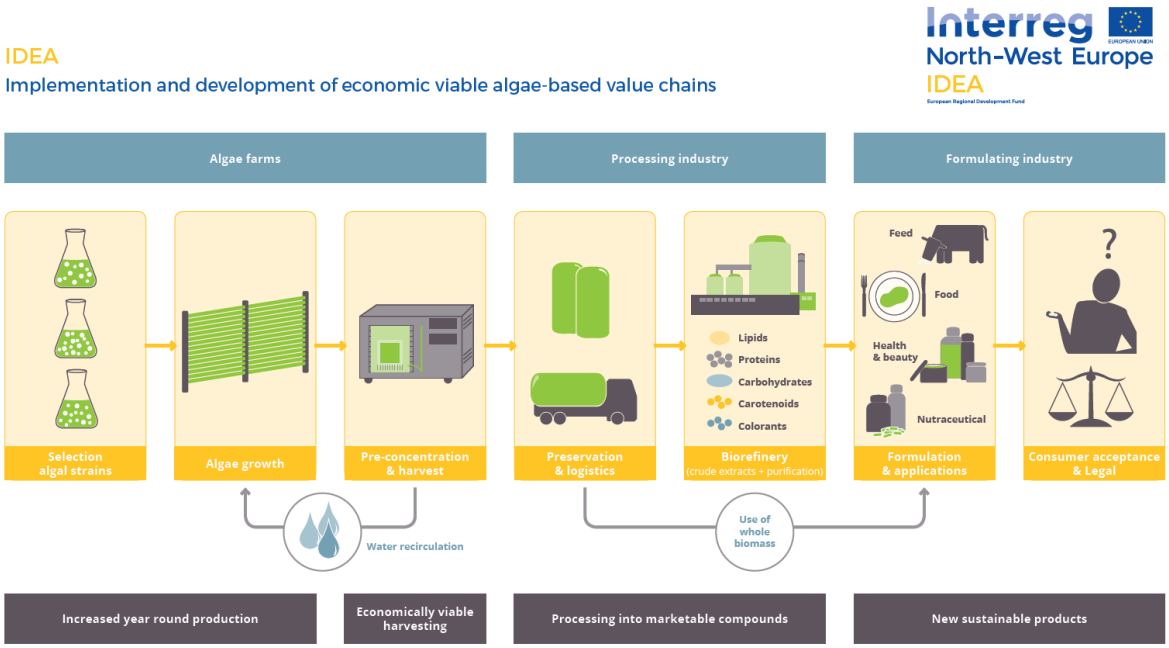
IDEA Webinar:
Algae value chains in (NW)Europe

July 6th, 2021 - On-line event

Programme
&
e-posters abstracts

Organised by VITO as lead partner of the Interreg NWEurope IDEA project and partner of the Interreg 2seas ValgOrize project.



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1 INTRODUCTION

Dear participant,

The Webinar on algae value chains in (NW)Europe is organized as a dissemination event for the Interreg NWEurope project IDEA and stakeholders meeting of the Interreg 2seas project ValgOrize.

IDEA is a NORTH-WEST EUROPE INTERREG project (grant number NWE 639) that envisions the development and enrolment of economic viable value chains based on micro-algae in NWEurope. Partners from Belgium (VITO, Thomas More, Innovatiesteunpunt), Germany (Forschungszentrum Jülich), France (Central Supélèc), The Netherlands (Feed Design Lab, University of Twente) and Ireland (TEAGASC) joined forces and are collaborating since end 2017 with VITO as lead partner. Project partners are presenting their findings via oral presentations and multiple e-posters. www.nweurope.eu/idea

The INTERREG 2 SEAS project ValgOrize is coordinated by ILVO (Belgium). Eleven partners (ILVO, VITO, NIOZ, HZ University of applied sciences, North sea farmers, Zeewaar, Ulco, University of Lille, University of Greenwich, The Marine Biological Association and Nausicaa) are collaborating towards valorisation of seaweed and algae for an improved taste for the European consumer, with a focus on quality and a zero-waste approach. www.valgorize.eu/en

During the event, different aspects of the algae value are presented and discussed, comprising

- year-round micro algae growth in NWeurope
- Increasing sustainability of micro-algae growth and harvest
- Wet preservation of algae biomass
- Processing of algae biomass into products
- Algae-based product evaluation (feed/food/cosmetics)
- Impact of algae on taste
- Whole value chain assessment with a focus on techno-economic and logistic aspects
- A roadmap towards implementation of an economic viable algae value chain
- Opportunities/barriers for algae in Europe.

The event offers opportunities to share results and exchange thoughts on algae value chains in Europe. This is relevant for all stakeholders of the algae value chain, comprising (potential) algae growers, algae biomass processors, companies that (potentially) produce algae-based products, equipment suppliers, authorities, investors and scientists.

The IDEA & ValgOrize consortiums are pleased to welcome you to the event!

The organising Committee:

- Joran Verspreet (VITO)
- Ewoud Beirlant (VITO)
- John Peeters (VITO)
- Katrien Vandeperre (VITO)
- Leen Bastiaens (VITO, Chair)
- With the support of the IDEA communication team (VITO, Innovatiesteunpunt)

Contact: IDEA-project@vito.be

2 PROGRAMME

9h15 Start connecting

9h25 Welcome

9h30 **Keynote: The IDEA project as a whole.**
Leen Bastiaens - Coordinator Interreg NWE project IDEA (VITO, B).

10h10 **Session 1: Algae biomass production.**

- Year-round micro-algae cultivation in NWEurope in two pilot facilities.
  Christina Kuchendorf - Forschungszentrum Jülich (D),
  Floris Schoeters - Thomas More Radius (B),
  Behnam Taidi - Centrale Supélèc (F)
  with links to other IDEA partners.

- Increasing sustainability at algae farms by using CO_2 captured from the air and medium re-use.
  Michel Schellevis – University of Twente (NL),
  Leen Bastiaens - VITO (B)
  with links to other IDEA partners.

- Algae growth on pretreated digestate – Interreg NWE project ALG-AD.
  Alla Silkina - Swansea University, UK.

