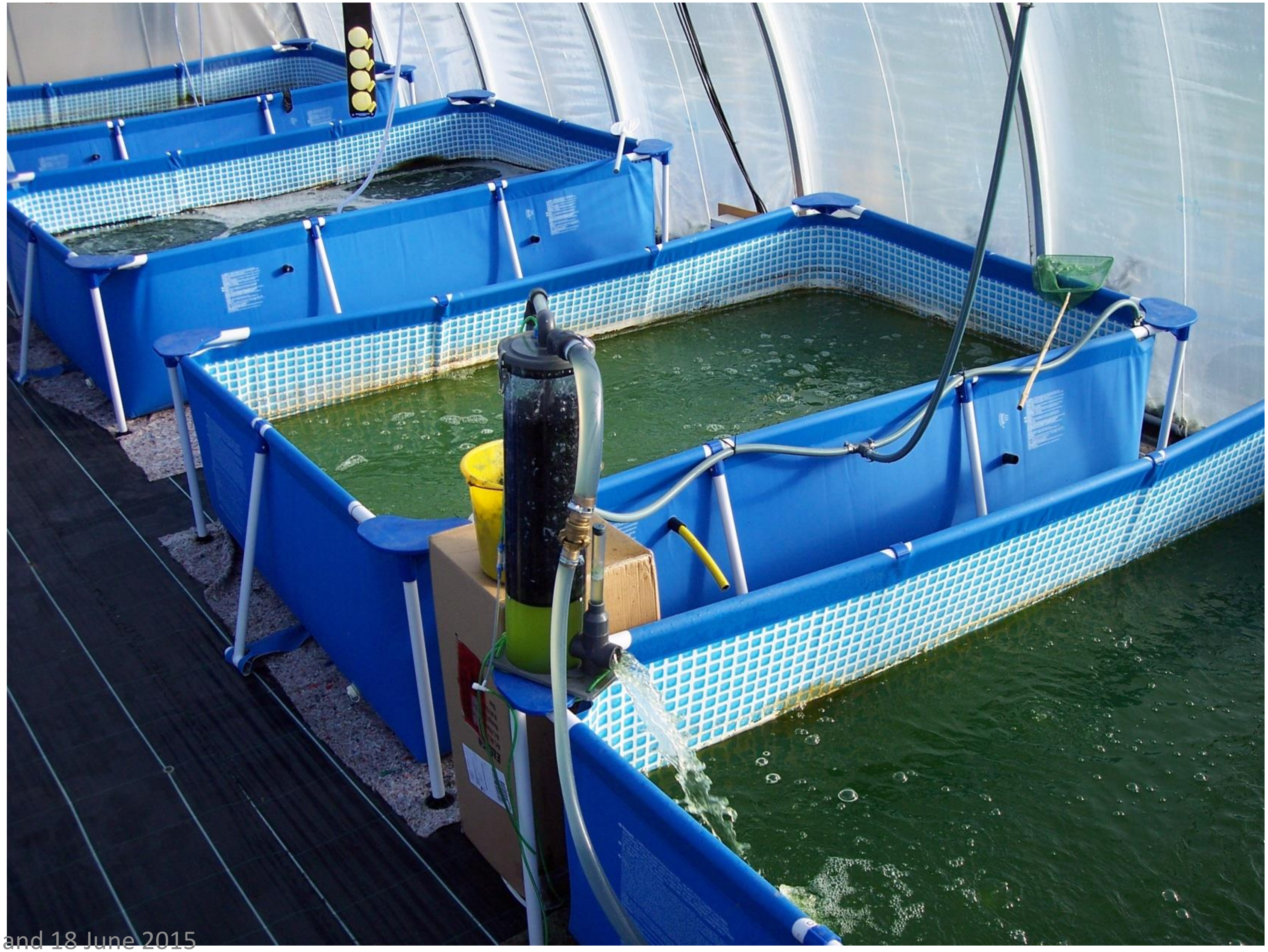
- Differences in the fatty acid composition were observed between the analyzed strains.

- Polyunsaturated fatty acids C18:3 (ALA, GLA), C20:4 (ARA), C20:5 (EPA) and C22:6 (DHA), which are of high nutritional interest were observed in the investigated strains.

