



Opportunities of algae as ingredient for animal feed

3N Eco-innovations from Biomass

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Wageningen UR ACRRES

ACRRES: Application Centre for Renewable RESources

Part of Wageningen University where we:

- experiment with, test and demonstrate
- sustainably energy solutions based on sun, wind or biomass and applications of green raw materials for chemicals, building materials and others
- at pilot/ semi practice scale.....
- in co-operation with companies, NGO's and governments



Content

- Motivation and goals
- Sustainable algae production
- Value algae for feed
- Challenges
- Conclusions



FAO report 2009



How to Feed the World in 2050

- World population in 2050: 9.1 billion people
- Increased income levels
- Need to increase food production by 70%
 - ❑ Meat production: 229 → 465 Mtonnes
 - ❑ Milk production: 580 → 1043 Mtonnes



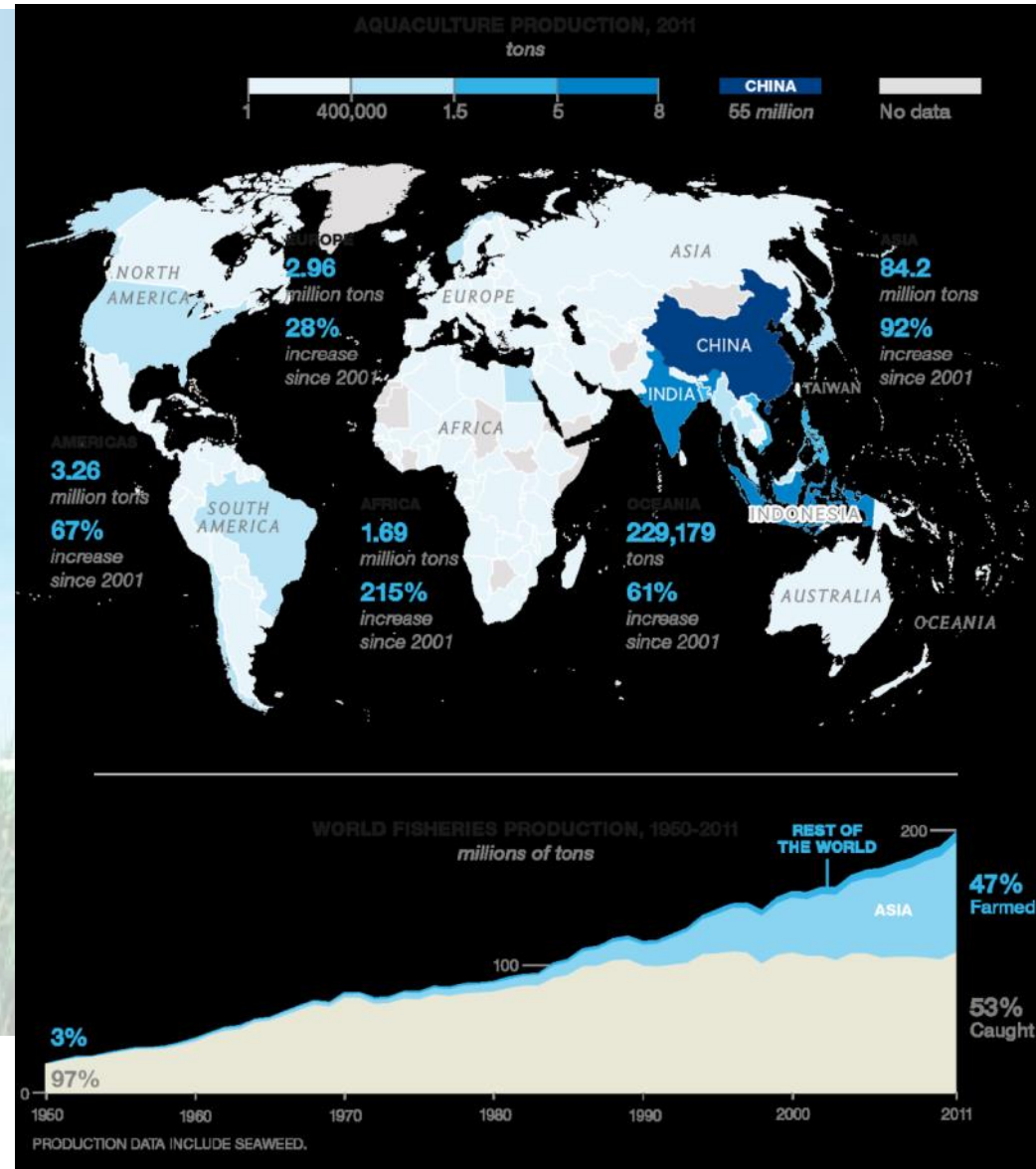
Max production but more people

Fish catch:

