Application Centre for Renewable Resources
ACRRES
een Wageningen UR initiatief

Opportunities of algae as ingedrient for animal feed

Rommie van der Weide en Marinus van Krimpen

Wageningen UR ACRRES

WAGENINGEN UR
For quality of life

PROVINCIE FLEVOLAND

Europees Landbouwfonds voor Plattelandsontwikkeling:
Europa investeert in zijn platteland

ACRRES: Application Centre for Renewable RESources

Part of Wageningen Unversity were 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

EnAlgae collaborate innovate communicate

Investing in Opportunities

This project has received European Regional Development Funding through INTERREG IV B.

nwe INTERREG IVB

INEMAD

PUFA Chain

GROW 2 BUILD

Content

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

FAO report 2009

- 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

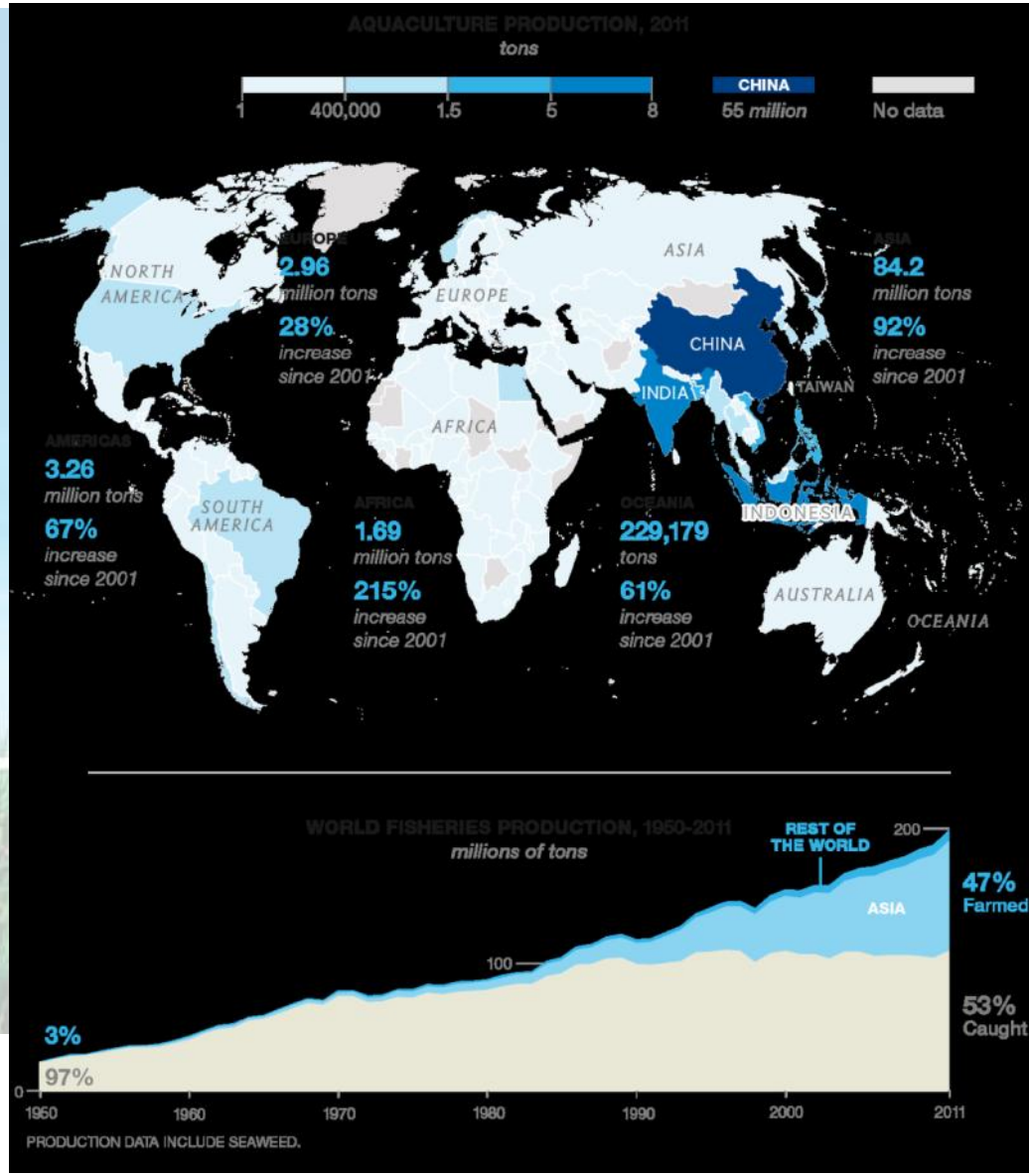
Max production but more people

Fish catch:

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

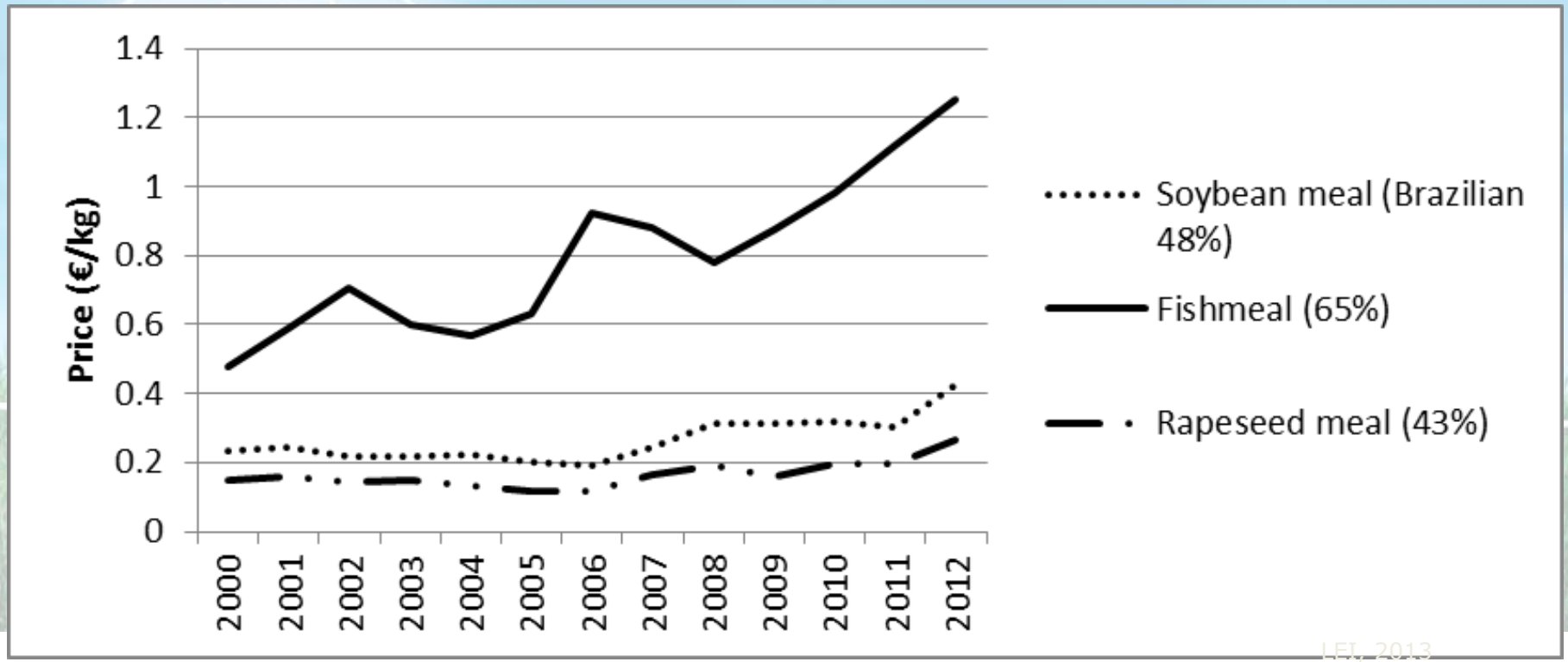
Commodities:

