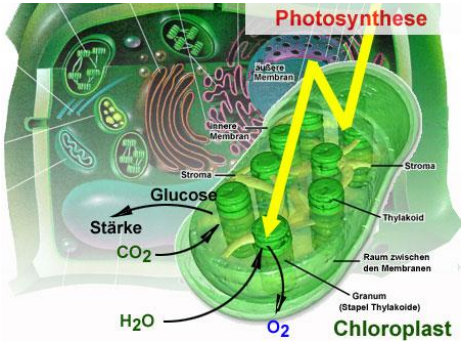
Microalgae

Microalgae: Systematic and diversity

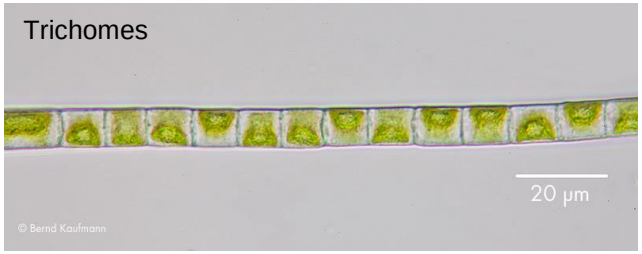
- **Microalgae functional definition:**

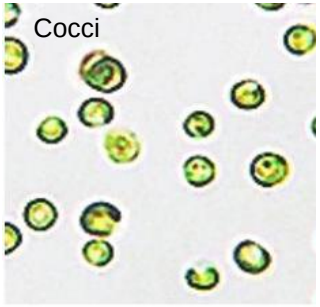
  Organisms capable of performing photosynthesis.

  These include:
  - Prokaryotes (Cyanobacteria & Prochlorobacteria)
  - Herbal protists (herbal progenitors)
  - Many mixotrophic representatives (auto and heterotrophic)



- **Life forms:**
  - Trichomes (multicellular filaments)
  - Cocci
  - Flagellates
  - Colonies (three-dimensional)





Microalgae culture

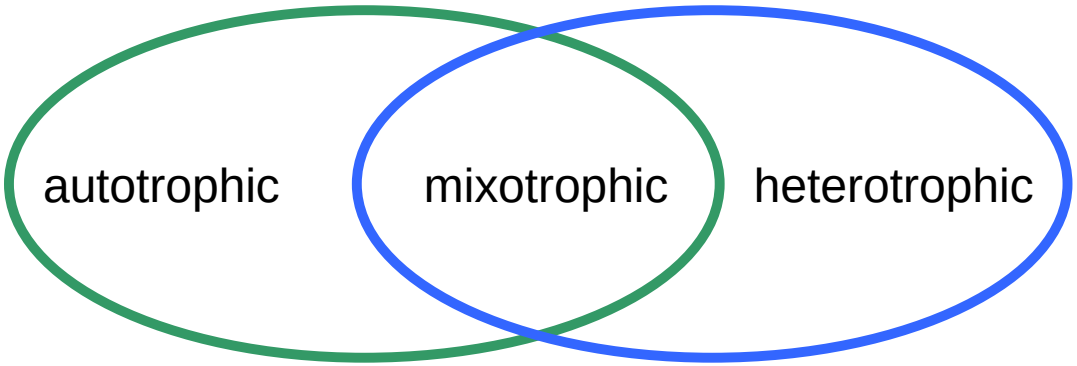
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Microalgae: Metabolism

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

- **Autotrophy**
  - Energy production by inorganic substrates (phototroph = by light)

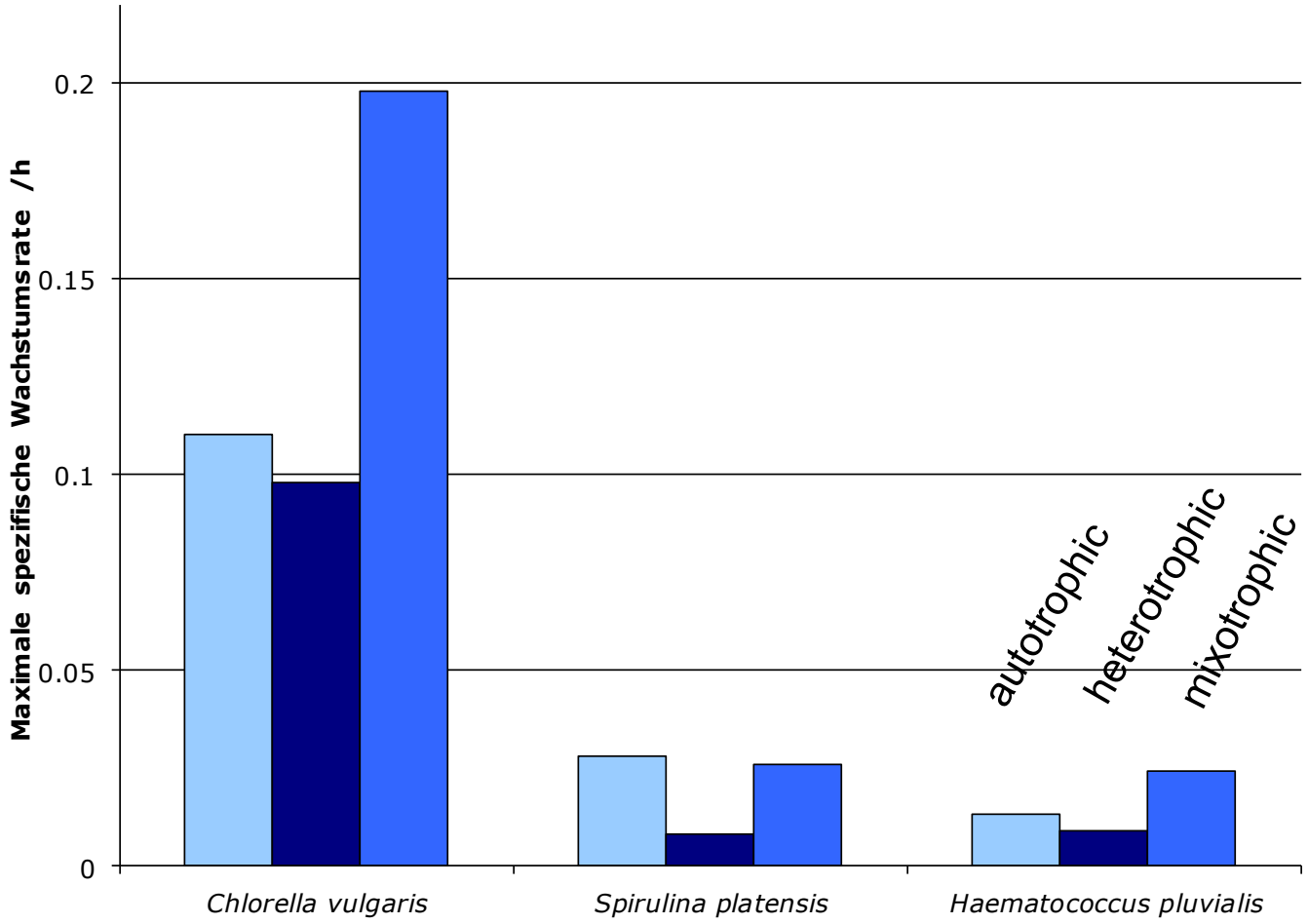
- **Heterotrophy**
  - The ability or requirement to synthesize all metabolites from organic compounds



HELMHOLTZ ASSOCIATION

Microalgae culture: Metabolism

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG



Microalgae culture

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Copyright Phytolutions

Copyright Phytolutions

Copyright Phytolutions

HELMHOLTZ ASSOCIATION

Microalgae culture: Culture parameters

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Culture medium/nutrients

Temperature

Aeration/mixing

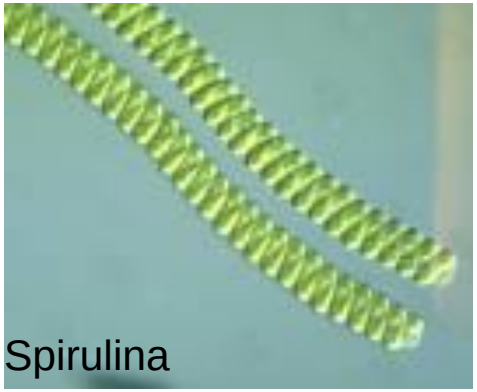
pH

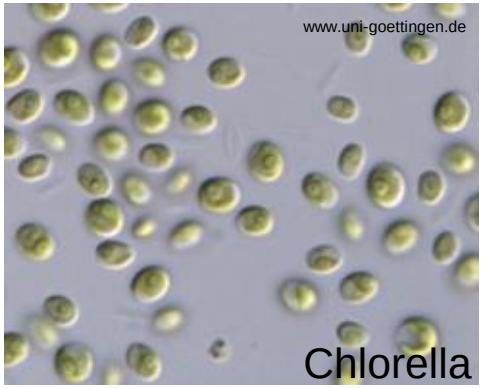
Light

Microalgae culture: Species selection

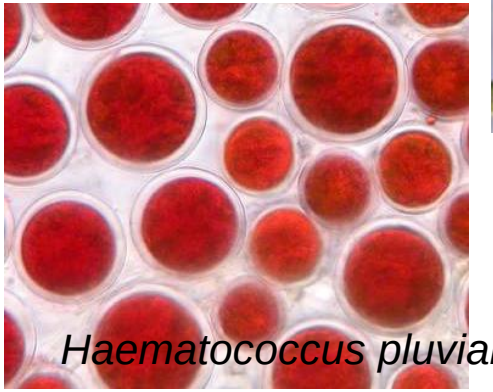
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

- **Species selection**
  - Ease of culture in traditional culturing systems
  - High productivity
  - Important bio compounds
    - Fatty acids;
    - Pigments;
    - Proteins/aminoacids
  - High value biomass


Spirulina



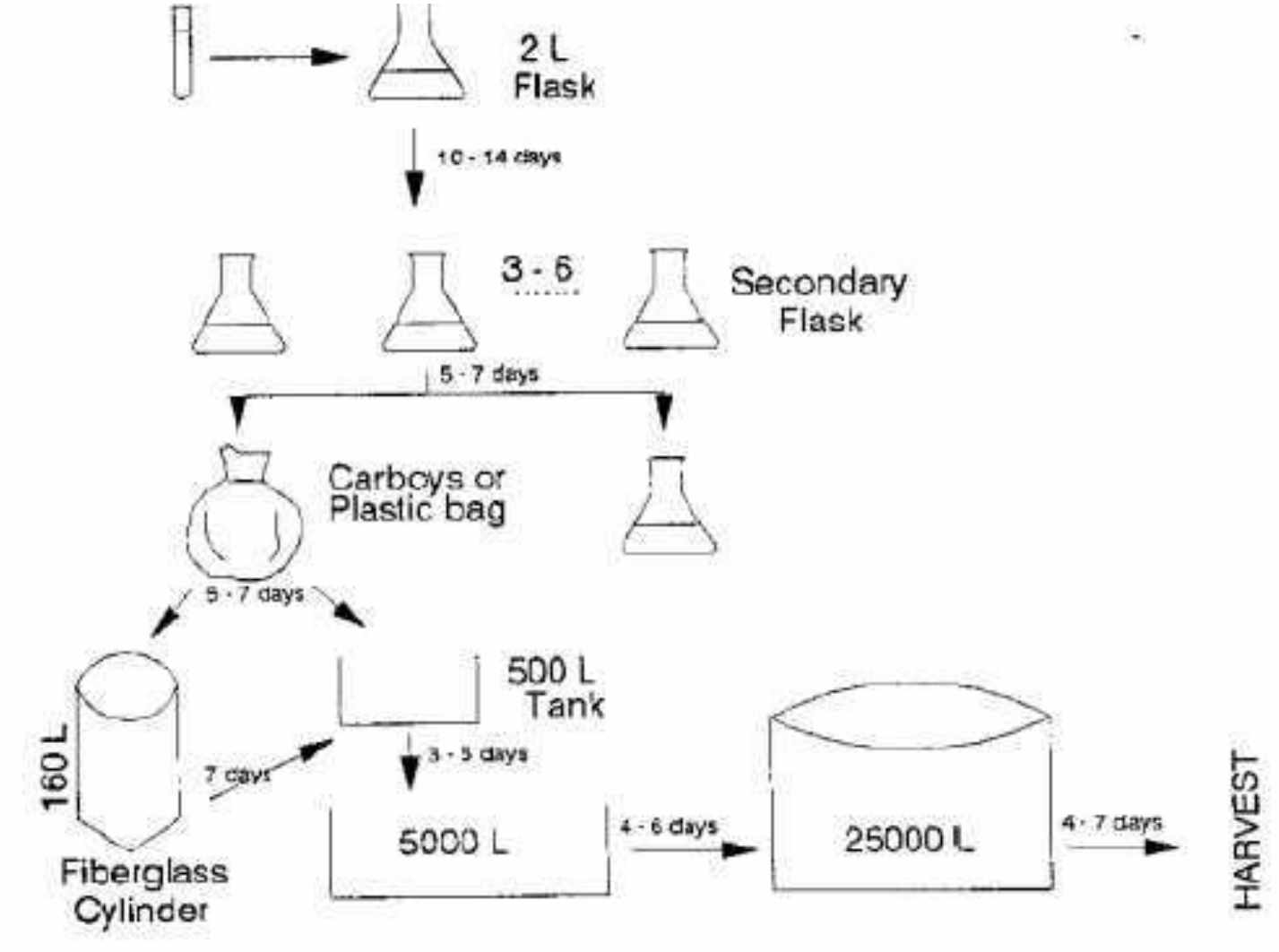
Chlorella


Haematococcus pluvialis

HELMHOLTZ ASSOCIATION

Microalgae culture: Cultivation systems

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG



Microalgae culture: Cultivation systems

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

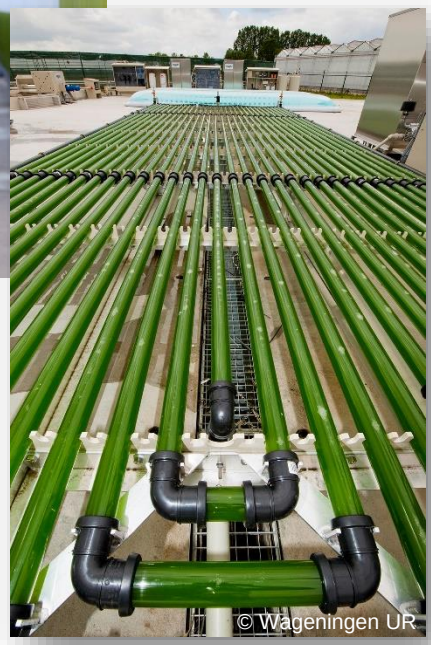
- **Open systems**
  - exposed to the atmosphere / direct exchange between culture and environment

HELMHOLTZ ASSOCIATION

Microalgae culture: Cultivation systems

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

- **Closed systems**
  - largely limited exchange between culture and environment

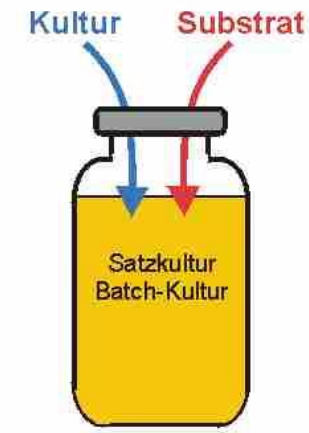


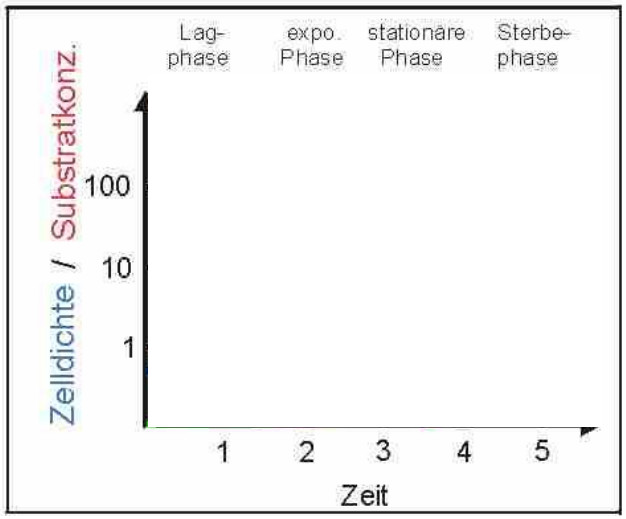
HELMHOLTZ ASSOCIATION

Microalgae culture: Cultivation systems

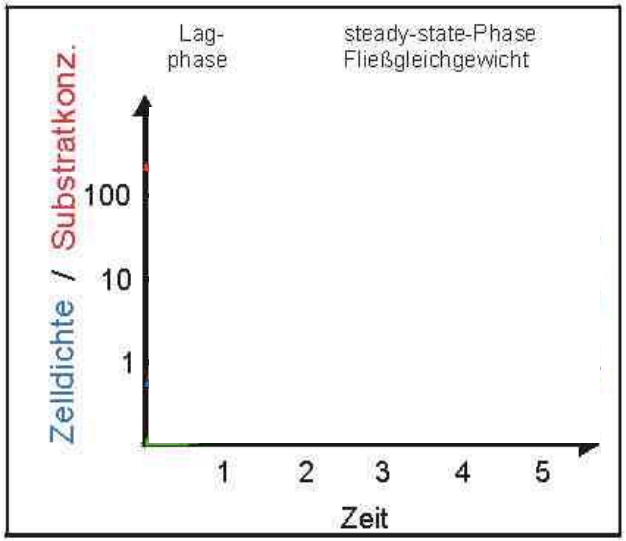
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