- Catch at max 1990
- More -> fish-farming

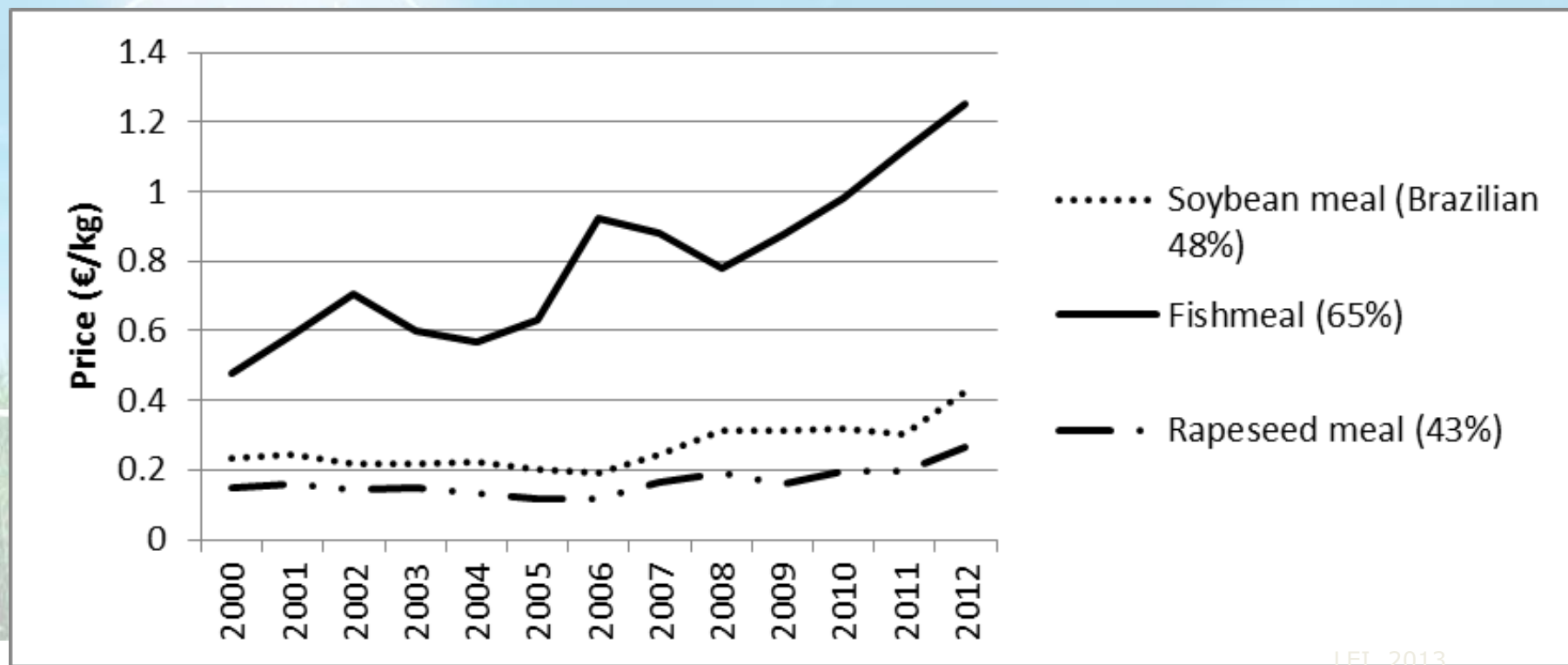
Commodities:

- 70% surface in use
- Shortage sweet water
- Short P on term
- Increase CO2 level



Scarcity of protein sources for feed: European price development

- *Price soybean meal: from 2000 – 2012 doubled*
- *Price fishmeal: from 2000 – 2012 tripled*



LEI, 2013



Need for new proteins

- Limited amount of fallow hectares
- Increasing crop yield can contribute
- Closing nutrient cycles to prevent waste
- High yield/ha proteins
 - ☐ Algae
 - ☐ Water plants
 - ☐ Insects



Goals

- Maximizing the valorisation of locally produced biomass or side streams for food/feed, chemicals or energy
- Transport high value products, minimise transport of 'water'
- Maximised local re-use of nutrients and side streams

➡ Sustainable algae production and usage for feed





ACRRES site Lelystad



Pilots at ACRRES in Lelystad digester –algae,..