- 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*



Need for new proteins

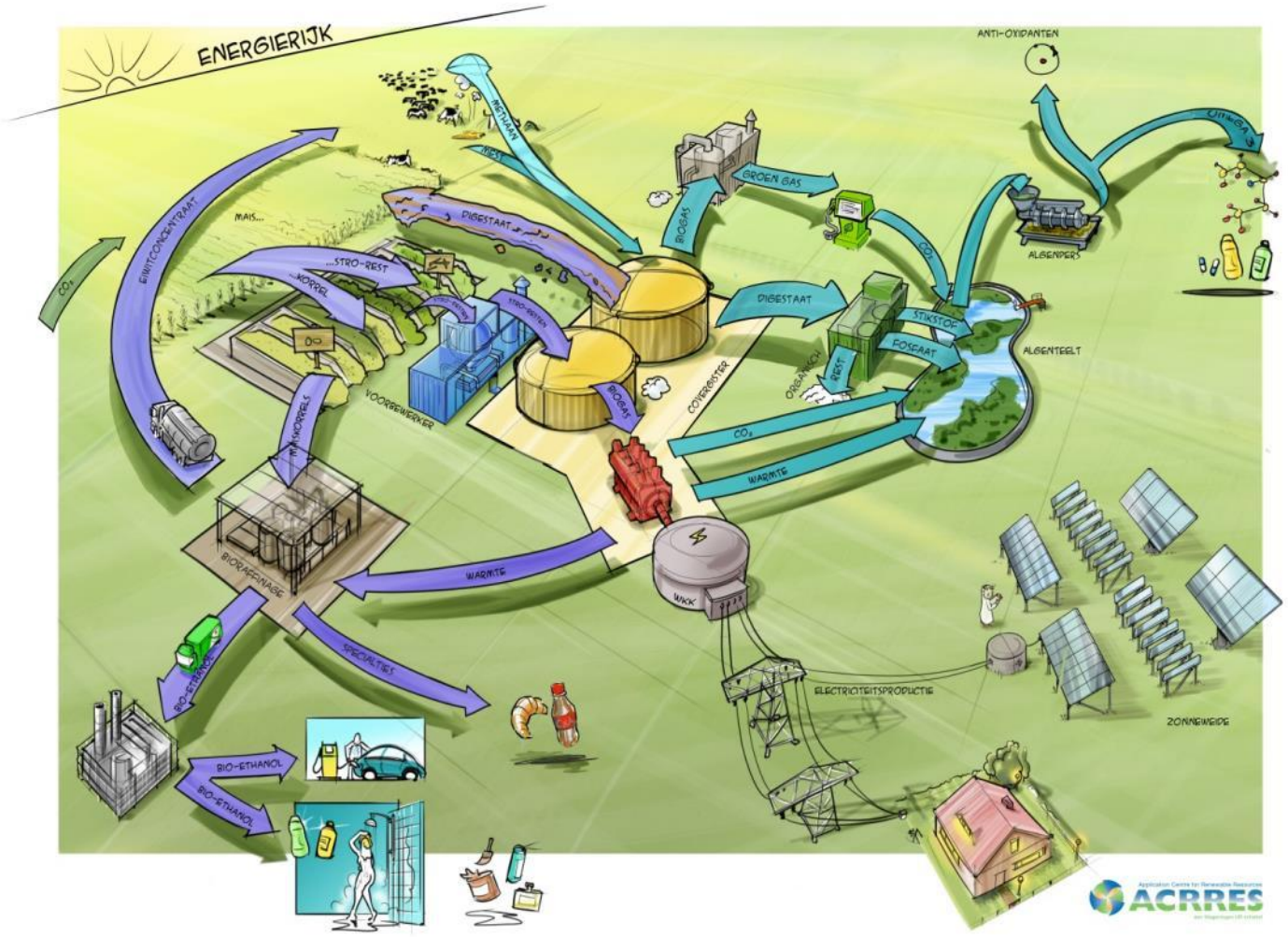
- Limited amount of fallow hectares
- Increasing crop yield can contribute
- Closing nutrient cycles to prevent waste
- High yield/ha proteins
  - ❑ Algae
  - ❑ Water plants
  - ❑ Insects