- **Batch- and Semi-batch cultures**





- **Continuous cultures**



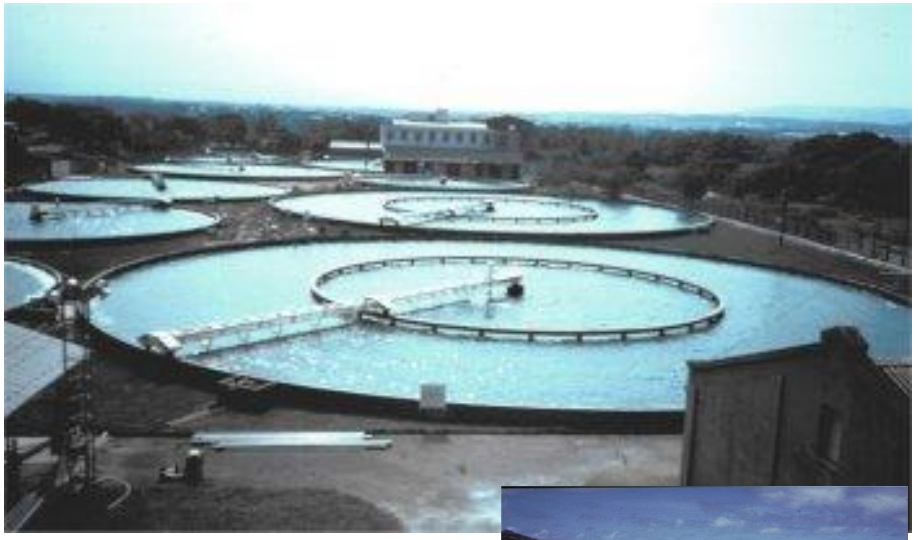
Microalgae culture: Cultivation systems

Open systems: natural water bodies

Burma: harvest with buckets from the lake and linen bags

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

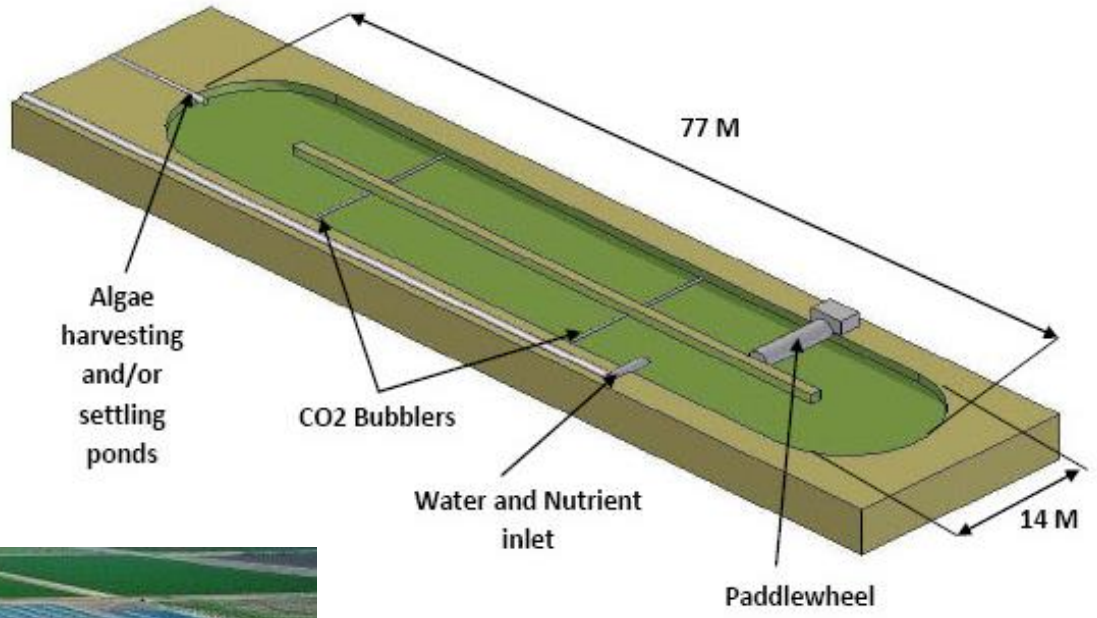
Open systems: open pond or raceway pond



- Low cell densities lead to large amounts of culture
- Frequently extremophilic species
  Dunaliella salina - high salinity
  Spirulina - alkaline medium
  Chlorella - high nutrient concentration
- Simple and cost-effective method

Microalgae culture: Cultivation systems

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG



ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Closed systems: Photobioreactors or fermentors

- Circumvented from the atmosphere
  (Gas exchange prevented - technical supply of gases)

  Tubular systems

  Flat-panel systems

  Plastic bag systems

  etc.

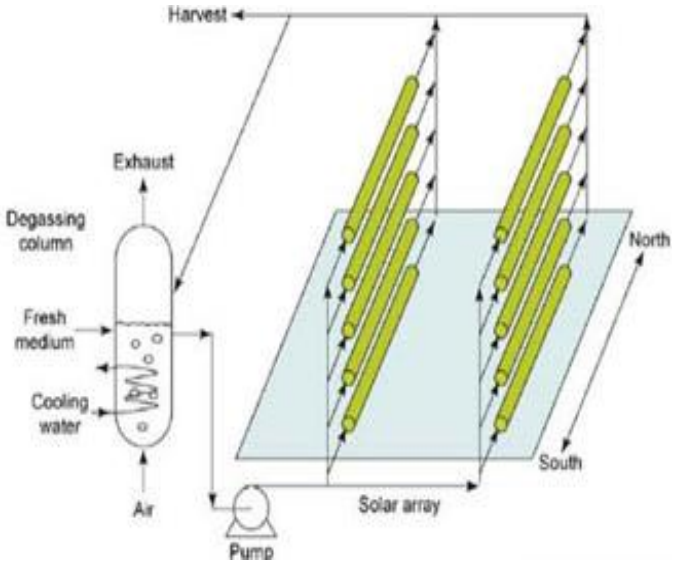
  Fermentors

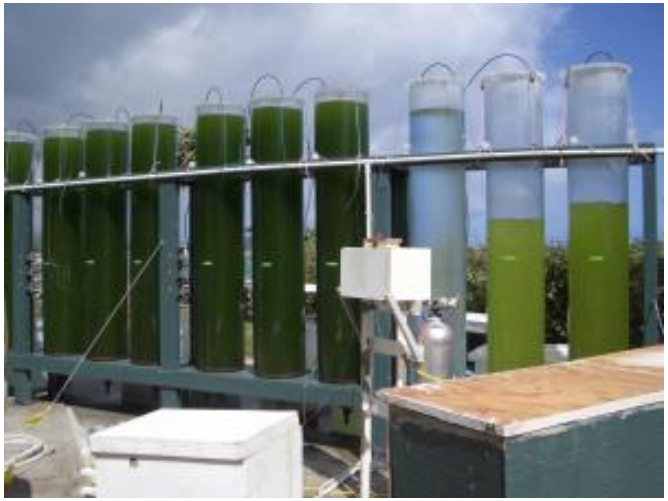
Optimization on photosynthesis performance

Microalgae culture: Cultivation systems

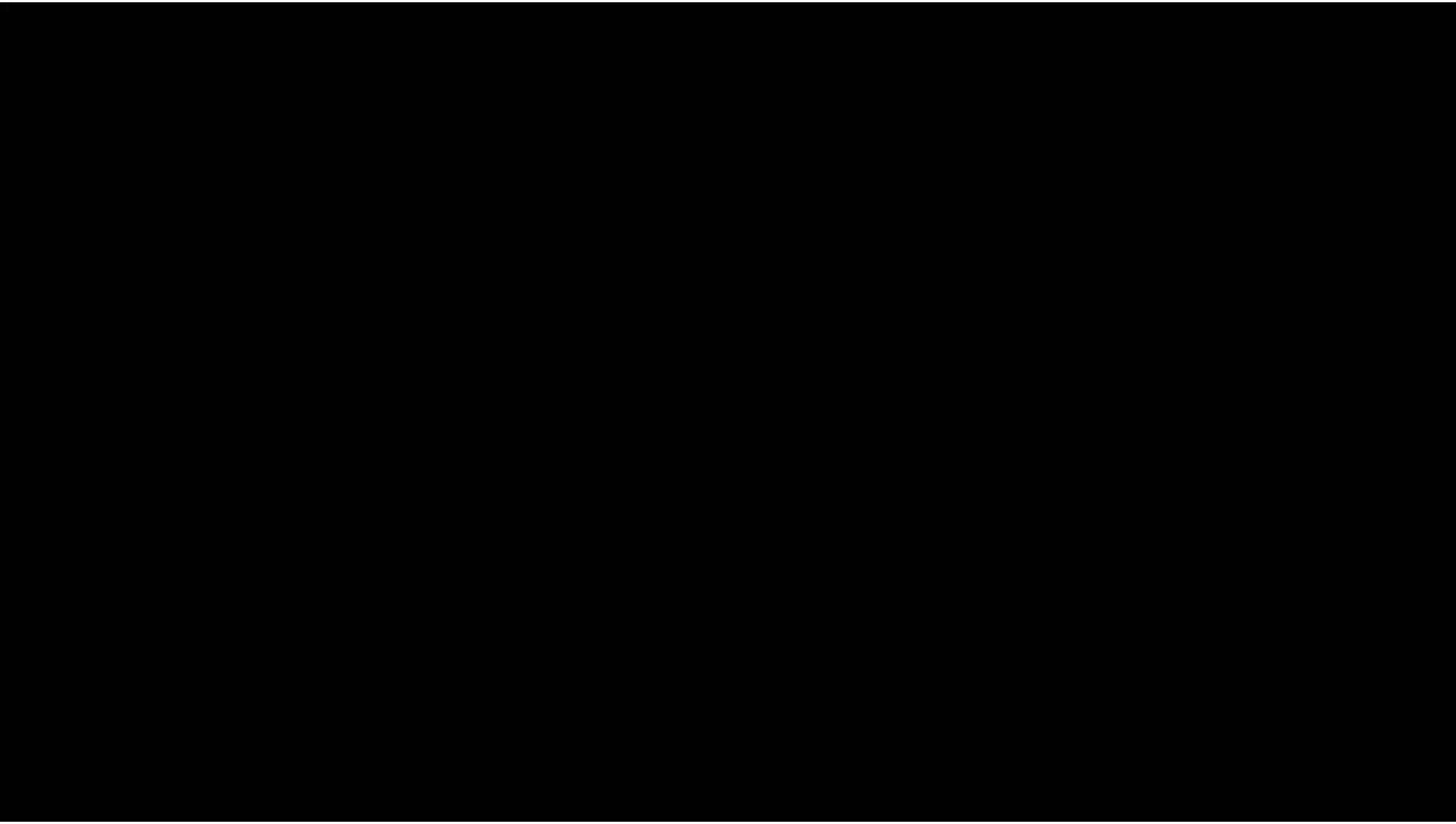
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Tubular systems / PBRs





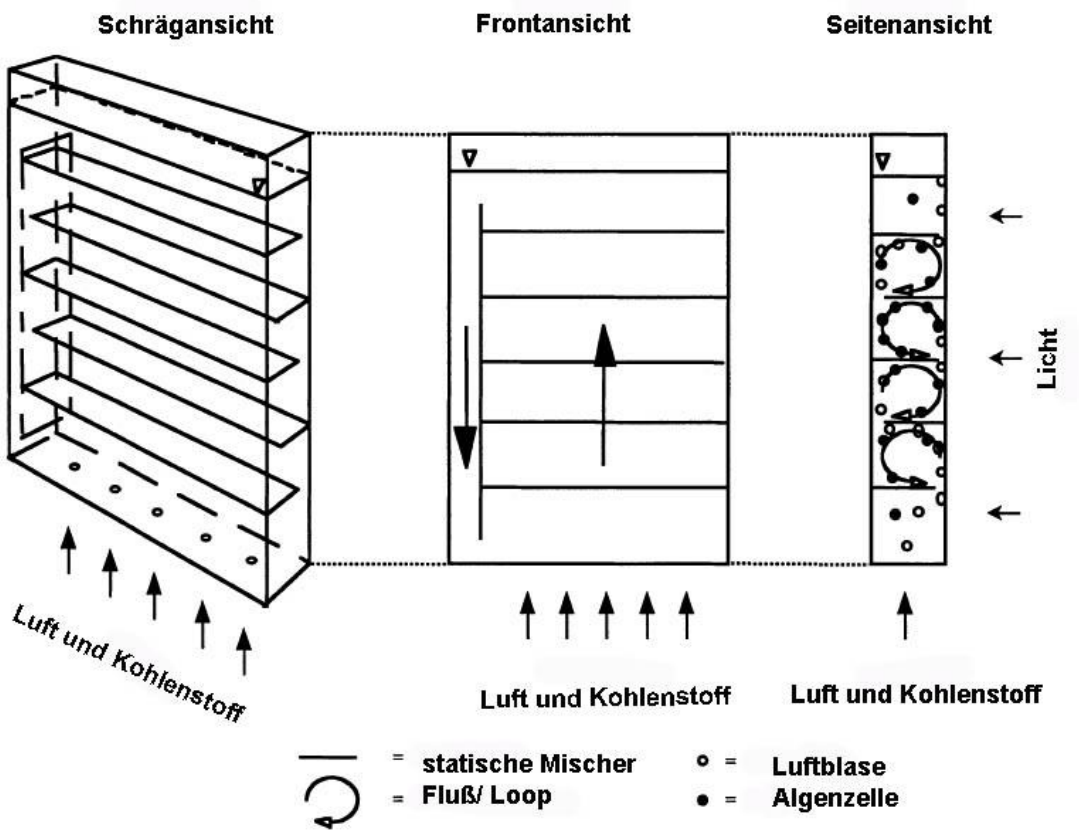
HELMHOLTZ ASSOCIATION

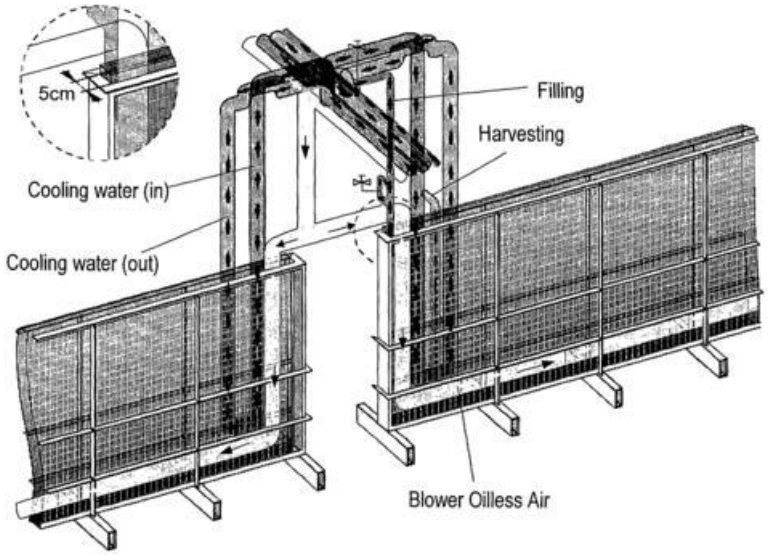


Microalgae culture: Cultivation systems

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Flat-panel systems / PBRs





Microalgae culture: Cultivation systems

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Plastic bag systems / PBRs

HELMHOLTZ ASSOCIATION

Microalgae culture: Cultivation systems

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

HELMHOLTZ ASSOCIATION

Microalgae culture: Cultivation systems

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Merkmal	Offene Systeme	Geschlossene Systeme
Algenart	Begrenzte Auswahl	Flexibel
Populationsdichte	Gering	Hoch
Ernteeffizienz	Gering	Hoch
Kultivierungszeitraum gemäßigte Breiten	Limitiert (z. B. warme Jahreszeit)	Ganzjährig
Verunreinigung	sehr groß	Unwahrscheinlich
Lichtnutzungseffizienz	Gering/mittel	Mittel/sehr gut
Temperaturkontrolle	Keine	Sehr gut
Qualität der Biomasse	Anfällig	Nicht anfällig
Flexibilität der Produktion	Kaum möglich	Problemlos möglich
Vergleichspräzision	Nicht	Zu gewissem Grad möglich
Prozesskontrolle	Nicht	Gegeben
Wetterabhängigkeit	Stark	Insignifikant
Effektivität des „Behandlungs-“ Prozesses	Niedrig, Zeitaufwändig, großes Volumen durch geringe Konzentration	Hoch, kurze Zeit, relativ kleines Volumen