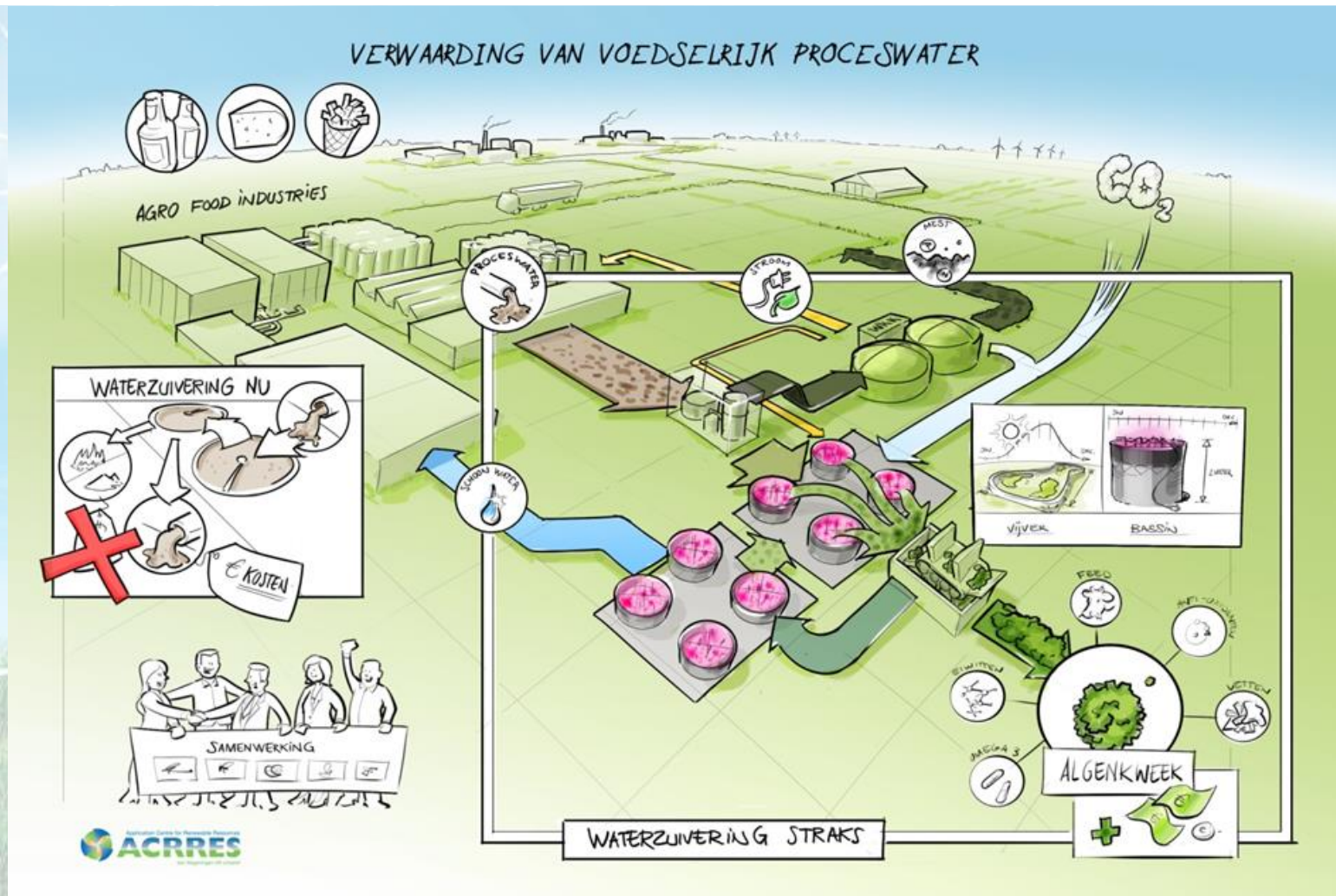


Sustainable algae growth

- Water
 - Nutrients (N/P)
 - CO₂
 - Heat
 - Light
 - Harvesting system
- } aqueous waste streams
- } re-use of flue gas
- } use of residual heat
- } natural available or LED



Algae for effluent polishing process water



Value algae for feed



Chemical composition algae (% of DM)

Source	Crude protein	Crude fat	Carbohydrates
Current ingredients			
Soya bean	37	20	30
Maize	10	4	85
Wheat	14	2	84
Algae			
<i>Spirogyra sp.</i>	6-20	11-21	33-64
<i>Anabaena cylindrical</i>	43-56	4-7	25-30
<i>Chlorella vulgaris</i>	51-58	14-22	12-16
<i>Arthrospira maxima (Spirulina)</i>	60-71	6-7	13-16
<i>Synechococcus sp.</i>	73	11	15
<i>Algae Acres</i>	53	7	29