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

Sustainable algae production ACRRES



ACRRES site Lelystad

Pilots at ACRRES in Lelystad digester –algae,..





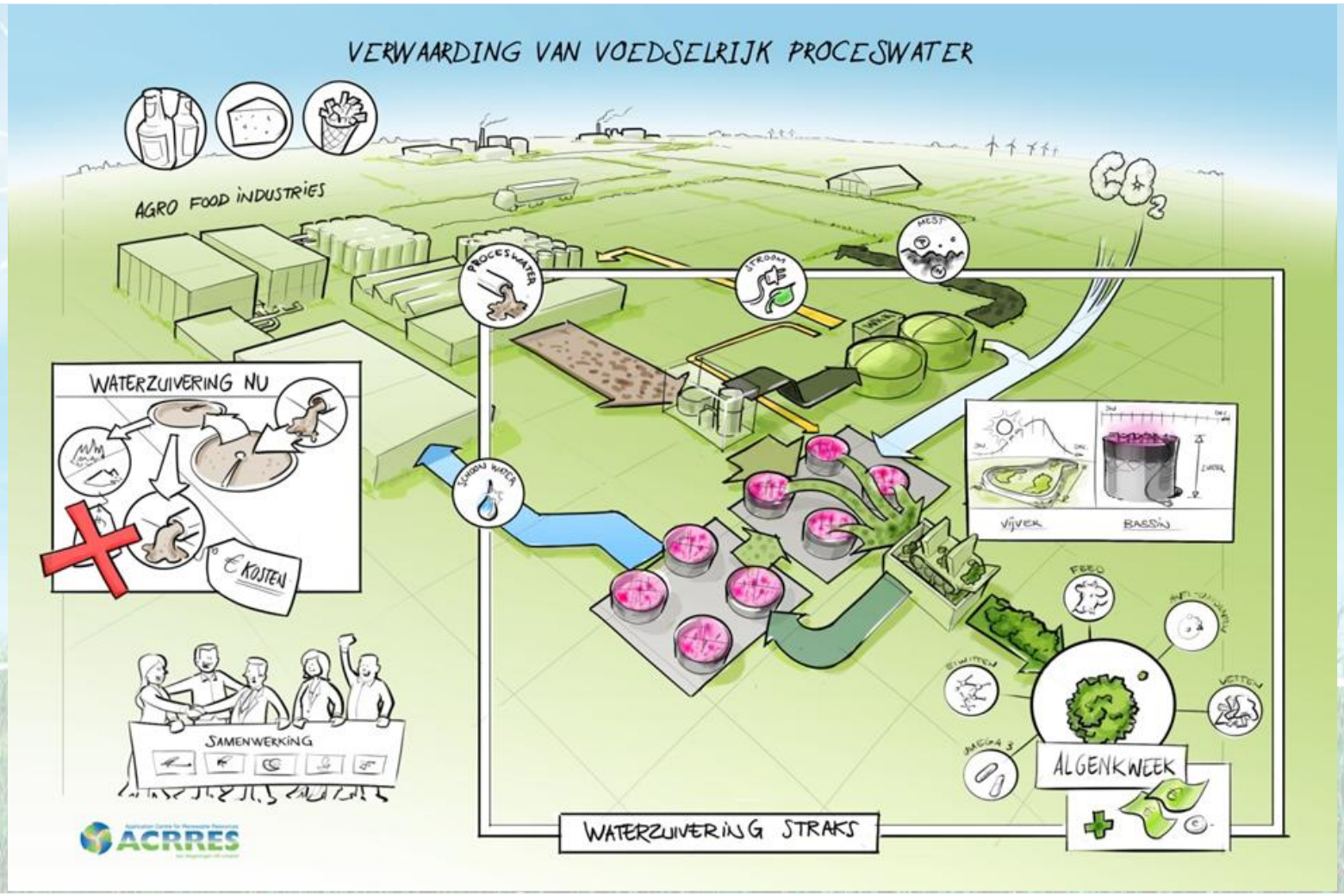

Sustainable algae growth

- Water
- Nutrients (N/P)

} aqueous waste streams

- CO_2 } re-use of flue gas
- Heat } use of residual heath
- Light } natural available or LED
- Harvesting system

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			
Spirogyra sp.	6-20	11-21	33-64
Anabaena cylindrical	43-56	4-7	25-30
Chlorella vulgaris	51-58	14-22	12-16
Arthrospira maxima (Spirulina)	60-71	6-7	13-16
Synechococcus sp.	73	11	15
Algae Acrres	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

Life Sciences 93 (2013) 479–486

Contents lists available at ScienceDirect

Life Sciences

journal homepage: www.elsevier.com/locate/lifescie

Minireview

Health applications of bioactive compounds from marine microalgae

Maria Filomena de Jesus Raposo, Rui Manuel Santos Costa de Morais, Alcina Maria Miranda Bernardo de Morais *

CBQF – Centro de Biotecnologia e Química Fina, Laboratório Associado, Escola Superior de Biotecnologia, Universidade Católica Portuguesa/Porto. Rua Dr. António Bernardino de Almeida, 4200-072 Porto, Portugal

ARTICLE INFO

Article history:
Received 24 May 2013
Accepted 8 August 2013