11h00 Break

11h10 **Virtual visit to SUNBUILT, algae growth & harvest pilot plant in Belgium.**

11h20 **Session 2: Algae biomass processing & formulation into marketable products.**

- Wet preservation of micro-algae biomass at algae farms –
  Joran Verspreet - VITO (B),
  Behnam Taidi - Centrale Supélèc (F)
  with links to other partners.

- The added value of algae-based ingredients in food & feed formulations
  Maria Hayes - TEAGASC (IRL),
  Ageeth Van der Lee - Feed Design Lab (NL)
  with links to other IDEA partners.

- Impact of micro- & macro-algae biomass on taste – Interreg2seas project ValgOrize
  Johan Robbens - Coordinator ValgOrize (ILVO, B).

- Algae as ingredients for cosmetics
  Patrick Gonry – GOVA (B)
  with links to IDEA partners.

12h30 LUNCH BREAK

13h15 **Virtual visit to VITO Labs and pilot infrastructure.**

13h25 **Session 3: Algae-based values chains.**

- Techno-economic and logistic considerations.
  Miet Van Daele Annelies De Meyer - VITO (B)
  with links to other IDEA partners.

- Roadmap towards implementation of the algae value chain in NWEurope.
  Leen Bastiaens - VITO (B),
  Kristof Severijns - Innovatiesteunpunt (B)
  with links to other IDEA project partners.

14h00 **Session 4: Parallel break-out discussion sessions**

- Plenary introduction
-
- Parallel sessions
  - Moderated discussions in groups of about 10 people on topics related to the algae value chains
  - Groups & topics will be defined based on interest expressed by the participants

- Short break

- Plenary conclusions by the moderators.

16h00 Closing conclusions.
Vitor Verdelho - EABA

16h15 End of meeting – e-poster session remains open

The E-poster session is open during and after the event
&
The information will become also available at www.nweurope.eu/idea

3 SPEAKERS & MODERATORS

Dr. ir. Leen Bastiaens is project manager at the applied research Institute VITO in Belgium and team leader of the renewable chemicals teams. Leen focusses on algae harvest technologies and fractionation of biomass (like algae and insects) into high value fractions for use in different application field. She is the coordinator of the Interreg NWE IDEA project and is strongly involved in activities to establish algae value chains.

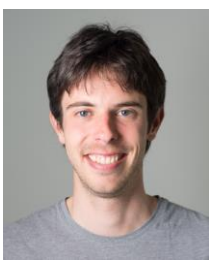
Dr. Christina Kuchendorf is a researcher and project coordinator at the Institute of at Forschungszentrum Jülich GmbH in Germany. Christina was during IDEA the coordinator of the IBG-2 AlgaeScienceCenter with three pilot scale algae production facilities. Control and study of microalgal productivity and growth dynamics in large-volume cultures are major research topics, besides year round algae cultivation and general nutrient cycling, also to soil and plant.

Dr. ir. Floris Schoeters is a researcher at Radius, Thomas More, in Belgium. The main topics of his research are the growth of microalgae on wastewaterstreams and year round growth of microalgae in the Sunbuilt pilot plant.

Dr. Behnam Taidi obtained his B.Sc. degree in Biochemistry and PhD in Microbial Physiology (University of Hull. He pursued his career in the brewing industry where he worked on numerous research and implementation projects as well as management of the pilot brewing facilities and the commercialisation of brewery by-products. He was the Director of Yeast Research a Carlsberg before taking up the position of Professor of Biotechnology at Centralesupélec (CS), University of Paris-Saclay where he was a founder-member of the Chair of Biotechnology of CS participating in the construction of the laboratories, research teams, and research programme of the biotechnology centre in Champagne-Ardenne. Since 2017 he is the French contact for the IDEA project

Ir. Michel Schellevis is a fourth year PhD candidate in the Sustainable Process Technology group at the University of Twente. He researches the extraction of CO2 from the atmosphere, also known as Direct Air Capture, to obtain a sustainable carbon source for e.g. microalgae cultivation. His primarily focuses on process design and process optimization.

Dr. Alla Silkina is a senior post-doctoral researcher within the algal biotechnology group at Swansea University. Alla has expertise with algal biotechnology and ecological physiology of microalgae, and her skills include mass culture of microalgae in PBR, the optimisation of growth kinetics and bioremediation. The main research interest is on the application of algal biomass for end-uses including feeds and higher value products. She is Research and Communication Officer for the ALG-AD project working on the effectiveness of algal bioremediation process and use of algal biomass growing on digestate as a fish feed.



Dr. Ir. Joran Verspreet works as a researcher at VITO (Belgium) at the intersection of biotechnology, food science, and product development. He combines field experience in food product development with scientific curiosity to support the implementation of algae in commercially viable applications.

Dr Maria Hayes has an honours degree in Science (Industrial Microbiology and Chemistry) from University College Dublin (UCD) and a PhD in Microbiology and chemistry from University College Cork (UCC) the topic of which concerned the generation of antimicrobial and heart health beneficial peptides from dairy processing waste streams. Maria works extensively on method development for the recovery of food and feed ingredients and biomolecules from marine, dairy, plant and animal by-products or co-products generated during food processing. Since 2017 she is the Irish contact on the IDEA project with a focus on protein recovery, bioactivity assessment and formulation of foods and feeds with microalga and their bioactive extracts.

Ageeth van der Lee BSc is project coordinator at Feed Design Lab in the Netherlands. Ageeth focusses on alternative protein sources for animal feed, pet food and fish and the processing applications in the feeds for these species.
On behalf of the 115 partners of Feed Design Lab active in many projects with topics animal feed, sustainability and processing.

Dr. Johan Robbens is leading the Blue Biotech/Food Integrity cell of ILVO- the Flemish Research Institute for Agriculture, Fisheries and Food. Johan is coordinator of the Interreg project ValgOrize, dealing with valorization of algae for food and feed. He is also WPleader of the Eranet BlueCC dealing with valorization of marine side-streams, with a focus on chitin. valorization of marine resources in a sustainable way is a main topic.