Microalgae culture: Status quo

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

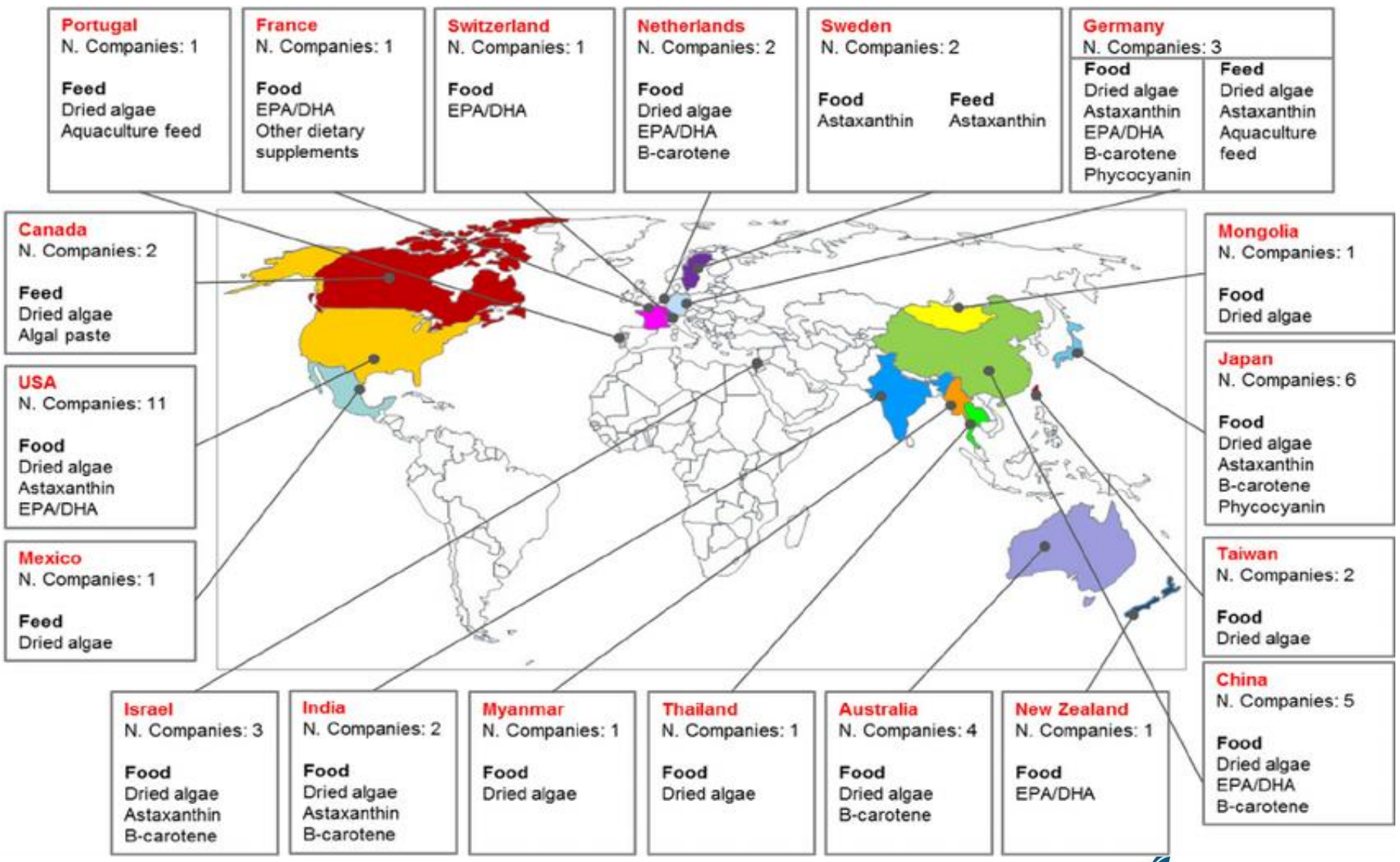
Used culturing systems in global ** and European microalgae companies
from Vieira & Pulz, not publ., from Pulz, 2007.

Culture system	***Europe***	***World****
Heterotrophic	4	7
Phototrophic		
- lakes	1 (+2)***	9
- ponds (open ponds and raceway)	13	41
Closed photobioreaktors	10	9
Total	**28**	**66**
Failed attempts (for 20 years)	20	64

HELMHOLTZ ASSOCIATION

** excl. Europe; *** Production abroad in European possession

Microalgae culture: Status quo



from Vigani et al. 2015

Microalgae culture: Utilization

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

?

Microalgae culture: Utilization

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

- **Products and visions**

  - mostly “high value” products
  - isolated products: dyes, fatty acids for the pharmaceutical industry, cosmetics, etc.
  - energy extraction
  - biomass: food and feed for animals - Aquaculture

HELMHOLTZ ASSOCIATION

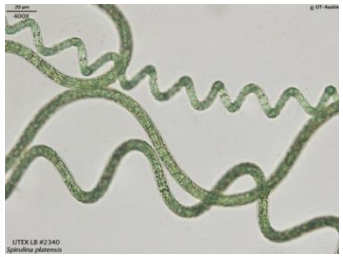
Microalgae culture: Products

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

HELMHOLTZ ASSOCIATION

Microalgae culture: Products

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG



HELMHOLTZ ASSOCIATION

Microalgae culture: Products

Grenzen Sie Ihre Suchergebnisse ein

Beauty & Gesundheit (46)
- Wohlbefinden & Wellness (44)
- Gewichtsreduzierung & Diät (2)

Bücher (3)
- Sachbücher & Ratgeber (3)

Ratgeber zu ähnlichen Produkten

- Spirulina platensis ...
- Hallo Ebayer Augen a...
- ALGENMASKE FÜR DEN K...

Alle Ratgeber zu ähnlichen Produkten aufrufen ...

Suchoptionen

Ort
- Europa
- Artikel in Umkreis von 200 km von 28203

Nur anzeigen:
- Zahlungsmethode PayPal
- Kaufoptionen: Auktionen
- Weitere Kaufoptionen

49 Artikel gefunden für: chlorella (Diese Suche speichern)

Listenansicht | Bildergalerie — Sortieren nach: bald endende Angebote zuerst — Ansicht anpassen

Vergleichen		Artikelbezeichnung	Gebote	Preis*	Versand nach 28203, DEU		Restzeit
☐		Chlorella Vegi-Kaps 120 Stück - Beste HANNES' Qualität	Sofort Kaufen	EUR 14,95	EUR 1,95		5Std. 43Min.
☐		Bärbel Drexel Chlorella Spirulina Guarana WildYams Set	4	EUR 15,60	EUR 5,30	P	5Std. 48Min.
☐		manako® Chlorella Presslinge 2x250g Dose, 2000 Stück	- Sofort Kaufen	EUR 36,90 EUR 39,90	EUR 5,90	P	6Std. 02Min.
☐		Chlorella , ohne Zusätze, rein, 2500 x400mg= 1kg Geprüfte Ware, 1A Qualität!! MHD 4/10	Sofort Kaufen oder Preis vorschlagen	EUR 50,90	EUR 4,90		6Std. 23Min.
☐		CHLORELLA ALGE 250 KONZENTRAT TABS JE 1000 MG NUR 14,90	Sofort & Neu	EUR 14,90	EUR 7,70 Aus Vereinigte Staaten von Amerika	P	6Std. 31Min.
☐		ARNDT, ULRICH: Spirulina, Chlorella, AFA-Algen GEB	Sofort & Neu	EUR 12,90	Kostenlos	P	6Std. 43Min.
☐		SPIRULINA 2500 TAB A 400 MG, 1 KG+BONUS 60 St CHLORELLA	-	EUR 29,00	EUR 6,95 Aus Niederlande		6Std. 46Min.
☐		CHLORELLA 4000 Tbl= 1kg SPITZEN Qualität mitNachweis	13	EUR 61,00	EUR 7,00	P	7Std. 31Min.

Microalgae culture: Products

Grenzen Sie Ihre Suchergebnisse ein

- Tierwelt (145)
  - Fische (141)
  - Reptilien (5)
  - Hunde (1)
- Beauty & Gesundheit (131)
  - Wohlbefinden & Wellness (124)
  - Gewichtsreduzierung & Diät (7)
- Bücher (13)
  - Sachbücher & Ratgeber (11)
  - Studium & Wissen (2)
- Musik (3)
- Garten (2)
- Möbel & Wohnen (1)

Ratgeber zu ähnlichen Produkten

- 100g gesunde Futters...
- Spirulina platensis ...
- ALGEN-SCHLANKHEITSUM...
- **Alle Ratgeber zu ähnlichen Produkten aufrufen ...**

Suchoptionen

Ort

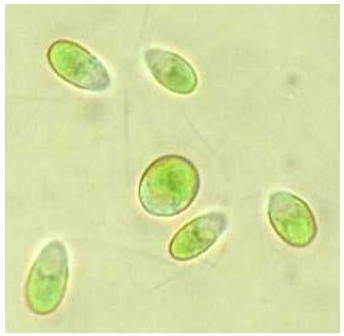
295 Artikel gefunden für spirulina (Diese Suche speichern)

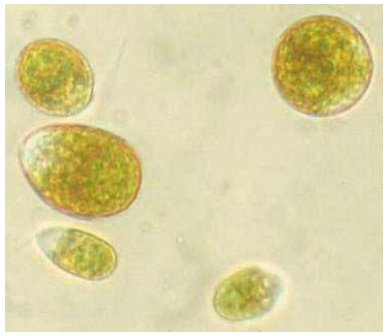
Listenansicht | Bildergalerie Sortieren nach: bald endende Angebote zuerst Ansicht anpassen

Vergleichen	Artikelbezeichnung	Gebote	Preis*	Versand nach 28203, DEU		Restzeit ▲
☐	100%ige reine Spirulina-Tabletten - 100ml	-	EUR 4,99	EUR 1,80 Aus Österreich	P	1Std. 12Min.
☐	Fischfutter Flockenfutter SPIRULINA Premiumqualität 2L	Sofort & Neu	EUR 15,40	EUR 1,90		1Std. 33Min.
☐	Fischfutter Flockenfutter SPIRULINA Premiumqualität 4L	Sofort & Neu	EUR 24,90	EUR 1,90		1Std. 38Min.
☐	1L Koi Pellets 3mm CypriCo Spirulina Koifutter	Sofort & Neu	EUR 4,30	EUR 2,40		2Std. 50Min.
☐	 Natura Vitalis Spirulina Herzdose 1700 Spiruletten	8	EUR 29,05	EUR 3,90		3Std. 18Min.
☐	 Spirulina - green power, 500 Kps. *** SENSATIONSPREIS	-	EUR 8,50	EUR 5,50	P	3Std. 18Min.
☐	Spirulina - die Wunderalge von Frank Felte (2002)	1	EUR 1,00	EUR 1,00	P	3Std. 20Min.
☐	Spirulina die blaugrüne Wundernahrung-Marianne E. Meyer	-	EUR 1,99	EUR 1,60	P	4Std. 16Min.
☐	 PRO-SANA Spirulina PUR 500 Tabletten à 400mg	-	EUR 7,69	EUR 3,50	P	4Std. 43Min.

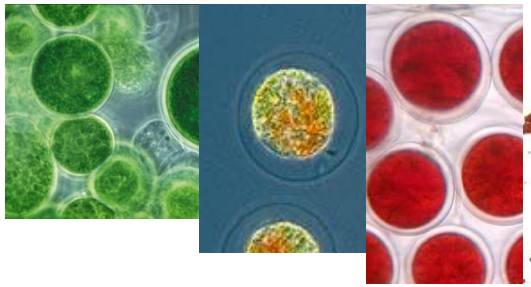
Microalgae culture: Isolated products

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG





Dunaliella salina - Accumulation of carotenoids under stress (orange and red pigments)



Haematococcus pluvialis – red colorant

Astaxanthin

Chlorella – yellow colorant

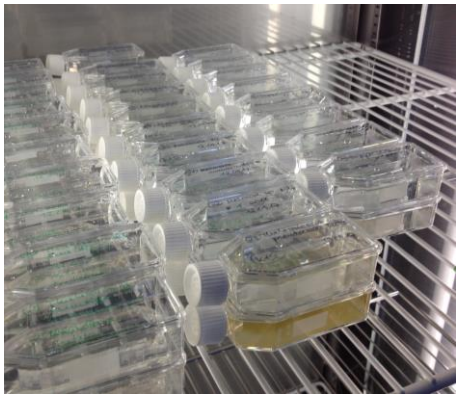
Lutein

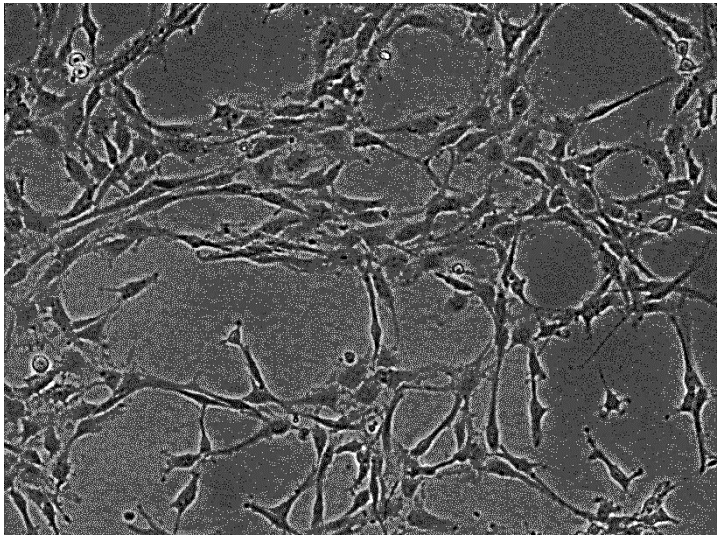
HELMHOLTZ ASSOCIATION

Microalgae culture: Isolated products

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Development of a nutritive and neuroprotective algae combination - the RecAl project





HELMHOLTZ ASSOCIATION

:AWI, University of Bremen, MIAL & CRM

Microalgae culture: Isolated products

RecAl

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

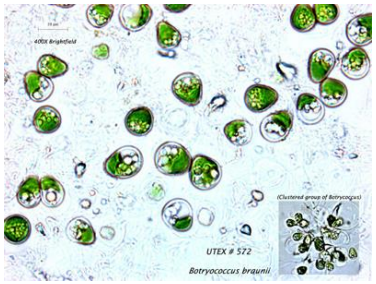
- Algae properties
  - Health promoting effects of specific ingredients e.g. essential aa, PUFA's, vitamins and minerals
  - Substances suitable for a preventive or therapeutic application against neurodegeneration.
- Project aims
  - Develop a formulated, high-quality food supplement (algae extract) from different algae with special emphasis on the neuroprotective effects.