Algae characteristics:

- High protein and fat content in the DM
- Amino acid profile comparable soya bean extract
- Contains desirable omega fatty acids (EPA en DHA)
- Significant variation in content



Digestibility protein in algae

- Variation between 55 and 82%, and depends of algae specie and drying method (Becker, 2013)
- *In vitro* digestibility algae protein Acrres varies between 50% (dried at 70°C) and 67% (dried with excipient) (Van Krimpen et al., 2014)
- More research necessary for desirable drying method



Other nutritional characteristics algae

- High levels of almost all vitamins
- Content minerals and heavy metals varies between species (point of focus)
- High inorganic matter (ash 6-14%) → prevent excess of salts in diet
- Relative many nucleic acids (approx. 5%) → positive effect on IgA (humoral immunity) and some anti nutritional level



Health improving properties

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Minireview

Health applications of bioactive compounds from marine microalgae



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ABSTRACT

Marine microalgae and cyanobacteria are very rich in several chemical compounds and, therefore, they may be used in several biological applications related with health benefits, among others. This review brings the research up-to-date on the bioactive compounds produced by marine unicellular algae, directly or indirectly related to human health. It covers and goes through the most studied applications of substances such as PUFA, sterols, proteins and enzymes, vitamins and pigments, in areas so diverse as human and animal nutrition, therapeutics, and aquaculture. The great potential of marine microalgae and the biocompounds they produce are discussed in this review.

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Health improving properties

- Anti-bacterial
 - Chlorellin → decreasing gram+ and gram- bacteria
 - Effects against MRSA, E. Coli, Staphylococci, etc.
- Anti-viral
 - Especially due to polysaccharides (spirulan)
 - Effects against herpes, measles, influenza, etc.
- Antioxidants
 - High contents after high oxygen challenge
- Chlorophyll and Carotenoids



Results of animal experiments



Results dairy

- Trial group: 200 g/d Spirulina 1^e 3 month after calving (90 d)

Parameter	Control	Spirulina	Ratio v.s. control (%)
Milk production (kg/d)	28	34	121
Fat content milk (%)	4.19	4.16	99
Protein content milk (%)	3.17	3.18	100
Lactose content milk (%)	4.79	4.83	101
Condition score peak lactation	2.36	2.62	111

- Major effects besides positive influence on feed digestibility probably explainable by the higher feed intake in the Spirulina group (Kulpys et al., 2009)



Results pigs

- *Chlorella* in feed lactating sows and piglets
 - Growth piglets rearing period 385 vs. 424 g/d (10%)
 - Feed conversion ratio rearing period 1.71 vs. 1.63 (4.7%) (Weber en Grimmer, 2001)
- No positive effects on performance of conventional growing-finishing pigs
- Improved feed conversion ratio with supplying *Spirulina platensis* to organic G-F pigs
(Bellof and Arlacon, 2013)



Results broilers/turkeys

- Inclusion of 1% dried *Chlorella vulgaris* to broiler diet between wk 1 and 4
 - Growth gain: 1,549 vs. 1,603 (3.5%)
 - Feed conversion ratio: 1.66 vs. 1.52 (8.5%)
 - Increased plasma immunoglobulin concentrations
→ increased immune competence

(Kang et al., 2013)

Significant mortality decrease in turkeys (from 12 to 3%) with 0.1% *Spirulina* in the diet (Becker, 2013)



Results layers

Review

Dietary enrichment of eggs with omega-3 fatty acids: A review

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ABSTRACT

The health benefits of omega-3 polyunsaturated fatty acids (n-3 PUFA) are generally recognized. Unfortunately, in most western countries, the recommended daily intake of these compounds is rarely met. Therefore, enrichment of commonly occurring foods can boost intake of these fatty acids. In this regard, eggs are an interesting target, as they form an integral part of the diet. Their n-3 PUFA profile can be modified through feed supplementation. A traditional n-3 PUFA source to be added to hens' diet is flaxseed, a plant source rich in α -linolenic acid. Alternatively, hens are often fed fish oil, which is rich in long chain n-3 PUFA eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). **A more recent trend is feed supplementation with microalgae as a source of EPA and/or DHA.** In this paper, recent scientific literature concerning n-3 PUFA enrichment in eggs is reviewed, giving an overview of advantages and disadvantages of the different approaches.