Patrick Gonry is a chemical engineer with more than 26 years of experience in the cosmetic industry. Patrick is business Development Manager for GOVA Distribution. His focus is on the development and worldwide commercialization of sustainable and environment friendly ingredients for cosmetic products.

Dr. Miet Van Dael holds a doctoral degree in applied economic sciences (2014) and masters degree in business engineering (economics) (2010). Currently she works as a researcher at VITO (Belgium) in the unit of separation and conversion technologies. As a researcher her ambitions are to further integrate techno-economic assessments with an environmental and social impact, make the methodology spatially explicit and link it with the acceptance of the assessed technologies. In doing so, her main fields of interest are biorefineries and CCU technologies.

Dr. ir. **Annelies De Meyer** (°1985) obtained a doctoral degree in bioscience engineering at the University of Leuven in 2015. In her research she has developed a comprehensive spatio-temporal optimisation approach for the strategic design and tactical management of supply chains for the bio-based sector. Since 2017, Annelies works at VITO on the implementation of MooV. She embeds her expertise on integrating geo-data analytics with network design and optimization modelling as well as on dashboard development. Annelies is passionate about solving complex issues with quantitative modelling and optimization techniques.

Ing. Kristof Severijns works at the Innovations Support Centre that supports agricultural entrepreneurs to Innovate. Kristof focusses on crops that are not common in farms. He advices farmers on getting started with those crops and helps them to close the gap between farmers and processing companies by looking at the whole value chain and organising inspirations tours.

Marzio Monagheddu facilitates synergistic collaboration between VITO, industry and academia, fostering sustainable industrial development and helping leading edge innovations to become business successes. He is responsible for business relations concerning algae value chain and biorefinery activities.

Frederik De Bruyn is Business Development Manager at the Unit of Sustainable Chemistry at VITO. He is responsible for prospection, business development and contract negotiation of bilateral projects with industry, with a focus on the circular bioeconomy. He has been involved in various EU projects as project manager or responsible for the exploitation and business planning.

Vitor Verdelho is general manager of the European Algae Biomass Association (EABA). EABA's main target is to act as a catalyst for fostering synergies among scientists, industrialists and decision makers in order to promote the development of research, technology and industrial capacities in the field of Algae.

4 ABSTRACTS E-POSTER SESSION

4.1 E-POSTER SESSION 1: ALGAE GROWTH

Abstract No. 2

Statistical Modelling of Microalgal Growth

Pérez-Bibbins B.[1], R. Filali [1], E. Bermejo-Padilla [2], H. Kinsou [1], R. Collis [3]. and B. Taidi[4]

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Domestication of microalgae is a necessary step towards the use of microalgae as all-year round crops. Domestication will require selection, study and adaption of wild strains to specific applications. Microalgae cultivation in greenhouses could be possible increasing carbon dioxide bio-fixation and biomass productivities (Wijffels *et al*., 2010). An *isolated consortium microalgae* from Germany and a pure strain of *Chlamydomonas nivalis* were studied within the INTERREG IDEA NWE project, because of their tolerance to low temperatures and ability to grow at low light intensities. Statistical Factorial Experimental Design 2^3 with three independent variables was used to construct growth models. The three variables studied at laboratory scale (20 ml) were: light intensity (20-200 µmol/m^2s), CO_2 concentration (0.04-5.0 %) and temperature (5-25ºC). Based on biomass production after 14 days of cultivation, *C. nivalis* best growth conditions were 5ºC, 20 µmol.m^{-2}.s^{-1} and 5 % of CO_2 resulting in a cell concentration of 0.68 g.l^{-1} and a productivity of 49.4 mg.l^{-1}.d^{-1} after 14 days of culture. The best conditions for the growth of the mixed culture were 25ºC, 20 µmol.m^{-2}.s^{-1} and 5 % of CO_2, giving 0.46 g.l^{-1} of biomass and a productivity of 33.4 mg.l^{-1}.d^{-1}over 14 days incubation. For both cultures, the main influencing variable was CO_2 in the range tested in this study. The growth models developed point out that under green-house culture conditions an adequate supply of CO_2 would allow cost savings on heating and artificial lighting.

Keywords: *Chlamydomonas nivalis*, microalgae cultivation, factorial statistical experiment design, statistical growth models

References: Wijffels RH, Barbosa MJ. (2010) An outlook on microalgal biofuels. Science 329:796–799.

This research was funded by NORTH-WEST EUROPE INTERREG as part of the IDEA project (NWE 639).

Improvements in the cultivation of *Botryococcus braunii* using commercial fertilisers

Bermejo, E. [1,a]***, C. González***[1]***, Z. Montero-Lobato***[1]***, C. Vílchez***[1]***, I. Garbayo***[1]***, M. Cuaresma***[1]

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Agricultural fertilisers (NPKs) have been recognised as an alternative to make microalgae cultivation cheaper as well as simpler in terms of the preparation of the medium. *Botryococcus braunii*, a green microalga, has the almost unique capacity to accumulate and excrete large amounts of long chain hydrocarbons and/or interesting groups of polysaccharides which can be further converted into bio-products. However, limitations in growth are currently hindering its industrial production. In this work, the use of different agricultural fertilisers (NPKs) was evaluated for the cultivation of two *B. braunii* races (A and B) in terms of productivity and final media labour and cost. Results corroborated that fertilisers-based media are easier to prepare and their prices are considerably lower compared to common culture media. At the same time, a good growth performance and photosynthetic efficiency can be maintained, and carbohydrate and hydrocarbon productivities can be further enhanced. However, special attention should be given to each particular strain since different behaviour in growth and metabolite production can be observed depending on the media composition.

The significantly higher productivities obtained, together with the important reduction in media price when using commercial fertilisers, and the advantages related to the easiness to prepare the culture media based on NPKs represent an important achievement for the development of an industry based on these renewable products.

Keywords: *Botryococcus braunii*, fertilisers/NPK, cost-reduction, hydrocarbons, polysaccharides, productivity improvement.

Acknowledgments: This work was supported financially by the European Union under the Seventh framework programme (Project SPLASH: http://www. eu-splash.eu; contract number 311956).