HELMHOLTZ ASSOCIATION

Microalgae culture: Energy extraction

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Possibilities of energy production



Processes	Final product
Extraction and Transesterfication	Biodiesel
Fermentation	Ethanol
Anaerobic digestion	Methan
Gasification	Hydrogen, Syn gas
Drying	Powder

HELMHOLTZ ASSOCIATION

Microalgae culture: Energy extraction

Start:
6.11.08 in Niederaussem

Objective:

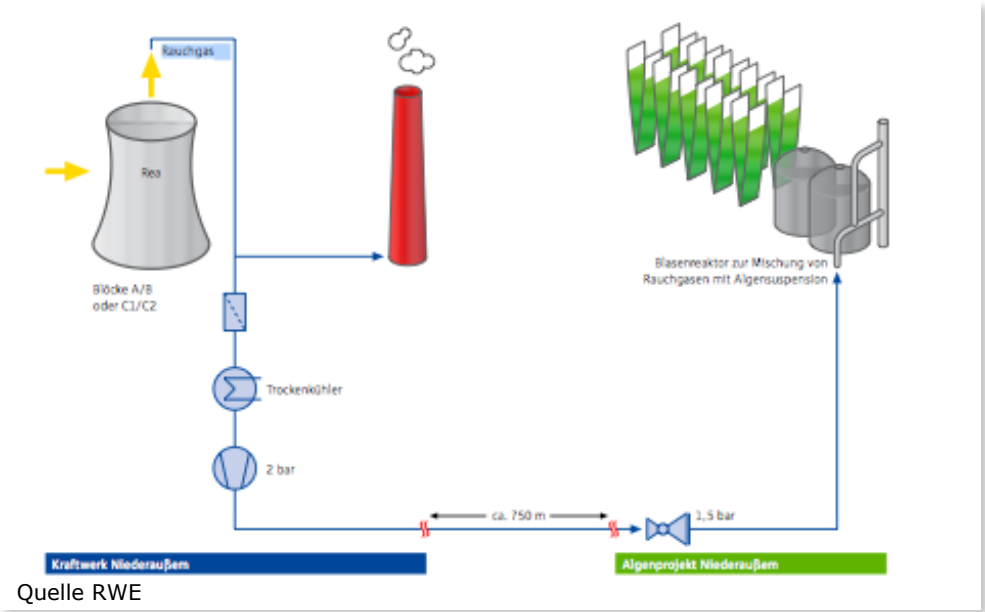
- Investigation of options for flue gas utilization

- Optimization of the complete process chain – from algae production to the final product using waste heat on flocculated algae to produce dried algae for chemical conversion.

Partners:
Phytolutions
RWE
Jacobs-University, Bremen,

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

1000 m^2 photobioreactor installation
Phase 1: in house
Phase 2 (2011): outdoor

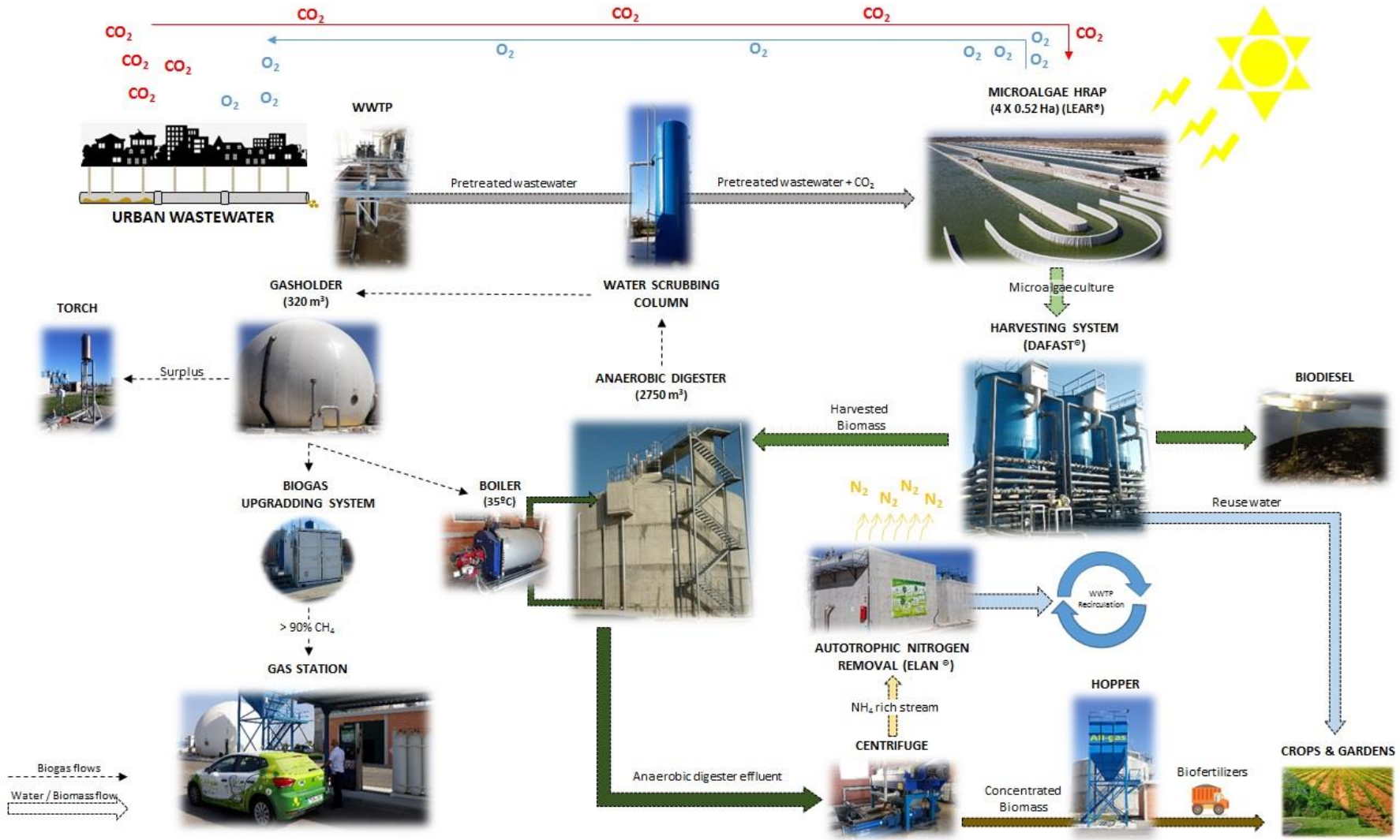


Quelle RWE

Microalgae culture: Energy extraction project

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Microalgae culture: Energy extraction – Project ALLGAS

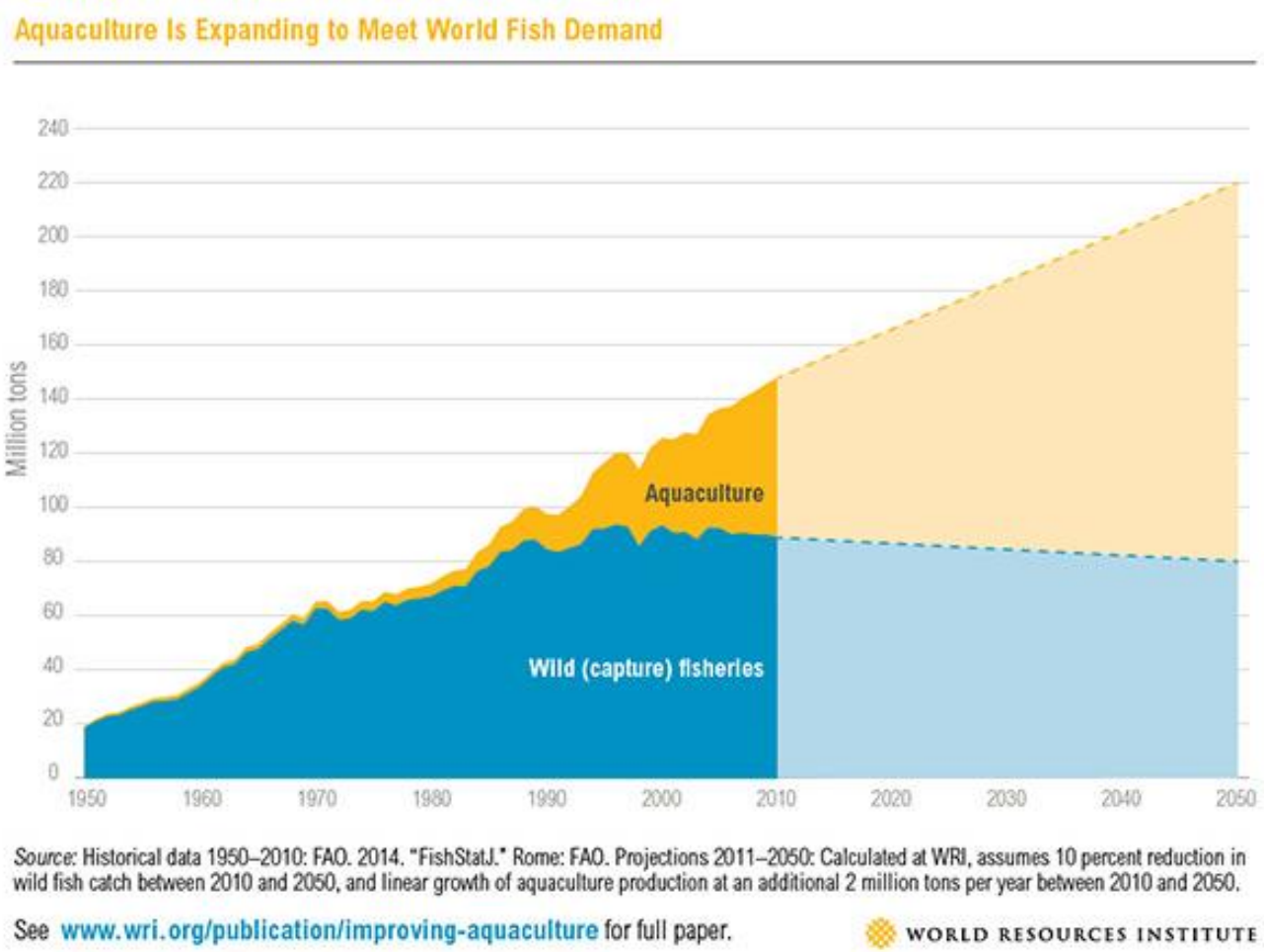


aqualia BDI Fraunhofer HYGEAR University of Southampton

HELMHOLTZ ASSOCIATION

Microalgae culture: Aquaculture

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG



10% reduction in wild fish catch until 2050!

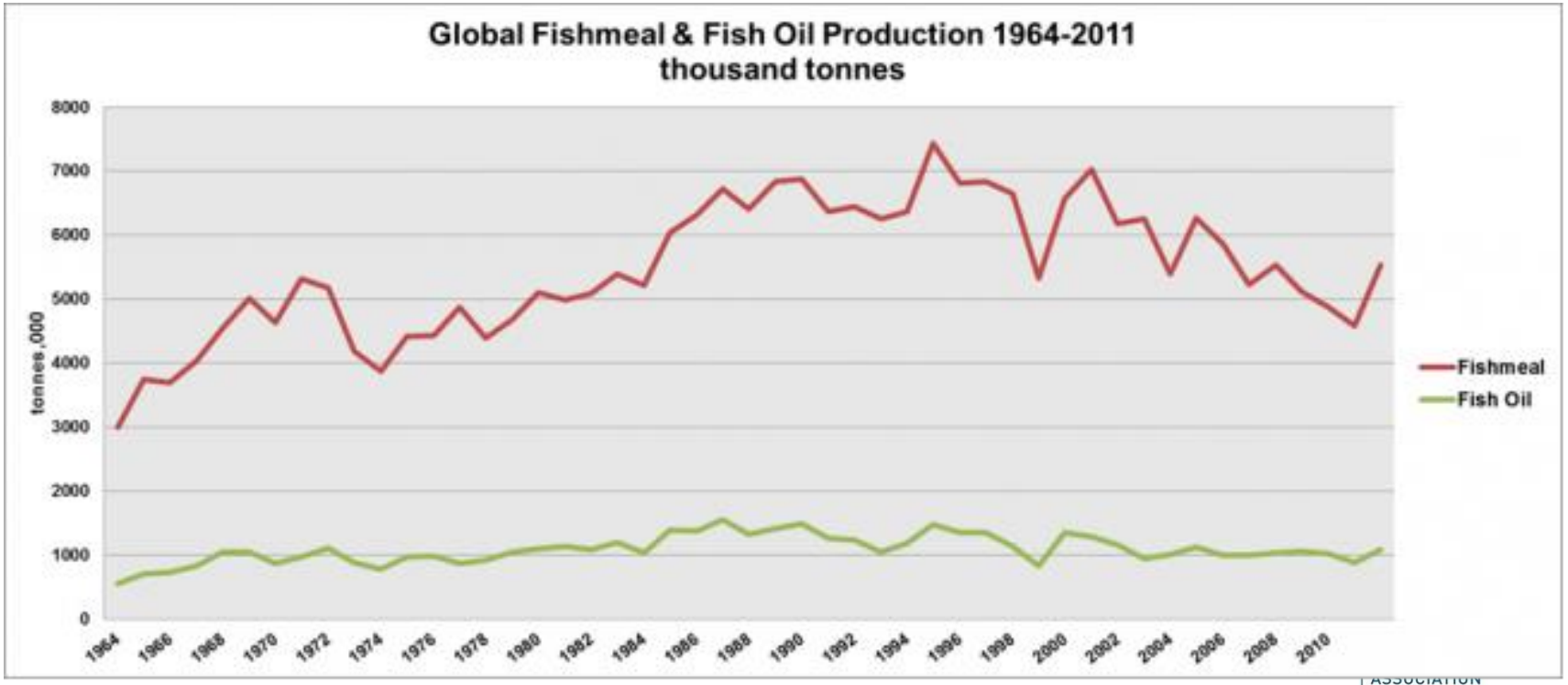
2 M additional ton per year of aquaculture production until 2050; ca. 50% are fed species!

HELMHOLTZ ASSOCIATION

Microalgae culture: for fish oil and/or meal replacement

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

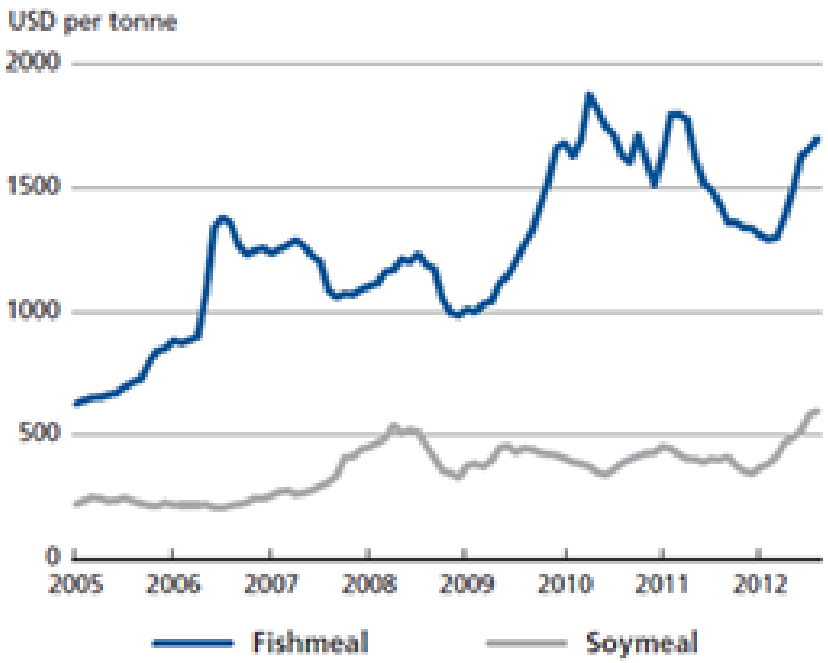
- Fish oil and fishmeal are essential ingredients of aquaculture feed
- Worldwide production of fishmeal and fish oil is stagnating, however...!

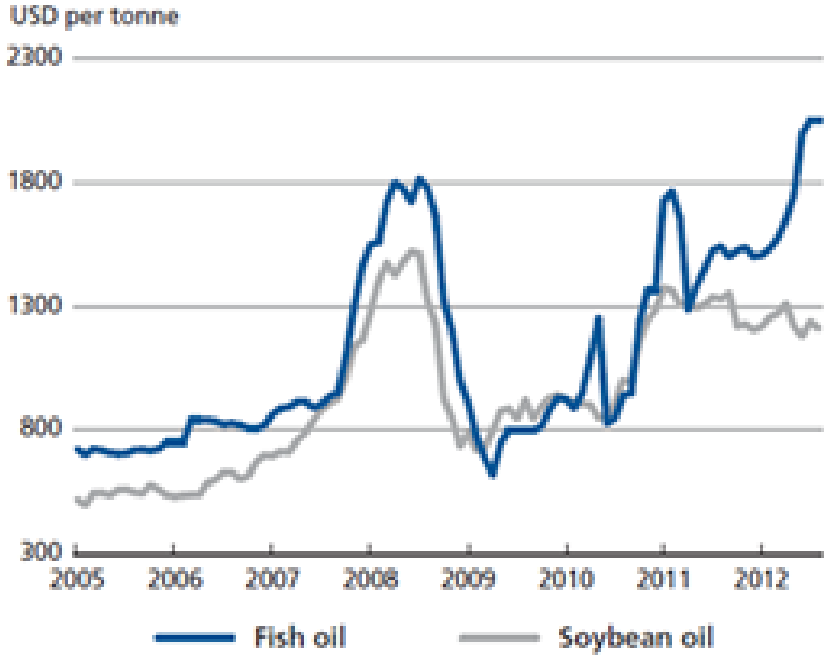


Microalgae culture: for fish oil and/or meal replacement

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

- …prices for fishmeal and fish oil are increasing!
- Prices for alternative protein and lipid sources are also increasing!