Keywords:
Marine microalgae
Cyanobacteria
Bioactive compounds
Health applications
Nutraceuticals
Oxidative stress

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 biocoumpounds they produce are discussed in this review.

Health improving properties

- Anti-bacterial
  - Chlorellin → decreasing gram+ and gram- bacteria
  - Effects again MRSA, E. Coli, Staphylococci, etc.
- Anti-viral
  - Especially due to polysaccharides (spirulan)
  - Effects again 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

Ilse Fraeye [a,*], Charlotte Bruneel [a], Charlotte Lemahieu [a], Johan Buyse [b], Koenraad Muylaert [c], Imogen Foubert [a]

[a] KU Leuven Campus Kortrijk (KULAK), Research Unit Food and Lipids, Department of Microbial and Molecular Systems, Leuven Food Science and Nutrition Research Centre (LFoRCe), E. Sabbelaan 53, B-8500 Kortrijk, Belgium
[b] KU Leuven, Division of Livestock-Nutrition-Quality, Department of Biosystems, Kasteelpark Arenberg 30-bus 2456, B-3001 Heverlee, Belgium
[c] KU Leuven Campus Kortrijk (KULAK), Research Unit Aquatic Biology, E. Sabbelaan 53, B-8500 Kortrijk, Belgium

ARTICLE INFO

Article history:
Received 27 February 2012
Accepted 26 March 2012

Keywords:
Omega-3 polyunsaturated fatty acids
Eggs
Flaxseed
Fish oil
Microalgae

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.