The challenges of microalgae culture scale

H. KINSOU*[1], E Bermejo-Padilla, R. Filali[1], and B. Taidi[1]

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Microalgae are well recognised for their production of high value-added molecules for the pharmaceutical, food and feed industries. To meet this growing demand, the scaling up of algae culture to large volumes is necessary. This scaling up is a complex process with technical difficulties. The challenge of scaling up microalgae culture lies in obtaining the right combination of parameters (light, agitation, temperature, dissolved CO_2, etc…).

Chlamydomonas nivalis has been identified as an organism that could be suitable for cultivation at low temperature and light conditions, often encountered during part of the year in Northwest Europe. Initial growth models obtained from shake-flask cultures indicated the promising aspects of this organism.

The batch growth of *C. nivalis* at 5L scale was attempted in stirred photobioreactor. This organism is motile and its growth was prevented by application of mechanical stirring. Mixing by bubbling and variations in CO_2 concentration, pH and light intensity were tested. Growth was performed in batch culture. The growth indicators used in this study were absorbance at 800nm, photosynthetic activity and dry mass concentration. Although, the conditions of growth in bioreactor were improved, growth remained very limited. A change in the type of bioreactor may be necessary in order to replicate the growth rate observed in shake-flask culture.

This work was performed as part of the Interreg NWE IDEA, project-contract number NWE639.

Valorization of *Pavlova lutheri* algal biomass: production and analytical methods

Souissi, A.[1], S. Das [2,3], C. Bialais [2], F. Pericat [2], B. Ouddane [3], I. Sadovskaya [1], T. Grard [1], S. Souissi [2]

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2 : Laboratoire d'Océanologie et de Géosciences, Université de Lille, CNRS, Université Littoral Côte d'Opale, UMR 8187, F-62930 Wimereux, France
3: Université de Lille, LASIRE (UMR CNRS 8516), Equipe Physico-chimie de l'Environnement, Bâtiment C8, 59655 Villeneuve d'Ascq Cedex, France

In the framework of VALGORIZE project, ULCO (PP7) and ULille (PP8) teams were involved in WPs 1, 2 and 3. For WP2, the algae *Pavlova lutheri (*also called *Diacronema lutheri)* was selected by both partners. This species is an interesting marine microalga that contains a large amount of polyunsaturated fatty acids but with less known polysaccharide profile.

In order to develop and explore the potential of *P. lutheri*, a small scale (2-6 L) culture was optimised then a scale up using a specifically designed vertical photobioreactors of 45L and 300L was developed to produce a safe biomass. The higher volumes of algal cultures (up to 300L) were performed in the pilot located in the aquarium Nausicaa (PP12) according to a collaboration agreement between ULille and Nausicaa. The obtained biomass was used for different tasks of the project. The MAF technology of VITO (PP2) was used to obtain a safe algal biomass prior to the trial of taste panel at ILVO (PP1).

The taste panel reported that *P. lutheri* had a fishy and sour odour, with an umami and salty taste corresponding to seafood with an appearance of contrasting brown or dark green colour.

Beside these experimental tasks, an evaluation of the biochemical composition of *P. lutheri* mainly focussed on sugar analysis was performed by ULCO (PP7). For that purpose, polysaccharides were extracted from defatted cells with hot water (100°C, 1 h).

Monosaccharide composition analysis of defatted cells showed the presence of Glucose (Glc) as a major component (80% of total sugars and approx. 2.5% of dry algal weight), indicating the prevalence of a glucan in *P. lutheri.* The glucan seems to be easily extracted from algal biomass with hot water.

In conclusion, during 2020 several trials were made to upscale *P. lutheri* production in 300 L vertical photobioreactors. Although the upscaling from 45 L to 300L was not easy. Large culture volumes were transferred twice to VITO (PP2) to use the MAF technique. Then, the freeze-dried biomass was sent to ILVO for taste panel. Additionally, *P. lutheri* seems to have an important potential as a source of easily extractable polysaccharide.

Turbidity and dry weight correlation for three algal species grown in photobioreactors

Schoeters F.[1*], J. Spit [1] and S. Van Miert [1]

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In order to establish an economical and viable microalgae culture system it is crucial to reduce the costs to cultivate microalgae in photobioreactors. An important contributor to the costs of microalgae cultivation is the manual labour linked with e.g. following up the growth of a microalgae culture and estimating the microalgal biomass. To reduce both, the costs and labour, an online continuously monitoring system of the microalgae culture was tested at the Sunbuilt installation at Thomas More. Three algal species (*Porphyridium purpureum*, *Nannochloropsis gaditana* and *Chloromonas typhlos*) were grown for several weeks in a 1500 liter photobioreactor equipped with an online turbidity meter and a correlation between the turbidity (in nephelometric turbidity units, NTU) and dry weight (DW) was established for each specific microalgae.

For *P. purpureum* the DW is given by the equation: DW = 0,0214xNTU^0,6503 (g/l), meaning that a DW of 1 g/l can be obtained at a turbidity of 369 NTU.

The correlation for *N. gaditana* is: DW = 0,0211xNTU^0,5889 (g/l); 1g/l thus corresponded with a value of 701 NTU. For *C. typhlos* the DW is given by the equation: DW = 0,0379xNTU^0,5496; for which 1 g/l equals a value of 385 NTU. Figure 1 shows an example of such a growth curve linking the DW and turbidity.