HELMHOLTZ ASSOCIATION

The importance of aquaculture

- 2050 an additional **80 M tons** of fish and seafood is required, approx. 50% are fed species!
  - **Question: what should we feed?**
  - Possible alternatives…
    - Vegetable commodities like soya and lupins
    - Byproducts from fish processing and animal production (e.g. heads, frames, viscera, feather and skin)
    - Insects (e.g. larvae black soldier fly)
    - **Microalgae???**

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Microalgae properties of interest for aquaculture

- Good composition of **amino acids** and **fatty acids**
- Strengthening of the **immune system**
- Improvement of **fat metabolism**
- **Antiviral** and **antibacterial** properties, improves intestinal function
- Increase of the **stress resistance**
- Supply of **vitamins**, **minerals** and other **bioactive substances**

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Uses of microalgae in aquaculture

- Replacement of fish oil and/or meal
- Feeding of filter-feeder organisms (e.g. mussels)
- Larval rearing (culture and enrichment of rotatoria, artemia)
- During development stages of shrimp (addition on reaching the Protozoea stage, during the Mysis stages, change to carnivorous lifestyle)
- Integrated Aquaculture (e.g. Aquaponic systems)
- As feed additive / supplement

Microalgae culture: Aquaculture

Tab.: Application of microalgae in aquaculture

Application form	Concentrate/Paste	Powder	Extract
	live	spray dried	water extract
	cooled	drum dried	solution
	frozen	freeze dried	supercritical extraction
Current aquaculture feed	**Nursery**	**Broodstock**	**Premix feed**
	green water	special feed	pigments and omega 3
	crustacean feed	Premix feed	(Astaxanthin, DHA/DPA)
	rotifers feed		
Research		grow-out	grow-out
		fishmeal and fish oil substitute	pigments and omega 3
			(Astaxanthin, DHA/DPA)

Microalgae culture: for fish oil and/or meal replacement

- Commercial application of microalgae **mainly** in niche markets such as larval and broodstock feed so far!

- Reason: Prices for microalgae biomass still so far away from prices of alternative commodities like soya

- BUT!!
  - All major aquaculture feed manufacturers are investing in research to replace fishmeal and fish oil with microalgae!

Microalgae culture: for fish oil and/or meal replacement

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

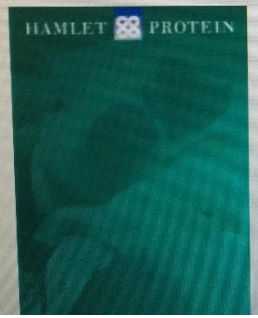
Skretting looks to insects and algae as fishmeal alternatives

By Jane Byrne
30-Jun-2014
Last updated on 01-Jul-2014 at 09:37 GMT

1 comment

Related tags: Skretting, Insect meal, Nutreco, Tilapia, Shrimp, Catfish, Soy, Algae

Nutreco's fish feed division, Skretting, is ploughing a significant amount of its research funds into the development of alternative proteins to fishmeal for the aquaculture sector.



The Dutch group recently organized Aquavision 2014 in Norway around the theme of farmed fish being a key element in feeding the global population of some nine billion in 2050.

Jose Villalon, corporate sustainability director at Nutreco, told delegates during the three-day event in Stavanger that aquaculture can be used as a model for how protein should be farmed in the future as it has far lower feed conversion ratios compared to pig, chicken, lamb and beef production.

Alltech acquires Coppens International, an innovative aquatic feed and nutrition company

June 10, 2016 Featured, Grain & Wheat News No comments

Alltech has acquired Coppens International, a **leading international aquatic feed solutions company** in the **Netherlands**. **Coppens International** is **now part of the Alltech family of companies**, which **includes 14 other companies** that **Alltech has acquired globally since 2011**.

For almost 24 years, **Coppens International** has **earned a strong reputation** for being an **innovative, high-quality aquatic feed producer**. The company's specialties include **temperate and tropical marine and freshwater diets** for a **variety of juvenile and adult species**. The company also produces top-quality ornamental, specialty and bait feeds.

range by
cutting-e
industry

Always th
in Kentuc

The Buzz

BioMar to produce fish feed from microalgae

May 27, 2016
AlgaeIndustryMagazine.com

Denmark-based feed company BioMar will start producing fish feed with omega-3 fatty acids obtained from microalgae, in what it says will reduce the stress on marine resources to provide sustainable feed. The product was developed in a joint venture with TerraVia Holdings and Bunge and will be produced at their renewable oils manufacturing plant in Brazil, BioMar said in a statement.

BioMar CEO Carlos Diaz has a background in both the aquaculture and pharmaceutical industries.

BioMar CEO Carlos Diaz calls the new product a "game changer" as it will reduce stress on limited supplies of omega-3 sources including fishmeal and oil or krill meal, which BioMar uses in its products sold to the aquaculture industry. The added supply will allow the aquaculture industry to grow, he said.

"The collaboration with TerraVia and Bunge goes very well in line with our new strategy as a focused aquaculture feed supplier and it will, for sure, be an important step for continuing the development of

Microalgae culture: for fish oil and/or meal replacement

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

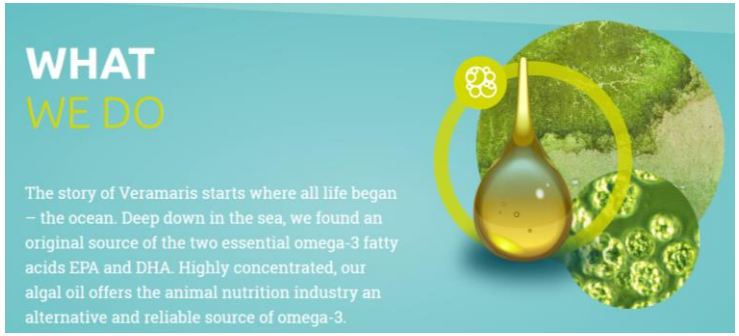
DSM and Evonik establish joint venture for omega-3 fatty acids from natural marine algae for animal nutrition

Share

Kaiseraugst, CH, 08 Mar 2017 08:00 CET

- Breakthrough for animal nutrition to reduce impact on ocean resources and making it more sustainable
- Commercial-scale facility for algal oil for salmon aquaculture and pet food to be built in the United States
- Further develop and produce a high value algal oil with a natural balance of EPA and DHA

Royal DSM and Evonik today announced their intention to establish a joint venture for omega-3 fatty acid products from natural marine algae for animal nutrition. This breakthrough innovation will, for the first time, enable the production of omega-3 fatty acids for animal nutrition without using fish oil from wild caught fish, a finite resource. Evonik and DSM's alternative omega-3 source is the first to offer both EPA and DHA and will be aimed at initial applications in salmon aquaculture and pet food. The companies will together build a commercial-scale production facility in the United States.



OMEGA-3 FROM NATURAL MARINE ALGAE

High-quality omega-3 produced from microalgae enables the industry to continue growing within planetary boundaries. Our product is 100% natural and easy to handle.

RESPONSIBLE SOURCING OF OMEGA-3

We produce our algal oil through fermentation using only renewable resources. Our waste-free process has minimal impact on the environment.

https://www.veramaris.com

Assesment criteria

- Nutrient value and amino acid profile
- Digestibility
- Growth / mortality
- Quality of fatty acids (PUFA, DHA)
- Anti-nutritional factors
- Availability and price

Microalgae culture: for fish oil and/or meal replacement

Tab.: Raw protein content in fishmeal, microalgae and vegetable raw materials (on a dry weight basis) (Data modified from Shields & Lupatsch 2012).

	% Crude Protein	% Crude Fat	% Crude Carbohydrates	% Ash	% Crude Energy MJ/kg
Fishmeal	**63**	11	-	15,8	20,1
Poulty meal	**58**	11,3	-	18,9	19,1
Corn gluten	**62**	5	18,5	4,8	21,3
Soja bean	**44**	2,2	39	6,1	18,2
Wheat	**12,2**	2,9	69	1,6	16,8
Spirulina	**58**	11,6	10,8	13,4	20,1
Chlorella	**52**	7,5	24,3	8,2	19,3
Tetraselmis	**27,2**	14	45,4	11,5	18
Gracilaria sp[1]	**34**	1,5	37,1	26,9	13,4
Ulva lactuca[1]	**37,4**	2,8	42,2	17,4	15,7
Schizochytrium[3]	**12,5**	40,2	38,9	8,4	25,6

[1] Cultured in effluent of fish tanks
[3] Commercial product, Martek Biosciences

Microalgae culture: for fish oil and/or meal replacement

Tab.: Essential amino acids (in EAA in g 100 g^{-1} protein) composition of autotrophically and heterotrophically grown *Chlorella regularis* as well as fish meal and soy bean meal. (Data from Ende in press)

AA in g 100g^{-1} protein)	Chlorella autotrophic	Chlorella heterotrophic	Fish meal	Soy bean meal
Isoleucine	4.21	3.35	5.23	2.63
Leucine	8.08	7.01	6.25	4.18
Lysine	7.74	9.42	6.79	3.50
Phenylalanine	5.08	3.19	3.26	2.46
Methionine	1.25	1.83	2.50	0.99
Threonine	3.62	3.96	3.97	2.06
Tryptophan	1.52	1.40	0.84	n.a.
Valine	5.94	5.05	3.93	1.94
Arginine	5.75	10.24	5.23	4.18
Histidine	1.82	2.98	1.97	1.53

Amino acid composition percent per N x 6.25 in cell weight

Microalgae culture: for fish oil and/or meal replacement

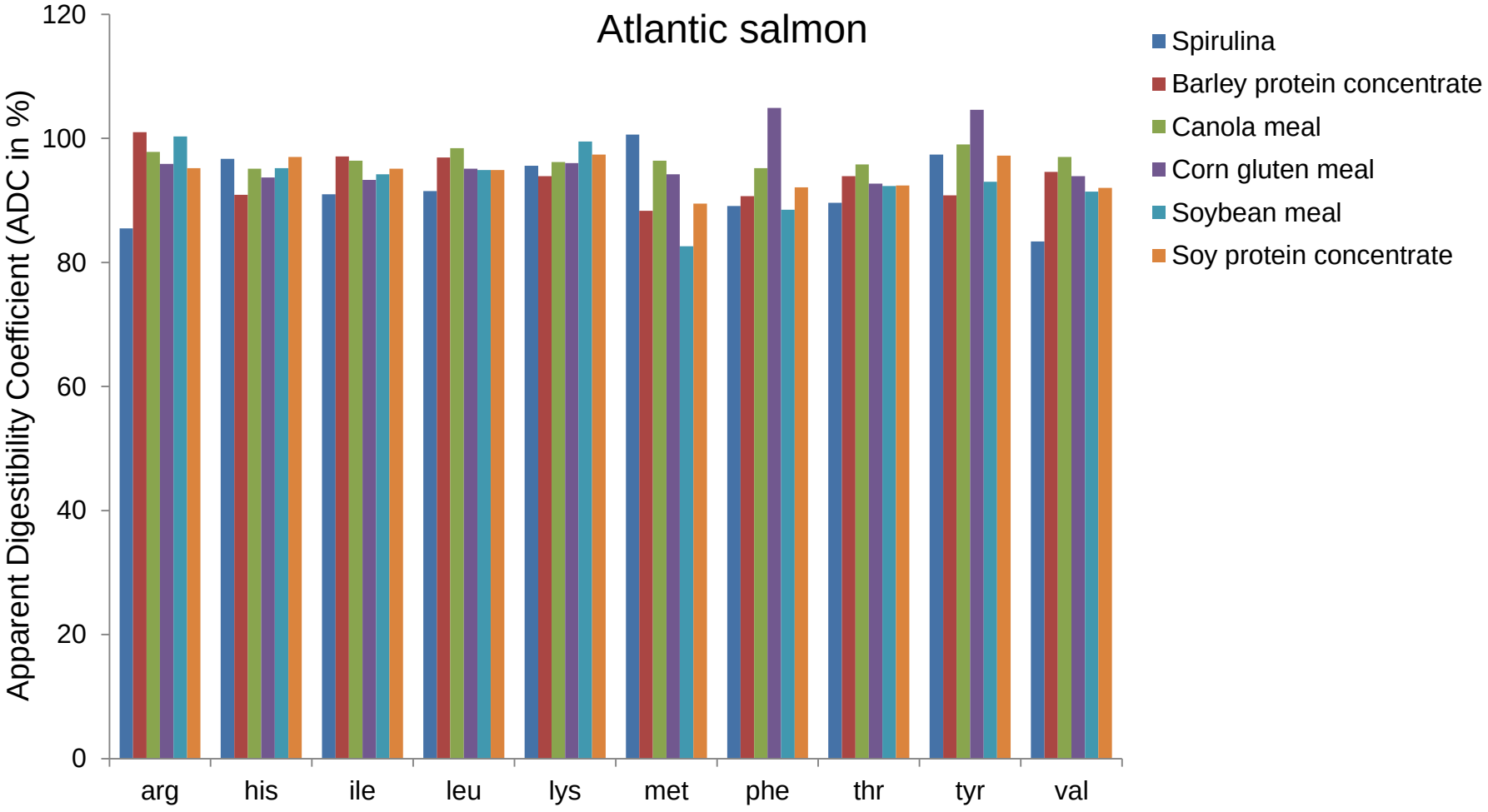


Fig.: **Essential amino acid digestibility** of Spirulina and vegetable raw materials in Atlantic salmon (Data from Burr et al. 2011)

Microalgae culture: for fish oil and/or meal replacement

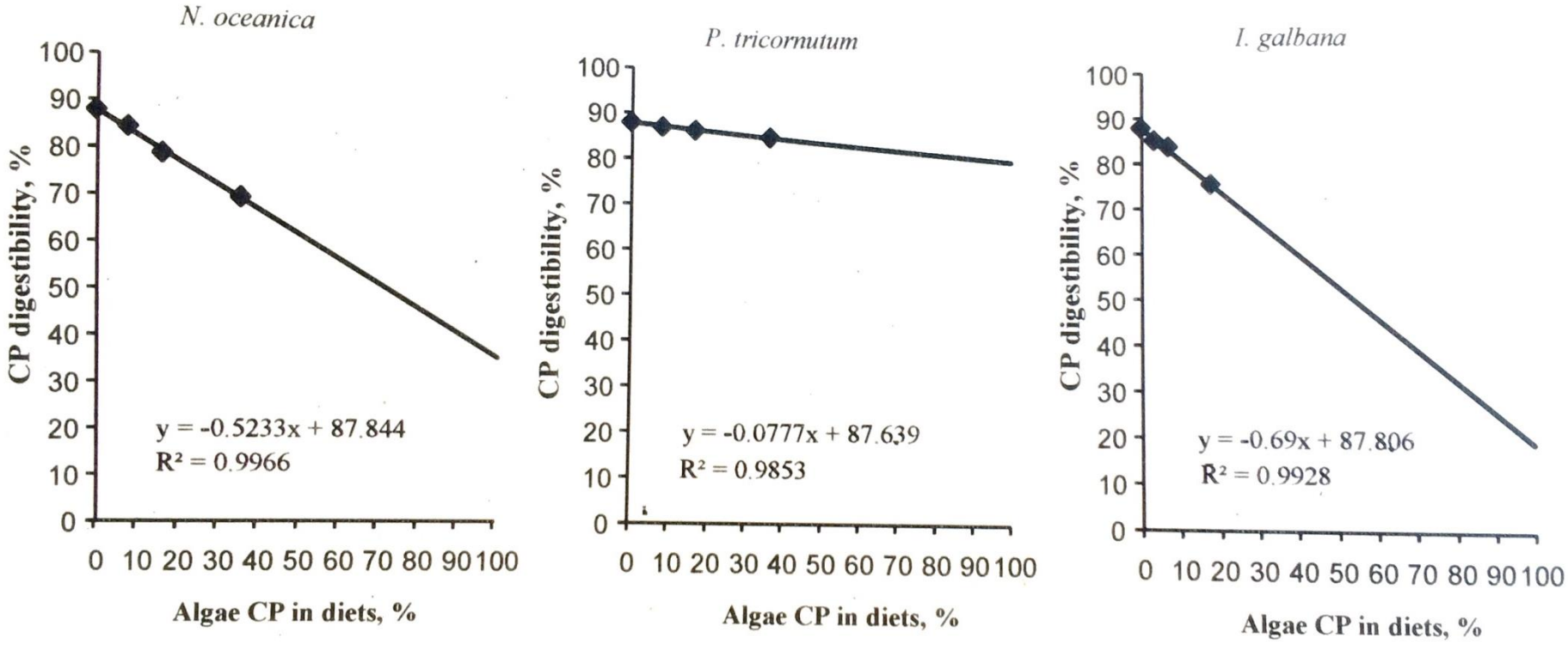


Fig.: **Protein digestibility** as a function of microalgae content in the diet of monogastric animals (mink) including salmonid fish (Data from Skrede et al. 2011)