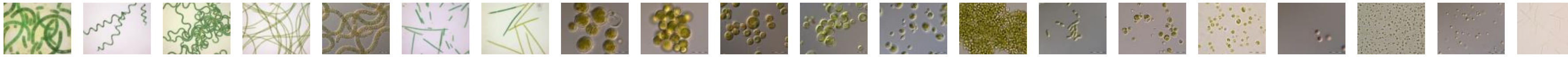
- Saturated fatty acids, which are of interest in biodiesel production were also detected in the investigated strains

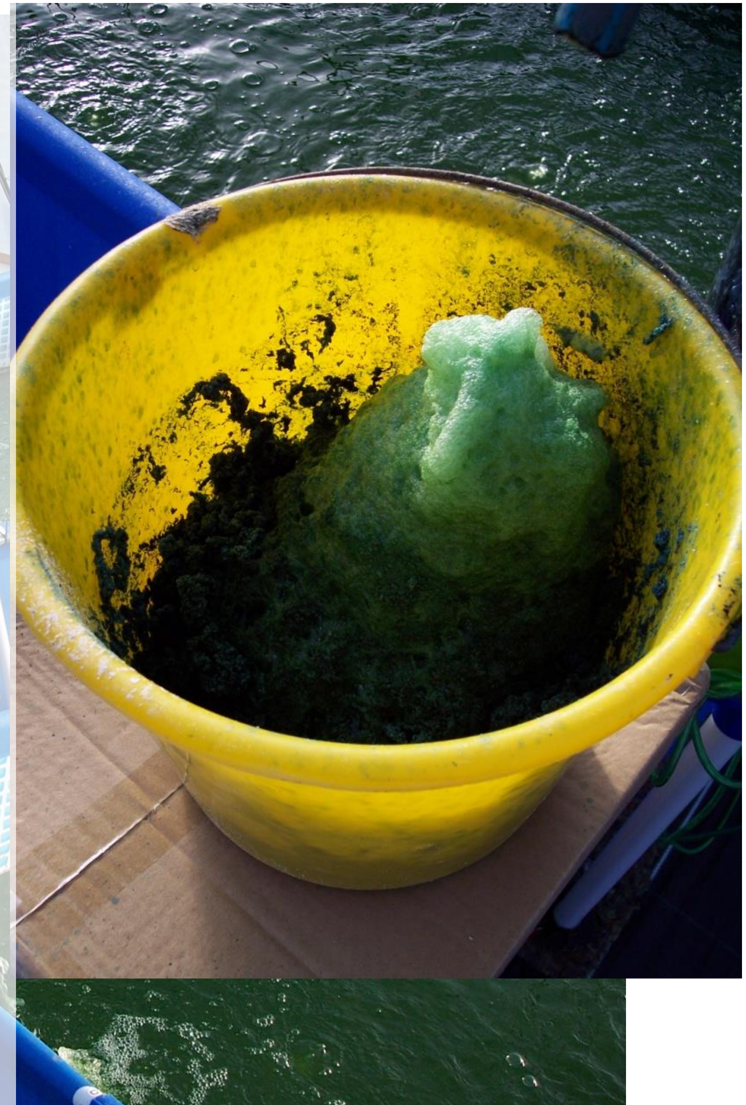
Energy efficient harvesting technique



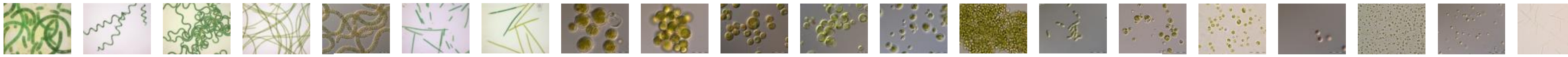


Energy efficient harvesting technique





Database



Dokumentenbibliothek

Spirulina

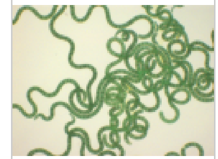
Genus: Spirulina

Species: platensis

Strain number: SAG 21.99

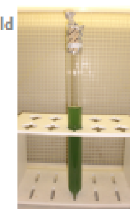
Division: Cyanobacteria

light cycle: 14 hours light, 10 hours dark

Bild


Growth temperature: 26°C

Medium: Spirulina

Bild


Date of receiving from SAG: 15.6.2009

Send to: Kiwiz (18.08.2009); Tocopherol analysis (24.11.2009)

Comment: no growth, infected with fungi (Aspergillus

Result: **fatty acid**: C16:0, C18:2, C18:3.