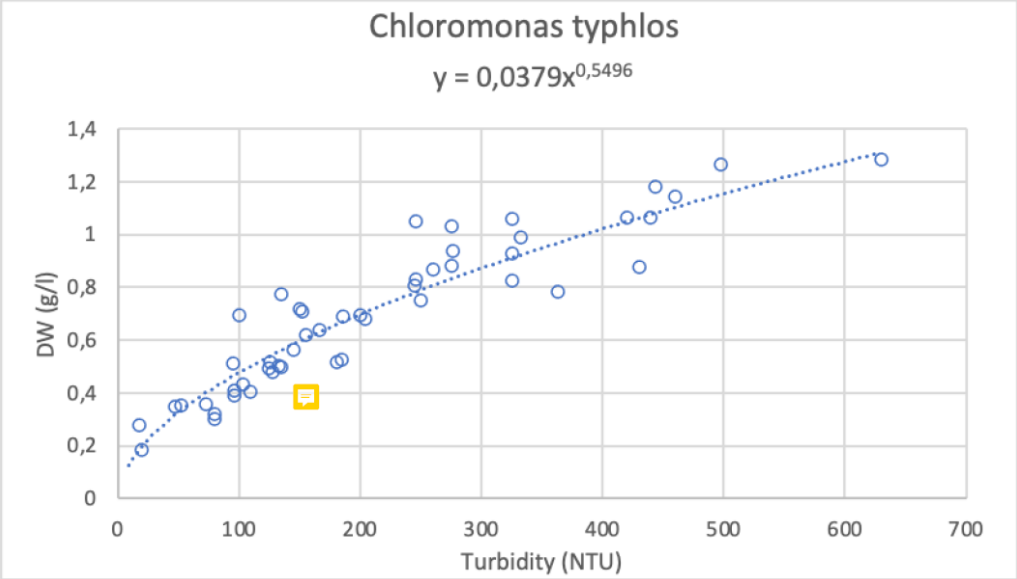

Figure 1: Corelation of the DW and turbidity for *C. typhlos*. See text for more details

This work was performed as part of the Interreg NWE IDEA, project-contract number NWE639.

A predictive growth model for *Nannochloropsis gaditana* in photobioreactors

Creylman J.[1,2], *F. Schoeters [1], F. De Ridder [1] and S. Van Miert [1]*

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Algae have the capability to fixate and convert CO_2 into biomass by using solar energy, making them not only a promising tool to lower CO_2 emissions, but also a manufacturer of clean energy and sustainable bioproducts. However, predicting the growth of microalgae in photobioreactors in greenhouses in North-western Europe is still difficult. In order to better predict this growth, *Nannochloropsis gaditana* was cultivated in the Sunbuilt installation at Thomas More in two photobioreactors. To identify factors limiting or driving algae growth, a parametric model was used. This model was combined with an information criterion to optimize model complexity. The growing conditions were artificially influenced and (more or less) controlled in the greenhouse, e.g. lighting was used to prolong the growing period and max. or min. temperature was controlled by cooling/heating. Mutliple datasets from the two photobioreactors were logged for a five-month period and used as input for modelling (e.g. pH, turdibity, temperature). *N. gaditana* was kept in optimal conditions in a continuous set-up. A growth period was defined based on photosynthetically active radiation (PAR – µmol/s.m²) and the sunset and sunrise times. The relative growth during this period was calculated for predictive modelling.

Data were randomly split in training and validation sets in a Monte Carlo set up. Each iteration, different multi linear models were fitted using a least squares estimator. Model selection was done using a modified Akaike information criterion (AIC). 88% of the observed relative growth of *N. gaditana* during this five-month growth period could be described with the following interplay of parameters: Relative growth = -2,15 T_0 + 1,70 T_0^2 + 0,74 PAR_{dose} – 0,13 + 0,23 tassim. The algae concentration (T0, measured as turbidity) showed to be the most important predicting factor, followed by the amount of PAR light during the defined growth period (PAR_{dose}). Other influencing parameters were the mean pH in the previous growth period () and the time of extra (artificial) lighting during the night time before (tassim). The temperature was kept stable within a predefined range during cultivation, thus this parameter could not be linked to any variance in the algae growth.

This model can be incorporated in a 'controller algorithm' to optimize algae growth, where for example expected PAR dose shortage can be compensated through longer assimilation during the night before. Subsequently such a controller algorithm can be developed that optimizes profit.

This work was performed as part of the Interreg NWE IDEA, project-contract number NWE639.

Algae biomass as a seasonal product - year-round phototrophic algae production in NWE

Ackermann, B.[1], M. Roeb[1], I. Meuser [1], and C. Kuchendorf [1]

1 Institute of Bio- and Geosciences/Plant Sciences (IBG-2), Forschungszentrum Jülich, Wilhelm-Johnen-Straße, 52428 Jülich, Germany

The realization of year-round cultivation of microalgae on pilot scale was a main target at IBG-2 during the IDEA project. This included algae production, monitoring, harvest and provision of biomass for the subsequent process chains at other IDEA partners. A microalgal consortium of naturally occuring local species (mainly *Chlorella vulgaris*, *Scenedesmus* sp., *Chlamydomonales*, *Synechocystis*) was cultivated in a bag system within a greenhouse and outdoors, continuously over several seasons. The primary goal was achievement of a year-round stable cultivation in 2017/18; this was followed up by targeting maximization of productivity in 2019/20. The algal consortium performed far more reliable and easier to handle than former mono-cultures and proved well suitable to the non-axenic and dynamic conditions (weather/light/temperature) in NWE. Especially in May/June/July, a productivity comparable to production rates of e.g. raceway ponds in climatically better-suited regions was reached and even surpassed, reaching a productivity of an avg. 32g/m²d; winter conditions still allowed for 5g/m²d in the consortia culture. The produced biomass was not homogeneous, but consisted to usually more than 80% of a main contributing species depending on the respective environmental conditions, especially temperature dynamics. The recurring species shifts up to 4 times per year make this biomass a seasonal product, which needs to be considered when establishing value chains. Yet the buffer capacity of the consortium against abiotic and biotic stress factors appears to make for a relatively simple but reliable biomass production in NWE. The biomass was supplied to the project partners for further processing; the very same algal consortium culture since 2017 is still in use today.

This research was co-funded by NORTH-WEST EUROPE INTERREG as part of the IDEA project (NWE 639).

4.2 E-POSTER SESSION 2: ALGAE HARVEST & SUSTAINABILITY ASPECTS OF ALGAE BIOMASS PRODUCTION

Abstract No. 19

Interference of AOM in coagulation of microalgae: influence of coagulant type and coagulation mechanism

Pappa, M., S. Lama, W. Marchal, D. Vandamme

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Microalgae are an attractive new biomass resource for the production of bio-based chemicals, materials, food or fuels. Microalgae are very small unicellular organisms that grow at low concentrations in waters. Harvesting microalgae from these waters to extract biomass remains expensive using current best available technologies. Therefore, our research team is focusing on the investigation of alternative methods based on coagulation and flocculation as pretreatment followed by sedimentation and dissolved air flotation, respectively, that could make it easier and cheaper to harvest microalgae. However, the presence of extracellular organic matter (AOM) could interfere (promotion or inhibition) because of interactions with cells, coagulants and flocs.