Microalgae culture: for fish oil and/or meal replacement

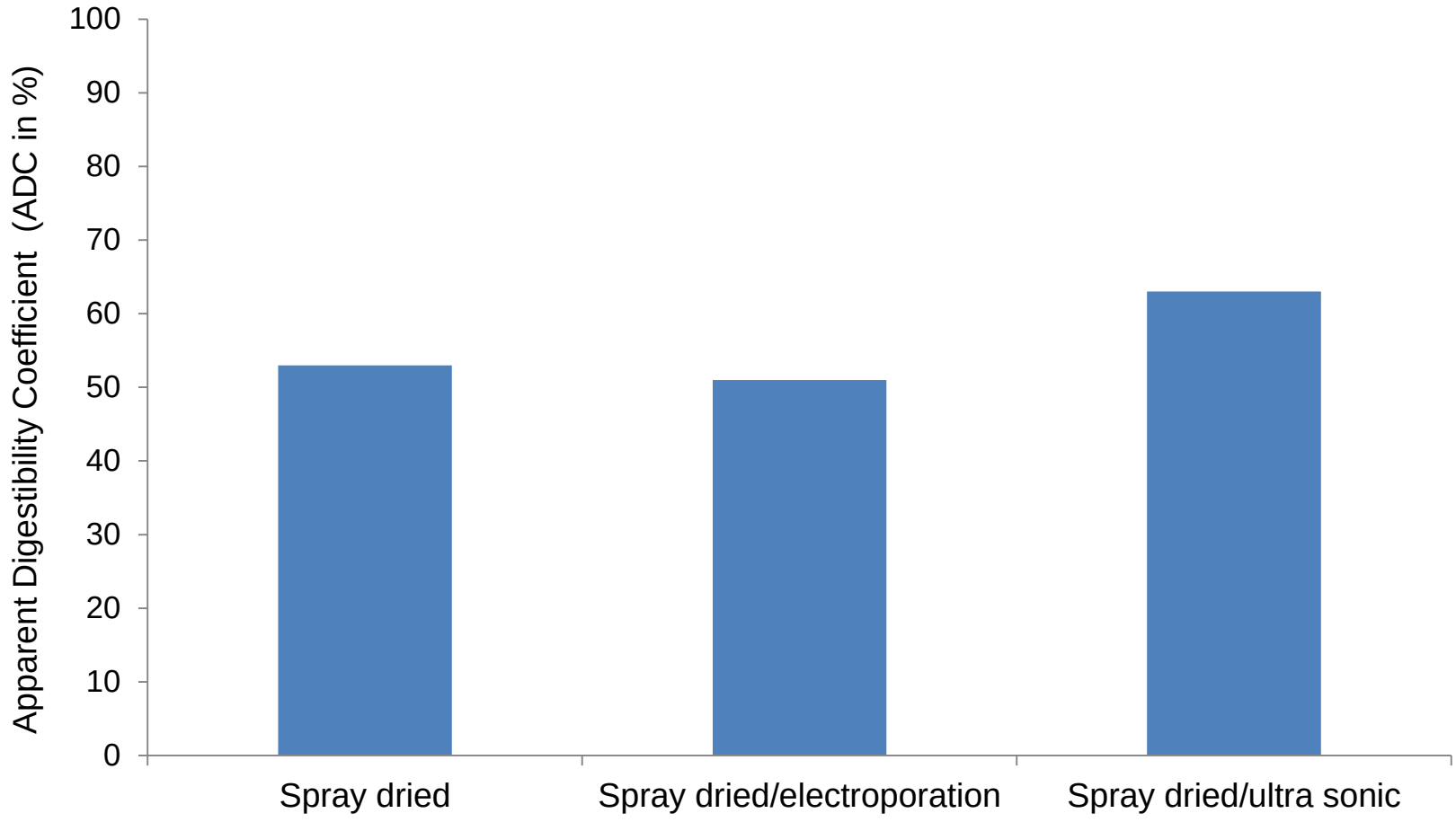


Fig.: **Apparent digestibility coefficient** (ADC in %) of *Chlorella vulgaris* after spray-drying and different pretreatment in rats (Data from Janczyk et al. 2007)

Microalgae culture: for fish oil and/or meal replacement

Fish species	Development stage	Microalgae	Content in feed (%)*	Growth**	Reference
Crucian carp	Larvae	*I. galbana*	100	sign. neg.	Coutinho et al. 2006
Carp	Juvenile	*S. platensis*	25-100%	sign. pos.	Nandeesha et al. 2001
Sturgeon	Juvenile	*S. platensis*	50%	sign. pos.	Palmegiano et al. 2005
Tilapia	Juvenile	*S. maxima*	20-40%	no sign. impact	Olvera-Novoa et al. 1998
Tilapia	Juvenile	*S. maxima*	>40%	sign. neg.	Olvera-Novoa et al. 1998
Atl. cod	Juvenile	*Nannochloropsis+I. sp.*	15-30%	sign. neg.	Walker & Berlinsky 2011
Tilapia	Juvenile	*Desmochloris sp.*	> 50%	sign. pos.	García- Ortega et al. 2015
Atl. salmon	Adult	*Nanofrustulum+Tetraselmis*	≤ 10%	no sign. impact	Kiron et al. 2012
Carp	Juvenile	*Nanofrustulum+Tetraselmis*	≤ 10%	no sign. impact	Kiron et al. 2012
Rainbow trout	Juvenile	*Spirulina sp*	10%	pos. impact	Nikolov 2012
Sturgeon	Juvenile	*Spirulina sp*	50%	pos. impact	Palmegiano et al. 2005
Shrimp	Juvenile	*Nanofrustulum+ Tetraselmis*	≤ 10%	no sign. impact	Kiron et al. 2012

* Proportion of fish meal substituted by microalgae

** Compared to fishmeal-based reference feed without microalgae content

Conclusion

- 9 out of 13 studies show no negative or positive impact on fish growth with partial substitution of fishmeal by microalgae
- Some microalgae with a high protein content and comparable amino acid composition
- High digestibility of protein and amino acids (few studies!)
- Pretreatment has a major influence on digestion coefficients (rats)
- The higher the amount of microalgae, the lower the digestibility

Microalgae culture: for fish oil and/or meal replacement

Tab.: Recent studies on replacement of microalgae biomass of fish oil for aquaculture feed (Data from Shah et al. 2018).

Author(s)	Microalgae species	Aquaculture species	% replacement of fish oil	Effect of microalgae biomass
Qiao et al. 2014	*Nannochloropsis sp* *Schizochytrium sp.*	Olive flounder (*Paralichthys olivaceus)*	100% replacement of fish oil	No negative effects on growth, feed efficiency or nutritive quality
Kousoulaki et al. 2015	*Schizochytrium sp.*	Atlantic salmon (*S. salar*)	Up to 5% replacement of fish oil	No signs of toxicity, stress, inflammation, or any other negative effects of supplementation in diets; fillet quality good
Haas et al. 2016	*Pavlova viridis* *Nannochloropsis sp.*	European sea bass (*D. labrax* L.)	50-100% replacement of fish oil in diets	No negative effects on the growth performance and nutrient utilization of fish
Sarker et al. 2016a	*Schizochytrium sp.*	Tilapia (*O. niloticus*)	100% replacement of fish oil	Improved weight gain, feed conversion ratio, and protein efficiency ratio; no significant change in survival rate

Conclusion

Microalgae biomass as a fishmeal, fish oil substitute or additive mainly dependent on the further development of biotechnology, the resulting availability of microalgae biomass and the price

Microalgae culture: for integrated aquaculture

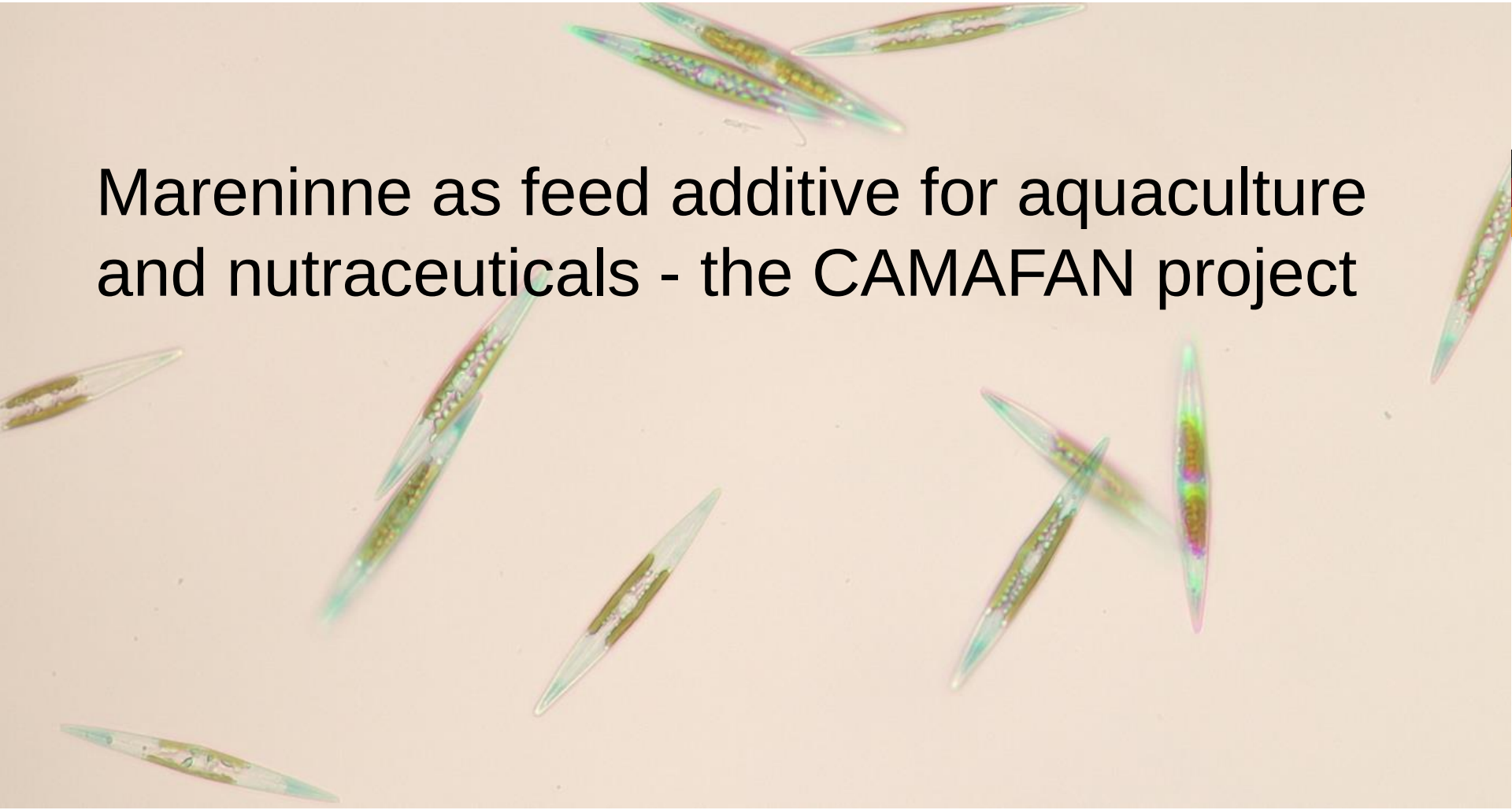
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Fish, crayfish, cropping plants and microalgae in an aquaponic-system - the AquaMoNa project

:AWI, Bell vital & Algatec

Microalgae culture: for feed additive/supplement

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG



Mareninne as feed additive for aquaculture and nutraceuticals - the CAMAFAN project

:AWI, MIAL & IPHAR

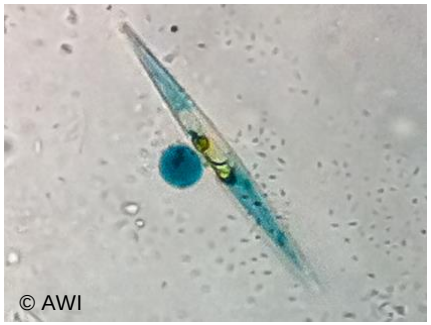
HELMHOLTZ ASSOCIATION

Microalgae culture: for feed additive/supplement

CAMAFAN project

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

- Marennine properties
  - Size ≈ 10kDa
  - Molecule of polyphenolic nature
  - Antioxidant; (Pouvreau *et al*., 2008 J. Agr. Food Chem)
  - Antiproliferative; (Gastineau *et al*., 2012 Aquaculture)
  - Antibacterial;
  - Antiviral;




© https://www.inahalfshell.com/oyster-myths-facts

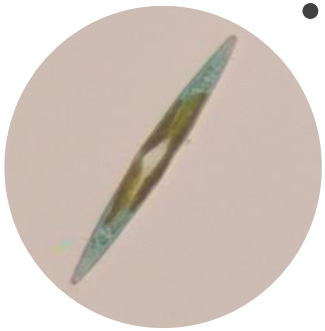
HELMHOLTZ ASSOCIATION

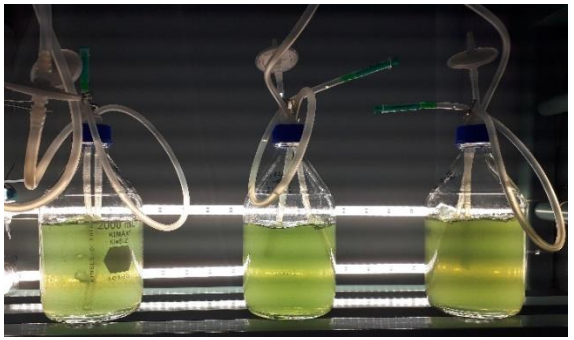
Microalgae culture: for feed additive/supplement

CAMAFAN project

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

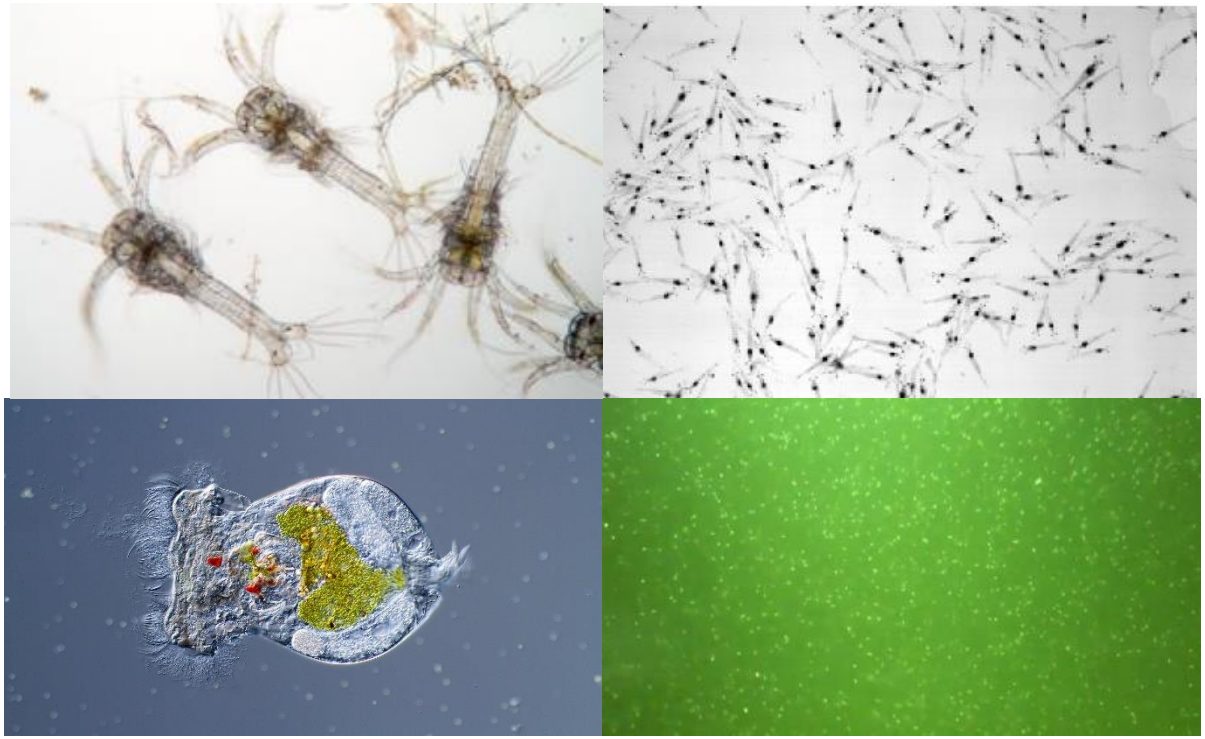
- Project aims
  - Optimization of culturing protocols of *Haslea ostrearia* and marennine production – light, nutrients, photoperiod, salinity*;*
  - Use of marennine in nutraceuticals & aquaculture
    - hatcheries - Oyster larvae
    - in fish feed - Fish juveniles