Bild


Sequence (Accession Nr.): 16S rRNA (DQ393283) and CpcB and

Literature:

PH Wert:

present cultures: yes

Datei einfügen

Datei exportieren

Chlorophyll a (µg/g) 1936.61 (aceton extraction)

Chlorophyll b (µg/g)

Lutein (µg/g)

Beta carotin (µg/g) 162.65 (aceton extraction)

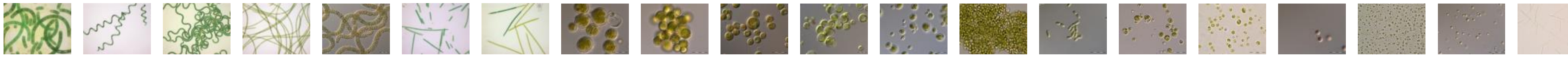
Neoxanthin (µg/g) 203.77 (Aceton extraction)

Violaxanthin (µg/g)

Zeaxanthin (µg/g) 116.19 (aceton extraction)

100 Blättern

Summary



- Microalgae and cyanobacteria are able to generate a large number of economically-interesting substances in differnt quantities dependent on strain type.

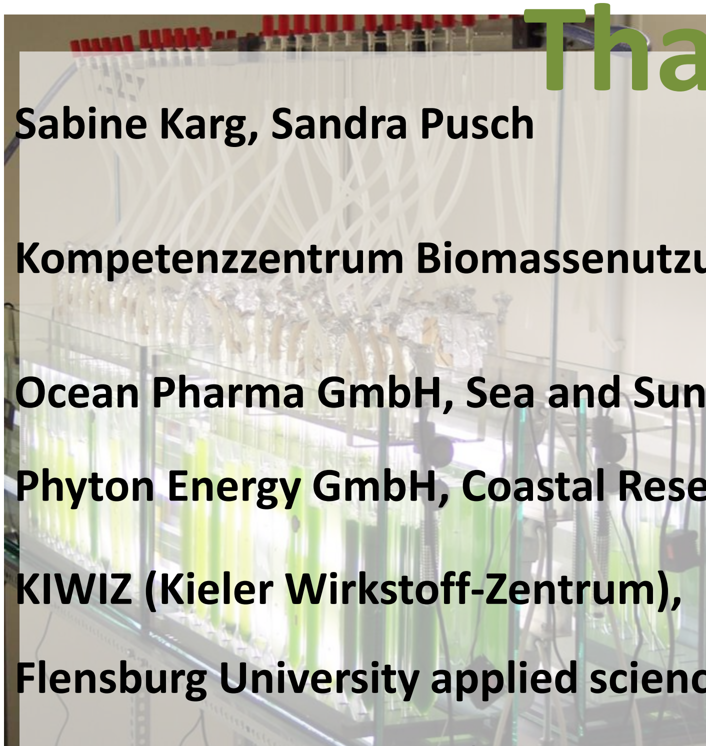
- Compared to crop plants the production of biomass by microalgae and cyanobacteria offers numerous advantages:
  - capability to grow througout the year
  - noncompetitive cultivation on arable land
  - the use of sea water as medium for marine species

- A few drawbacks in the utilization of microalgae and cyanobacteria biomass as substrate are:
  - low production capacity of biomass
  - actual high costs for their cultivation
  - actual energy inefficient harvesting technique

- Selection of good candidate for the optimizing the processe involved in microalgae and cyanobacteria biorefinery, which produce multiple products and bioenergy from biomass.

Kompetenzzentrum Biomassenutzung

Thank you



Sabine Karg, Sandra Pusch — **cultures and more**

Kompetenzzentrum Biomassenutzung SH — **financial support**

Ocean Pharma GmbH, Sea and Sun Organic — **collaboration**

Phyton Energy GmbH, Coastal Research & Management

KIWIZ (Kieler Wirkstoff-Zentrum),

Flensburg University applied sciences (Prof. Born)

Organic Geochemistry (CAU, Prof. Schwark)

Ecophysiology of plants (CAU, Prof. Bilger)

AG Schulz: — team work

Kirstin GuteKunst, Karoline Schreiber, Claudia Marquardt, Tatjana Liese, Susanne Mang, Heinrich Burgstaller, Lena Göthlich, Yingying Wang, Kevin Nack, Inga Koopmann, Nadja Schmidhuber