This first study focuses therefore on the interference of AOM in coagulation of microalgae (*Chlorella sp.* and *Nannochloropsis sp.*) in terms of separation efficiency for 3 types of coagulants: $FeCl_3$, chitosan, and alkaline flocculation. Generally, the presence of AOM resulted for both strains in a significant increase up to 20% of the required coagulant dose to achieve separation efficiencies higher than 90%. However, the coagulant type and the occurring coagulation mechanism clearly influenced the inhibitory effect of AOM. Eventually it was possible to achieve neutralization of the observed inhibitory effect of AOM. Future work is focused on the fundamental understanding in the interactions between cells, flocs and AOM in order to predict the most optimal coagulation, sedimentation and flotation conditions.

This study is financially supported by an FWO junior fundamental research project (2020-2021, G050220N, 573k€) entitled “The presence of extracellular algal organic matter (AOM) in coagulation, flocculation and flotation processes for harvesting microalgae biomass: problem or opportunity?” and a UHasselt BOF research project (2019-2023, R-9781, 216.5 k€) entitled “The role of extracellular algogenic organic matter (AOM) in flocculation-based harvesting of microalgae biomass.”

Dewatering and desalting of different algae species using submerged membranes (MAF-technology)

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An integrated technology for algae pre-concentration and medium re-use was developed and examined by VITO. It concerns a submerged membrane-based technology named MAF (Membrane based Algae Filtration). The technology has been developed focusing on the robust microalgae species *Nannochloropsis gaditana*, but meanwhile its application field has been extended to other species and larger scale MAF-devices. Other species like *Chloromonas*, *Chlorella*, *Scenedesmus* and *Pavlova* (Cultivated by Thomas More in Belgium, Forschungszentrum Jülich in Germany and the University of Lille in France) were concentrated successfully with volume concentration factors up to 50 and more. One of the features of the MAF-technology, is the low shear force that is implied on the algae during the concentration. For this reason, the MAF-technology offers potential for harvesting fragile algae species, like species without a cell-wall. Within the Interreg 2seas Valgorize project, the MAF-technology was applied to *Rhodomonas* cultures, being a fragile algae species without a cell wall. Batches of a *Rhodomonas* culture, cultivated by Hogeschool Zeeland (The Netherlands) in closed bioreactors with a density of 0.2-0.4 g/L, were concentrated up to 100 times using the MAF-technology. Permeation fluxes reached at that time were still good, suggesting higher concentration factors are likely to be within reach. The cell integrity during the process was monitored. Microscopic analyses proved that cells remained intact during the concentration process. For all algae species it was observed that the storage time and conditions of the algae prior to the MAF-concentration influence the quality of the culture and as such the filtration fluxes. In addition, the MAF technology has also been applied to desalt preconcentrated biomass, allowing its application in feed formulation for animal that are sensitive to high salt concentrations

This research was co-funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains In North-West Europe) & Interreg 2Seas project ValgOrize.

Medium re-use during pilot scale algae cultivation facilitated by submerged membranes (MAF-technology)

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Algae densities in photobioreactors at harvest time are present at concentration between 0.1 g and 3 g dry matter per litre. This implies that significant amounts of water are required and that re-use of the water is crucial for larger scale algae plants. But also re-use of salts that can be present in the medium at 15->50 g/l for brackish and salt growth conditions, would increase the sustainability of algae cultivation, especially when seawater is not nearby. Earlier, an integrated technology for algae pre-concentration and medium re-use was developed and examined by VITO. It concerns a submerged membrane-based technology named MAF (Membrane based Algae Filtration) that retains the algae biomass, while water and salts migrate to the permeate that can be re-used immediately as growth medium. Within the IDEA project, this MAF-technology was used to facilitate medium recycling, simultaneous with harvesting activities, during pilot scale algae cultivation.

In the Sunbuilt pilot plant (installed in a greenhouse) in Belgium (VITO & Thomas More), the fresh water algae *Chloromonas* was cultivated during 3-4 weeks in winter time in a 1500 L closed photobioreactor. Daily, 10% of the reactor volume was harvested in a continuous mode and a medium re-use level of 100% was implemented. Good algae growth was observed. A similar trial is being performed with the saltwater algae *Nannochloropsis* in spring time, allowing a higher daily harvest.

Also at the algae plant of Forschungszentrum Jülich in Germany, the MAF technology will be demonstrated in June 2021 for water re-use connected to a 2400 L green wall algae bioreactor. Here a mixed culture dominated by *Chlorella* will be grown on recycled medium, aiming at a daily harvest of at least 12.5 % of the reactor volume.

Conclusions of these three pilot test will be presented.

This research was co-funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains In North-West Europe)

Dynamic modelling and optimization of a fixed bed direct air capture system

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The extraction of CO_2 directly from the atmosphere (Direct Air Capture) is commonly employed using supported amine sorbents. This adsorption technology is under rapid development with novel sorbents materials emerging and with processes being demonstrated on increasingly larger scale. Optimization of such processes require accurate knowledge on sorbent characteristics and knowledge on how operational variables change process performance. This study is primarily focused on the latter, where we aim to quantify the influence of operational parameters on the energy duty and CO_2 productivity. In addition, we examined the influence of weather conditions on the adsorption rate. For this, we developed a dynamic model of the complete temperature-pressure swing adsorption cycle (TPSA). The model is validated by experimental results on a kg-scale direct air capture system. The impact of selected operational variables is assessed by two-dimensional sensitivity analyses. We show that desorption temperature is preferably high, limited by the chemical stability of the sorbent material in this particular case. In addition, the sorbent working capacity should be large when opting for an optimization towards energy duty, whereas it reaches a clear optimum in terms of CO_2 productivity. Finally, we conclude that weather conditions and diurnal variations can significantly affect the performance of a direct air capture process and should certainly be considered during design and operation. With these insights and the model developed, it provides a sound basis for further process development and optimization of direct air capture using fixed bed technology combined with solid amine sorbents.