HELMHOLTZ ASSOCIATION

Application as live feeds in aquaculture



Microalgae culture: Aquaculture

Tab.: Application of microalgae in aquaculture

Application form	Concentrate/Paste	Powder	Extract
	live	spray dried	water extract
	cooled	drum dried	solution
	frozen	freeze dried	supercritical extraction
Current aquaculture feed	**Nursery**	**Broodstock**	**Premix feed**
	green water	special feed	pigments and omega 3
	crustacean feed	Premix feed	(Astaxanthin, DHA/DPA)
	rotifers feed		
Research		grow-out	grow-out
		fishmeal and fish oil substitute	pigments and omega 3
			(Astaxanthin, DHA/DPA)

Microalgae culture: live feeds

Three groups of live diets are widely applied in industrial larviculture of fish and shellfish:

- different species of **2 to 20 µm** microalgae for:
  - bivalves
  - penaeid shrimp
  - rotifers, copepods,...
  - fish

- the **50 to 200 µm** rotifer *Brachionus plicatilis* for:
  - crustaceans
  - marine fish

- the **400 to 800 µm** brine shrimp *Artemia* spp. (meta-)nauplii for:
  - crustaceans
  - fish

Microalgae culture: live feeds

Nutritional value: fatty acids

Table 3 Fatty acid (FA) profile of the microalgae tested. Data are given as mg g^{-1} of dry weight

	Chroococcus sp.	*Synechococcus* sp.	*Isochrysis galbana*	*Pavlova* sp.	*Phaeodactylum tricornutum*	*Porphyridium cruentum*	*Rhodomonas baltica*	*Oocystis* sp.	*Pseudokirchneriella subcapitata*	*Tetraselmis* sp.	*Tribonema* sp.	*Nannochloropsis oceanica*
Saturated												
C12:0	2.1	0.7	–	–	–	–	2.0	–	–	–	–	1.2
C14:0	0.1	5.6	8.9	7.5	8.8	–	4.1	0.2	0.1	0.5	1.1	16.9
C16:0	21.3	3.4	11.5	13.4	16.6	5.9	6.0	3.8	16.2	6.3	2.5	17.2
C 18:0	0.3	–	–	0.4	0.6	0.2	0.8	–	1.3	1.2	0.1	1.8
C 20:0	0.2	–	–	–	–	–	0.1	–	0.2	–	–	–
C 24:0	–	–	–	–	1.6	–	4.0	0.1	0.7	–	–	–
Sum	24.0	9.7	20.4	21.3	27.6	6.1	17	4.1	18.5	8.0.	3.7	37.1
Monosaturated												
C 16:1	1.1	10.8	3.3	12.8	26.0	–	0.4	1.5	1.0	1.3	5.1	18.2
C18:1[c]	0.4	–	13.1	2.9	1.8	0.1	3.4	3.9	31.1	10.7	0.2	4.1
C 20:1[c]	–	–	–		–	–	0.1	–	0.9	0.9	–	0.5
C 22:1[c]	0.1	–	0.6	0.8	0.3	–	0.1	–	0.8	–	–	
Sum	1.6	10.8	17.0	16.5	28.1	0.1	4.0	5.4	33.8	12.9	5.3	22.8
Polyunsaturated												
C 18:2[b]	10.7	–	7.0	2.1	1.5	2.1	11.7	6.4	5.1	2.5	0.2	9.7
C 18:3[a]	1.0	–	3.8	1.8	0.3	–	12.0	8.1	11.4	6.4	–	0.5
C 18:4[a]	–	–	12.5	4.3	3.3	–	5.1	0.7	3.0	4.1	0.1	
C 20:2[b]	0.1	–	–		–	0.3	0.1	–	–	–	–	0.5
C 20:4[b]	0.1	–	–	0.4	2.2	6.0	0.2	0.5	–	0.6	–	3.7
C 20:5[a]	–	–	0.8	18.0	28.4	6.1	4.4	1.1	–	4.8	3.2	23.4
C22:5[b]	–	–	–		1.3	–	0.2	–	2.1	–	–	–
C22:6[a]	–	–	15.8	13.2	0.2	–	–	–	0.1	0.2	–	–
Sum	11.9	–	39.9	39.8	37.2	14.5	33.7	16.8	21.7	18.6	3.5	37.8

ARA

EPA

DHA

Dashes indicate FA not detected

[a] ω-3 fatty acids

[b] ω-6 fatty acids

[c] ω-9 fatty acids

Patil et al. (2007) Fatty acid composition of 12 microalgae for possible use in aquaculture feed. Aquacult Int. 15:1–9

Microalgae culture: larval rearing

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Larvae rearing with rotatoria

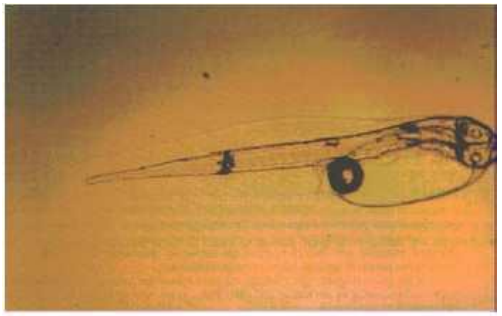


Figure 1.2. Gilthead seabream larva with yolk sac.

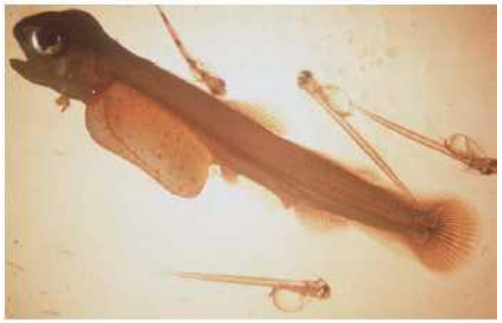
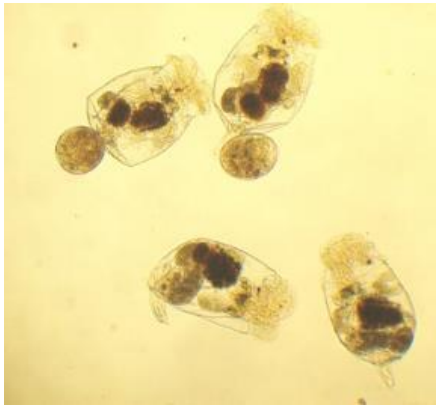


Figure 1.3. Atlantic salmon and gilthead seabream larvae at first feeding.



HELMHOLTZ ASSOCIATION

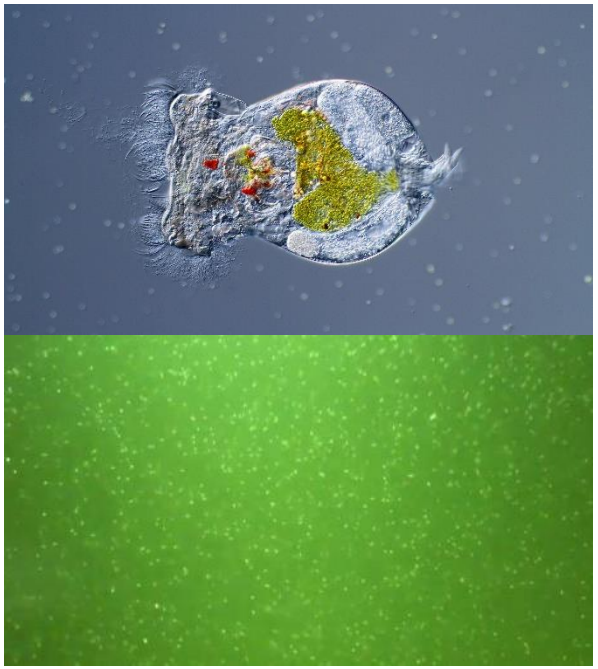
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Rotatoria feeding

Brachionus spp.

- 2-20 microns
- Feeds on microalgae
- Own nutritional profile influenced by fed microalgae

➢ Manipulation of nutritional value by selected combinations of microalgae

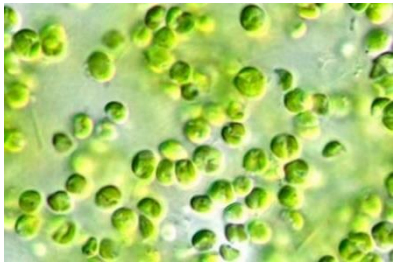


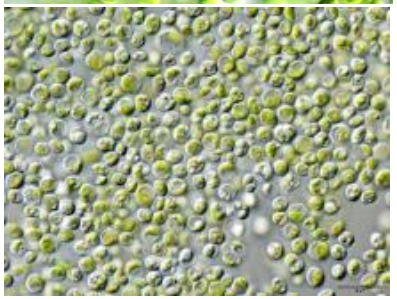
Microalgae culture: live feeds

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Trophic transfer microalgae – *Brachionus* – fish larvae

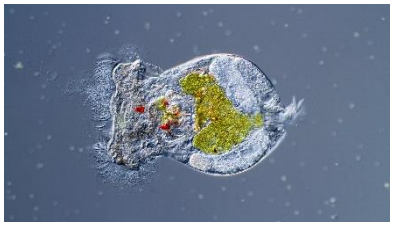
Nannochloropsis oculata



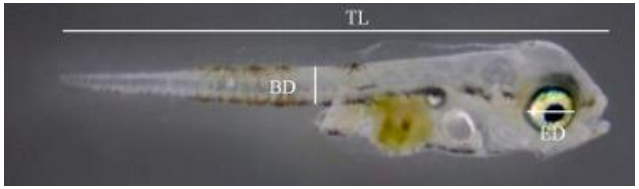


Chlorella vulgaris

Brachionous spp.



Barramundi larvae



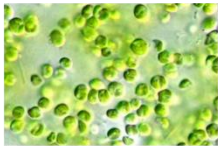
Thépot et al. (2016) Rotifers enriched with a mixed algal diet promote survival, growth and development of barramundi larvae, *Lates calcarifer* (Bloch). Aquaculture Reports (3), 147-158

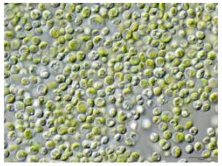
HELMHOLTZ ASSOCIATION

Microalgae culture: live feeds

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

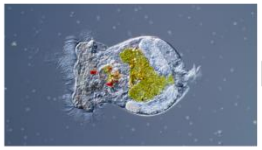
Nannochloropsis oculata



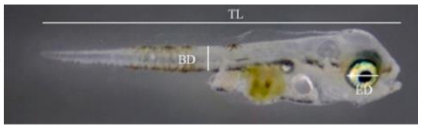


Chlorella vulgaris

Brachionous spp.



Barramundi larvae



- The **fatty acid content** of the barramundi larvae reflected the fatty acid content of their respective diets
- **Microalgal blends** induced equal or better larval performance compared to the monospecific diets.
- The equiproportional blend of microalgae enhanced growth, development and stress resistance in the barramundi larvae.

Thépot et al. (2016) Rotifers enriched with a mixed algal diet promote survival, growth and development of barramundi larvae, *Lates calcarifer* (Bloch). Aquaculture Reports (3), 147-158

HELMHOLTZ ASSOCIATION

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Live feeds for shrimp

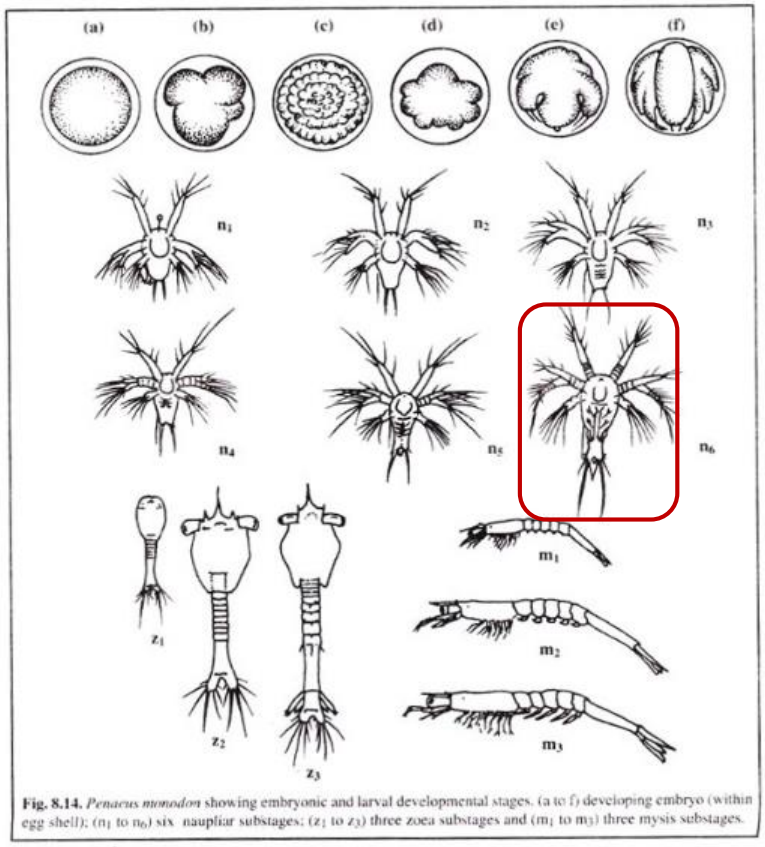


Fig. 8.14. *Penaeus monodon* showing embryonic and larval developmental stages. (a to f) developing embryo (within egg shell); (n_1 to n_6) six naupliar substages; (z_1 to z_3) three zoea substages and (m_1 to m_3) three mysis substages.