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- Layers can convert efficient fatty acids from algae to DHA and EPA in the egg (Fraeye et al., 2012)



Inclusion level in diets

- As protein and energy source: 10 – 30%
- To improve immune response: 1 – 2%
- To increase omega-3 content egg: ~ 5%
- Dairy: positive effects on production and condition at 200 g/cow/day



Economy (calculation with poultry model)

- Broiler experiment 1% Chlorella →
(growth 3.5%, FCR 8.5%)
- Control group: Gross margin **€ 31.35/100 broilers**
- Exp. group: Gross margin **€ 41.12/100 broilers**
- Turning point at **+ € 5.25/100 kg feed** →
Dosage 1%: cost price algae max. **€ 5.25/kg**
at base growth (not yet antibiotic use, mortality
or quality improvement included)



Challenges algae and sustainability

Outside agriculture and less ground usage:

- Traditional agricultural crops 1,000-2,000 kg protein/ha
- Algae 4,000-15,000 kg protein/ha

Reuse residues:

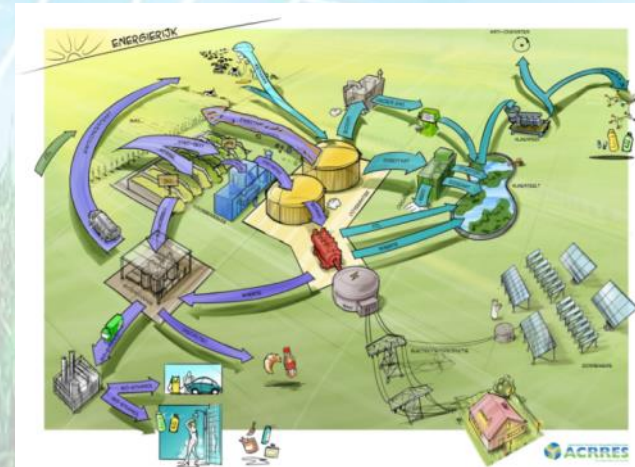
- Nutrients and hydrocarbon in watery effluent
- Heat and CO₂ (flue gas)

Less energy and greenhouse gas?

Local (phosphate) cycle

Additional value for feed/food

Legislation



Conclusions

- Algae are a valuable ingredient for animal feed
- Algae production not competing with agriculture
- Possible to valorise side streams in local biorefineries with algae production (as stepping stone in circular economy and biobased)
- Challenges to address, innovate and improve in cooperation with companies and research



More info

www.acrres.nl

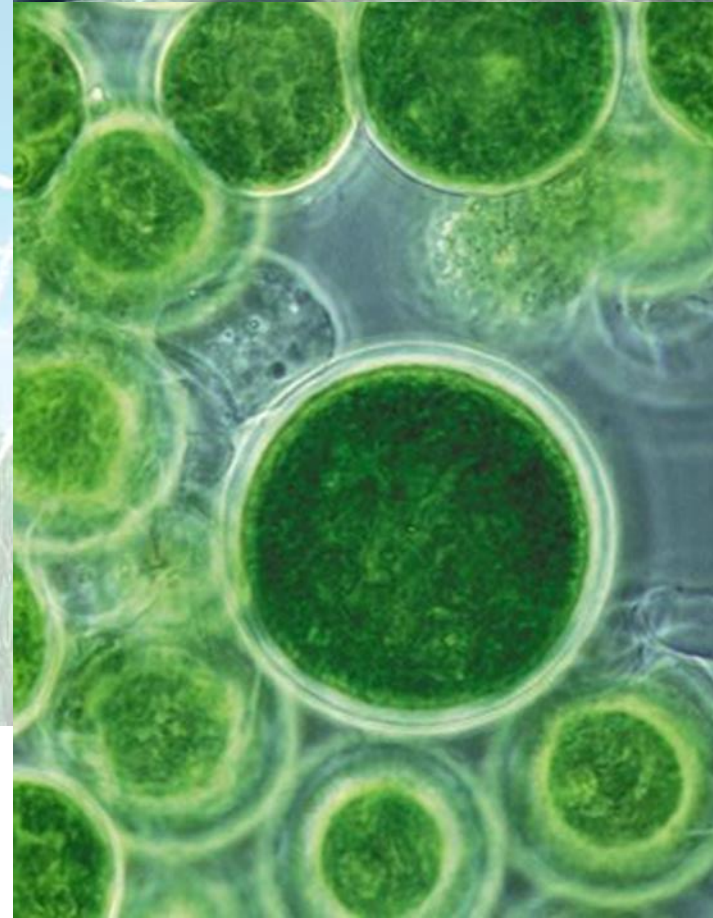
www.enalgae.eu

Further collaboration

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Thanks for your attention

And discussion!