This research was co-funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains In North-West Europe)

CO_2 capture from air to provide a sustainable carbon source for microalgae cultivation

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Direct Air Capture is the extraction of CO_2 directly from the atmosphere. This technology provides a sustainable carbon source, which can be utilized in a variety of conversion processes, e.g. the cultivation of microalgae. Using CO_2 from air for algae cultivation increases the sustainability of such cultivation process, since conventional CO_2 sources are usually fossil based. This technology is demonstrated at algae cultivation facilities. In these demonstrations, the product CO2 is used as feed for a photobioreactor and the algae growth is compared to a photobioreactor with the conventional CO_2 source. For the direct air capture process, a fixed bed reactor was designed with a capacity of 1 kg CO_2/day with a temperature-pressure swing adsorption cycle. Here, we present the design considerations for this fixed bed reactor and show experimental results of the demonstration campaigns at Sunbuilt (Thomas More & VITO, Belgium) and Forschungszentrum Jülich (Germany) with *Chloromonas typhlos*, *Nannochloropsis* oceanica and *Chlorella* sp. cultures.

This research was co-funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains In North-West Europe)

4.3 E-POSTER SESSION 3: ALGAE BIOMASS PROCESSING & FRACTIONATION

Abstract No. 8

The wet preservation of *Nannochloropsis gaditana* concentrates

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Wet preservation of algae allows us to bridge the time period between algae harvest and processing while avoiding the costs and nutritional losses associated with algae drying. This study aimed to identify suitable storage conditions for the wet preservation of *Nannochloropsis gaditana* concentrates. The impact of storage temperature, time and the way of closing the storage recipient was evaluated using a full factorial design. The effect of acetic acid addition was tested for one storage condition. Storage temperature was the main factor determining the microbial count and had a vast impact on the formation of odorous metabolites. Storage at 20 °C in closed recipients led to rapid O2 consumption, accumulation of malodorous short-chain fatty acids above their odor thresholds, and the production of H2S and methanethiol. These odorous metabolites were not formed or to a much lower extent during 4°C and 8°C storage in closed recipients. Acetic acid supplementation (50 mM) suppressed the formation of short-chain fatty acids during 8°C storage in unsealed recipients and reduced the aerobic microbial count and the number of yeasts and molds by approximately one log unit after 14 days. Yet, acetic acid addition also induced lipid hydrolysis and decreased chlorophyll levels when algae were stored for more than one week. This study demonstrated that temperature control is needed and that acetic acid addition is a promising approach when *N. gaditana* concentrates are stored for less than one week.

This research was co-funded by NORTH-WEST EUROPE INTERREG as part of the IDEA project (NWE 639).

The wet preservation of *Porphyridium purpureum*

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It is often impossible in practice to process micro-algae immediately after their cultivation and harvest. This study, therefore, aimed to identify appropriate storage conditions for the wet preservation of *Porphyridium purpureum*. Algae were stored either as a concentrate or as a dilute culture at 4°C, 8°C, or 20°C for 14 days and their quality was monitored. Concentrate storage tended to result in higher microbial numbers than dilute culture storage and clearly led to higher concentrations of malodorous organic acids. Butyric and isovaleric acid concentrations were about two orders of magnitude larger than their odor threshold values after 14 days of concentrate storage at 20°C. Average B-phycoeryhrin (B-PE) levels were slightly higher after concentrate storage (2.5 ± 0.2 g B-PE/100 g organic matter) than after dilute culture storage (2.2 ± 0.5 g B-PE/100 g organic matter), probably due to respiration losses of other organic compounds in the first case. Significant amounts of organic matter got lost during concentrate storage (4–35%) as a result of carbohydrate degradation. The main restriction of concentrate storage was the rapid viscosity increase and formation of a weak gel structure complicating the later processing of the concentrates. These findings are highly relevant for *P. purpureum* cultivators and processors who have to store *Porphyridium* suspensions, even on a term of one day or less.

This research was co-funded by NORTH-WEST EUROPE INTERREG as part of the IDEA project (NWE 639).

Wet preservation of *Nannochloropsis gaditana* and *Porphyridium purpureum*: Lessons learned from pilot-scale studies

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Pilot-scale storage tests were performed at the Sunbuilt facility with *Nannochloropsis gaditana* and *Porphyridium purpureum* cultures. A 2 m3 storage tank was isolated and connected with a cooling unit to enable cooled storage.

In a first test, 400 L of a *P. purpureum* culture was stored for 3 weeks at 8°C under continuous stirring. Organic matter losses and carbohydrate losses were minimal during the first 2 weeks. The level of B-phycoerythrin, the most valuable constituent, did not decrease during storage although it was more difficult to extract the pigment from the stored biomass than from the fresh biomass. Analysis of concentrates obtained by centrifugation revealed that storage had a significant impact on the rheologic behavior of these concentrates.

In a second test, about 250 L of an *N. gaditana* culture was kept at 8°C. A significant loss of organic matter was observed already after 3 days. Moreover, the yield of centrifuging the stored culture decreased drastically, and this decrease was larger than the decrease in organic matter in the culture. The high initial free fatty acid level (10% on a lipid basis) together with the culture's color indicated that the culture was exposed to stressful conditions before the start of the experiment. As this complicates the evaluation of the storage conditions, another pilot test was performed. **In a third test**, 400 L of an *N. gaditana* culture was kept for one week at 8°C. No large organic matter loss was observed and centrifugation of the stored culture yielded a similar amount of biomass as centrifugation of the fresh culture. Lipid levels did not decrease during storage and fluorescence measurements suggested that storage had no major impact on chlorophyll activity. These results indicate that the tested conditions are appropriate for pilot-scale storage of *N. gaditana* and *P. purpureum*. Yet, it does not prevent organic matter losses during storage of a stressed *N. gaditana* culture.