Penaeid shrimp

Development of digestive track at stage N6

➢ First feeding

Live feeds for shrimp

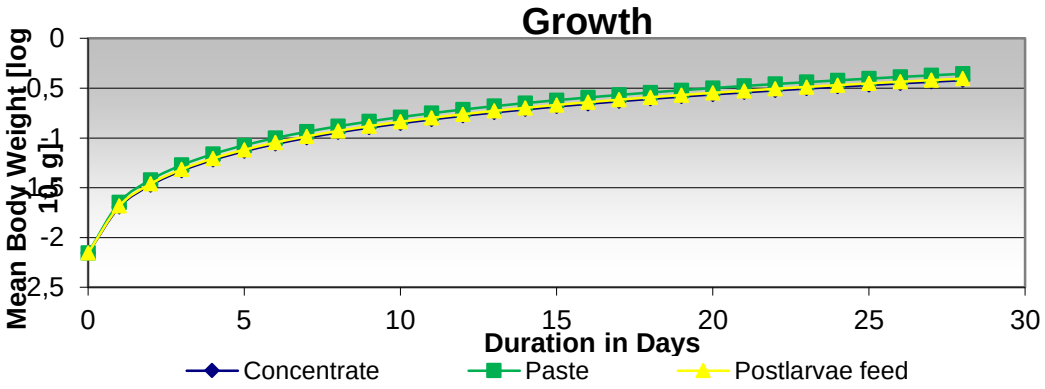
Beneficial effects, direct and indirect:

- **enhanced growth and survival** - also due to the algae's **attractant properties** that stimulate the appetite of the larvae
- microalgae trigger the **digestive system** by stimulating the digestive enzymes such as trypsin
- The presence of microalgae in the prawn larval tanks also **positively affects the bacterial population** in the rearing water and thus contributes to a well balanced gut microbial flora in shrimp larvae

Microalgae culture: live feeds

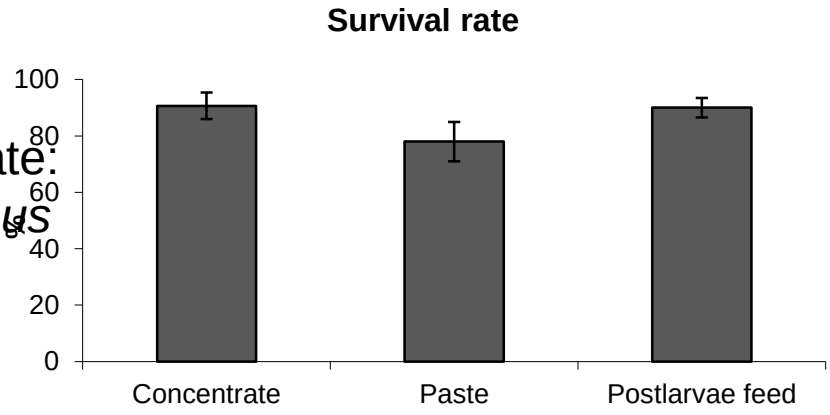
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Microalgae culture: live feeds



Aquaculture candidate:
Postlarvae of *Paeneus vannamei*

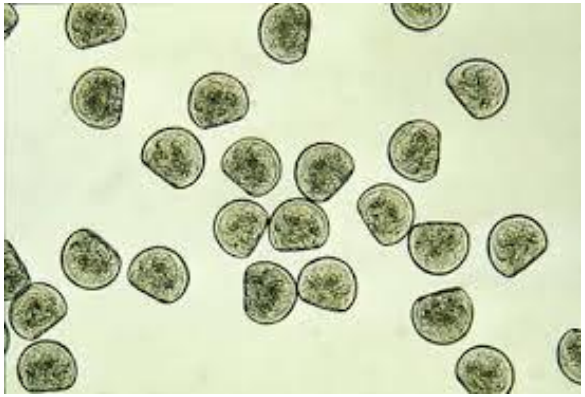
Microlgae:
Tetraselmis suecica



HELMHOLTZ ASSOCIATION

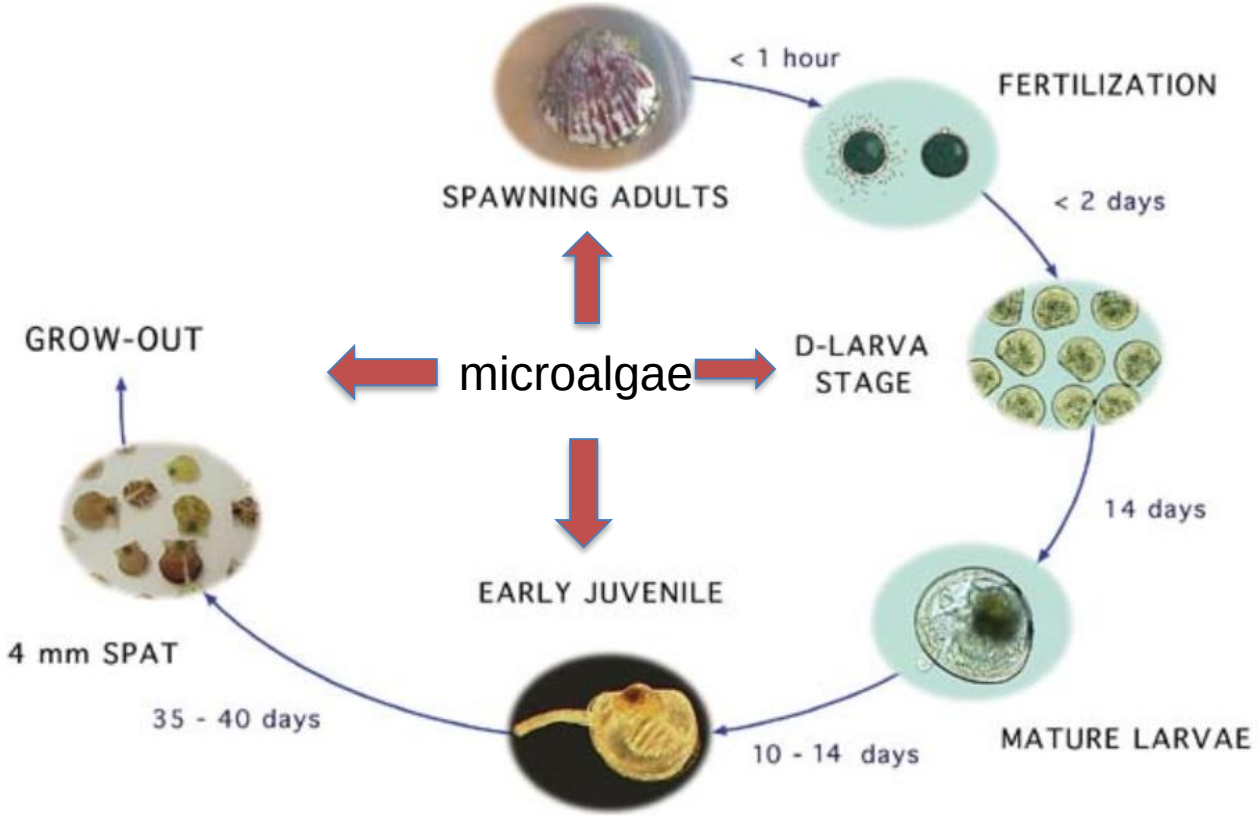
Bivalve culture

- Microalgae comprises on average 30% of the operating costs in a bivalve hatchery



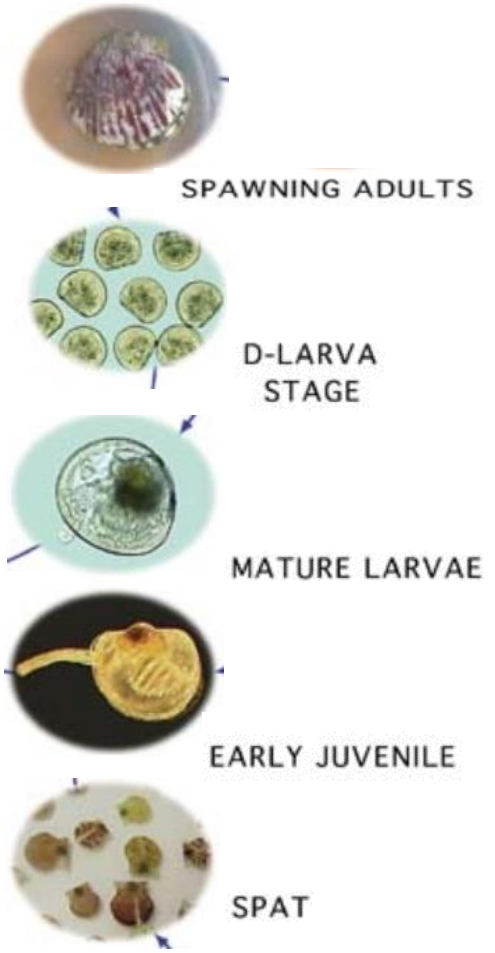
Microalgae culture: bivalve culture

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG



Helm&Bourne, 2004,
FAO 471

Microalgae culture: bivalve culture

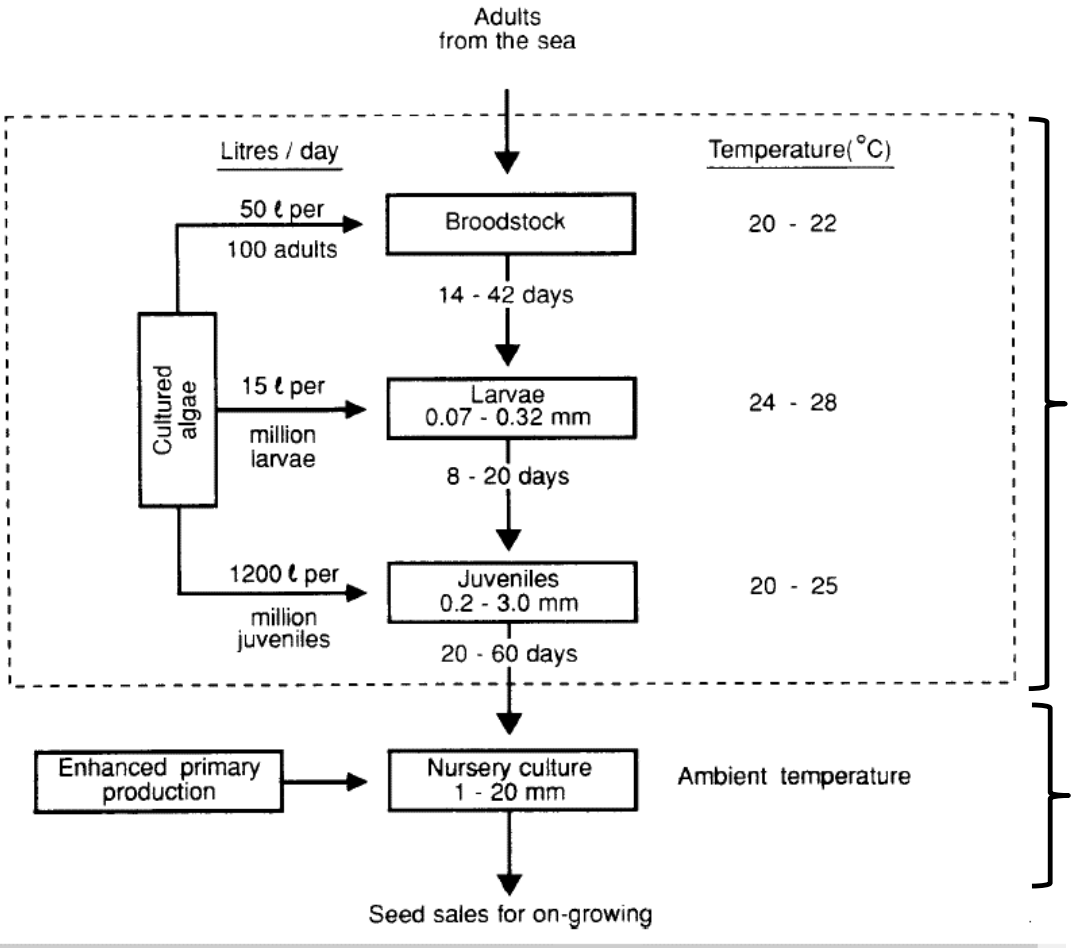


Different life stages require different microalge:

- Size
- Nutritional value
- Nutritional requirements
- High volume production

Microalgae culture: bivalve culture

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG



Indoor culture with added feeds

outdoor culture (mariculture) with natural occuring feed

Microalgae culture: bivalve culture

Algal species	frequency of use†	total daily production n‡	volume (m^3)
Isochrysis sp., clone T-Iso	31	18	23.8
Chaetoceros gracilis	23	11	14.1
Chaetoceros calcitrans	16	10	6.0
Tetraselmis suecica	15	10	39.1
Thalassiosira pseudonana, clone 3H	14	9	112.0
Pavlova lutheri	11	7	11.7
Isochrysis galbana	8	5	9.1
Skeletonema costatum	6	3	58.8
Chroomonas salina	5	3	0.76
Dunaliella tertiolecta	4	2	2.2
Chaetoceros simplex	3	3	1.76
Chaetoceros muelleri	3	2	5.0
Nannochloropsis sp.	3	2	0.20
Cyclotella sp.	2	1	0.36
Phaeodactylum tricornutum	2	1	2.0
Tetraselmis chui	2	0	-
Pavlova salina	1	1	3.18
Dicruteria sp.	1	1	4.07
Dunaliella perva	1	1	0.012
Chlamydomonas sp.	1	1	0.52
Chlorella sp.	1	1	0.36
TOTAL	**43**	**23**	**295**

Eight species represent 90% of cultured algae in mollusc

Algal species used in hatchery and nursery rearing of bivalve molluscs as reported in an international questionnaire 1991. Species are ranked according to decreasing frequency of use (Coutteau and Sorgeloos, 1992).
Adapted from FAO

Microalgae culture: bivalve culture

- larvae of most bivalve species have similar food preferences;
- Combinations of flagellates and diatoms provide well balanced diet, which will generally accelerate the rate of larval development to metamorphosis in comparison with unialgal diets
- quantity depends on larval density, suitable cell concentrations (expressed as cells.µl^{-1}) are given by each of the following combinations, e.g., :

- *Isochrysis galbana*; 50
- *Chaetoceros calcitrans*; 250
- *I. galbana*/*C. calcitrans*; 25/125
- *I. galbana*/*C. calcitrans*/ *Tetraselmis suecica*; 33/83/3.3 (larvae > 120µm)

„Green water“ in larval fish rearing

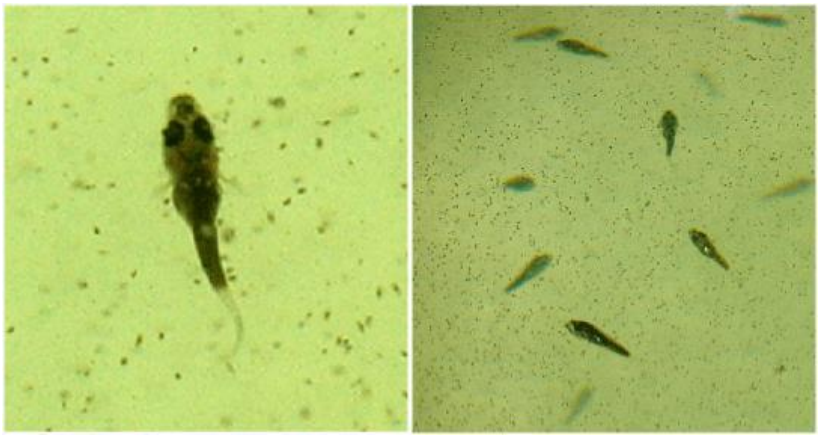
- “green water” polyculture ponds, co-culture of fish larvae, rotifers and microalgae
- microalgae are either suspended or attached to submerged substrata as periphyton (Spataru et al. 1983), “natural food” also includes macrophytes, bacteria, other microbes, and zooplankton
- Enhanced first feeding, survival, growth, stress resistance
- Historically applied in SE Asia in open pond systems for carp culture

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

„Green water“ in larval fish rearing

beneficial effects green water:

- a **direct food source** through active uptake
- **stimulation** of the non-specific **immune system** in the larvae action as a probiotic
- microbial control by algal exudates in tank water and/or larval gut
- cost of producing “green water” microalgae by the aquaculturists—mostly in SE Asia—is low



Microalgae culture: Biotechnological benefits

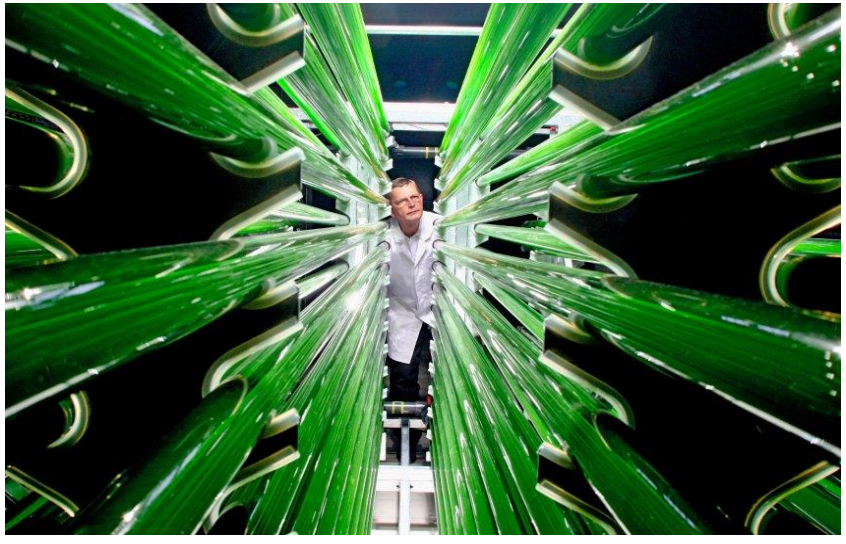
Summary

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

- In aquaculture as a farm animal feed:
- Bioremediation (removal of pollutants)
- Food
- Cosmetics
- Natural Products
- Energy
- Extraction of functional molecules

Rotatoria

photobioreactor



Artemia sp.

The future of microalgae industry?

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Acknowledgments

- “This project received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement nº 810139.”

- Poster and oral presentations must include, not only the statement above, but also the project logo and EU logo