- 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:

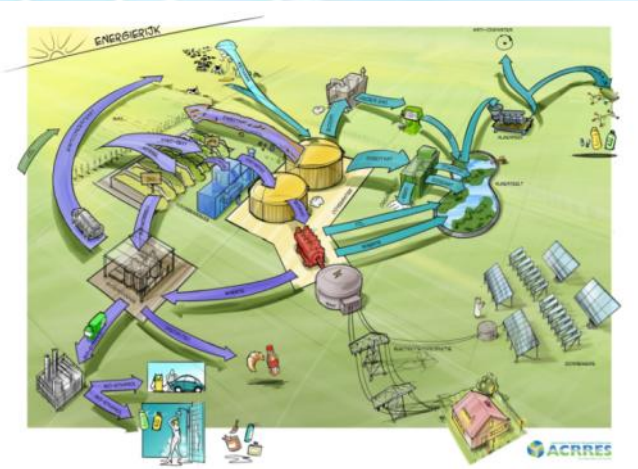
- Nutrients and hydrocarbon in watery effluent
- Heat and CO2 (flue gas)

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

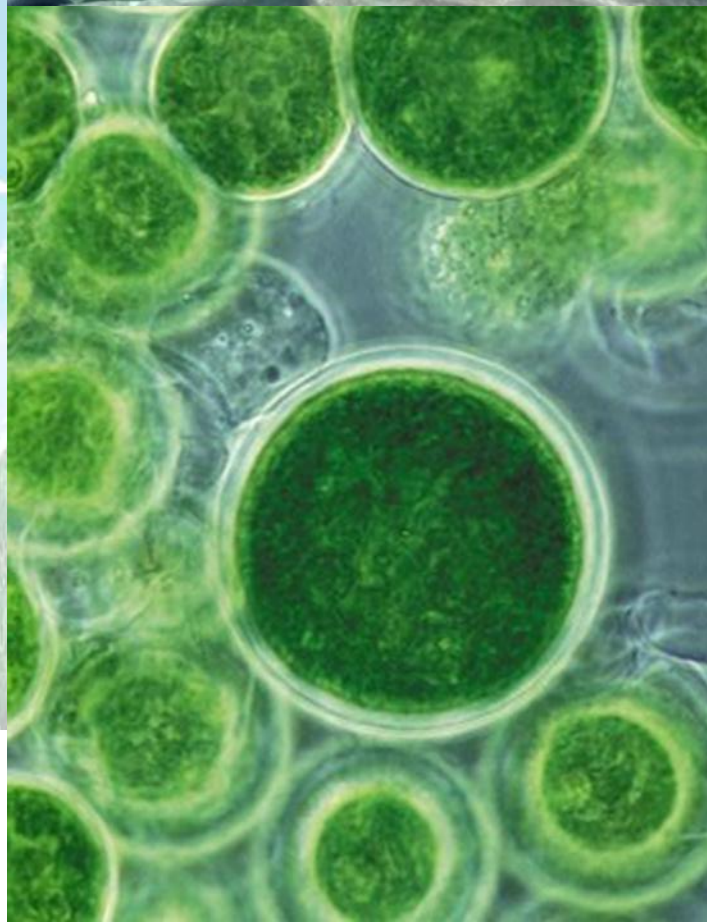
www.enalgae.eu

Further collaboration

Rommie.vanderweide@wur.nl

+31 320-291631

Chris.devisser@wur.nl



Application Centre for Renewable Resources
ACRRES
een Wageningen UR initiatief

Thanks for your attention

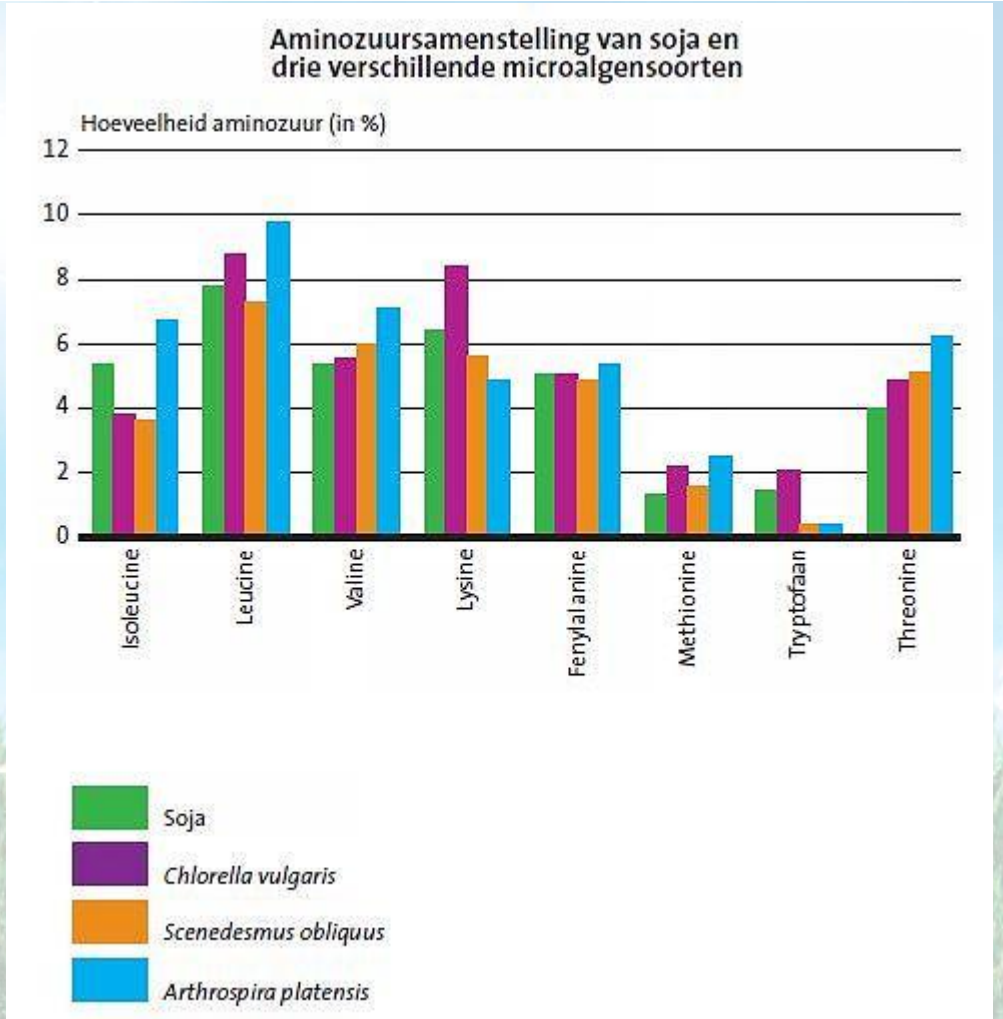
And discussion!

WAGENINGEN UR
For quality of life

PROVINCIE FLEVOLAND

Europees Landbouwfonds voor Plattelandsontwikkeling:
Europa investeert in zijn platteland

Aminoacid profile soya and algae



(Source: Lammers, 2013)

Fatty acid profile algae (mg/100 g)

Fatty acid	Spirulina maxima	Chlorella Vulgaris (green)	Chlorella Vulgaris (orange)	Haemato-Coccus Pluvialis	Diacronema vlkianum	Isochrysis galbana
Total fatty acids	2551	2736	23691	35646	13956	19756
Σ Multiple unsaturated FA	1003	1399	6328	14537	6750	8862
Omega-3 fatty acids						
18:03 ω3 (ALA)	40	661	3665	3981	14	421
20:05 ω3 (EPA)	–	19	39	579	3212	4875
22:06 ω3 (DHA)	–	16	80	–	836	1156
Other PUFA-ω3	13	111	308	52	1234	10
Σ PUFA-ω3	58	971	4781	5770	5407	6461
Σ PUFA-ω6	945	428	1547	8767	1343	2401
Ratio ω3/ω6	0.1	2.3	3.1	0.7	4.1	2.7

- In human diets: in general excess of ω6 and shortage of ω3 fatty acids; in particular need for EPA and DHA
- *Diacronema vlkianum* and *Isochrysis galbana* provide mostly desired ω3 fatty acids and relative few ω6 → transmission to meat and egg