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The wet preservation of *Chlorella vulgaris*

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A *Chlorella vulgaris* storage test was performed to study the effects of growth conditions and harvest method on the algae quality during wet storage. *C. vulgaris* cultivated by Forschungszentrum Jülich was either well-fed until harvest or received no nutrients during the last week before harvest. Algae were harvested by either continuous centrifugation or by batch centrifugation in the laboratory. In the latter case, algae had experienced fewer shear forces than during continuous centrifugation. The total microbial load was evaluated by plate counting, microbial metabolites were monitored, as well as lipid content and free fatty acid levels. The lowest number of micro-organisms was observed for the nutrient-depleted concentrate immediately after harvest by continuous centrifugation, which was probably related to the low pH of this batch. It contained the highest concentrations of fermentation products, particularly lactic acid but also acetic acid and ethanol. Lipid levels were rather constant but free fatty acid levels were affected by the harvest method. This study showed that not only storage conditions but also (pre-)harvest conditions affect algae quality after storage.

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Effect of ensilage on taste, sensory and health properties of Ulva

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The biomass yield and nutritional composition of seaweeds are both highly variable over the growing season (Schiener et al. (2014)). The biomass should therefore be harvested when the dry weight and the content of the storage carbohydrates are at the highest. This requires efficient preservation and storage of the biomass to allow whole-year processing for a sustainable seaweed industry. The cheapest and most feasible method for preserving large volumes of seaweed biomass is acid preservation, either by adding acid, or by microbial acid production by lactic acid bacteria (ensiling). Ensilage/fermentation is an ancient and widely used method for preservation of perishable foods, i.e. milk, cereals, meat and vegetables, hereby producing new foods or beverages (Bruhn et al., 2019). The principle of silage is the conversion of water-soluble carbohydrates present in the crops to organic acids, mainly lactic acid, by epiphytic lactic acid bacteria under anaerobic conditions, resulting in a pH drop that inhibits the growth of undesirable microorganisms and reduces feed deterioration.

In the INTERREG ValgOrize project we are studying the parameters that can stimulate the ensilage of the green seaweed *Ulva* sp.. The effect of different bacterial inocula on the ensilage are followed by a decrease of pH but also the production of volatile fatty acids and the degradation of the carbohydrates in the Ulva sp.. In addition, the effect of the ensilage on the taste and sensory properties of the ensiled seaweed are investigated. As a second part, the enzymatic conversion of the polysaccharide ulvan into oligosaccharides and their prebiotic and antioxidant activities are being explored.

Interreg
2 Seas Mers Zeeën
ValgOrize
European Regional Development Fund

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Rapid indicators of microalgae cellular health

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In order to develop a sustainable and economically viable industry around microalgae culture, a certain number of quality standards must be put in place, accepted widely and applied by all the participants in the value chain from producer to the seller of high value extracts.

The microalgae industry could be based on a dispersed production model with large centres for the treatment and valorisation of the microalgae and their products. In this sense, the industry could resemble the dairy industry with a key step of collection and transport of the microalgae biomass to the treatment centre or Biorefinery. Quality control at the point of collection is preferable in order to minimise the transport costs.

Such system would require rapid and reliable indicators of microalgae quality upon collection at the production site or reception at the biorefinery. A number of biomarkers exist that could be used for such purpose and these were examined. The work presented in this poster will outline the study, suggest a method of preservation of the microalgae suspension and propose a method for rapid assessment of quality.

This work was performed as part of the Interreg NWE IDEA, project-contract number NWE639.

Disruption of Scenedesmus and other microalgae cells: Impact of disruption approach and algae biomass preservation prior to disruption

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Microalgae are a potential source of a variety of compounds like fatty acids, proteins, sugars, carotenoids and colorants. To make the intracellular compounds accessible, the cells need to be disrupted, which might be challenging as some algae species have strong cell walls. Therefore, cell disruption is an important algae processing step that needs to be evaluated at an algae species level. Within the Interreg NWE IDEA project large quantities of algae biomass (kg-level) needed to be treated at multiple moments. For this purpose cell disruption approaches were elaborated for *Nannochloropsis sp.*, *Porphyridium sp.*, *Chloromonas sp.*, *Chlorella* sp. and *Scenedesmus sp.*. Beadmilling was the technology that was applied in most cases.

For *Scenedesmus*, beadmilling (available at VITO) and high pressure processing (HPP, available at TEAGASC) were compared as disruption methods as well as the impact of biomass preservation prior to cell disruption. The impact of the cell disruption process was evaluated by measuring the amount of the water soluble and non-soluble compounds. When using fresh algae biomass (10-14 % DM) the disruption degree (% solubilized) with the beadmill approach was 40-42 % based on dry matter and total carbons and 50 % based on proteins (N-based). Freezing of fresh biomass caused a partial cell disruption (10-20 %) and the maximum disruption degree reached with subsequent beadmilling process was only 21-31%. The temperature at which the samples were stored (-20°C and -80°C) did not seem to influence the results much. Frozen biomass was also treated with HPP approach and the mounts solubilized were found to be much lower. To evaluate whether cell disruption occurred without solubilization of the compounds, confocal microscopy will be performed. Beadmilling of fresh *Scenedesmus* sp. biomass was selected for larger quantities.

This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains in North-West Europe).

Cascading fractionation of algae biomass at lab and pilot scale

Bastiaens, L. [1], *S. Van Roy* [1], *Q. Simons* [1], *B. Van den Bosch* [1], *S. Vloemans* [1], *J. Verspreet* [1], *P. De Rechter* [1] *& K. Elst* [1]

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The Interreg NWEurope project IDEA envisions the development and enrolment of economic viable value chains based on micro-algae in NWEurope. An important aspect in the value chain is the valorisation of the algae biomass. Algae can be used as whole (disrupted) biomass, but also algae fractions are marketable. For the algae species *Porphyridium*, *Chloromonas*, *Nannochloropsis* and *Chlorella*, cascading fractionation processes were elaborated to generate fractions like oil extracts, sugar enriched fractions, protein enriched fraction, defatted fractions. The technologies used comprise beadmilling, solvent extraction, supercritical extraction, water based precipitation reactions, enzymatic conversions, centrifugation, filtration and sorption. Although multiple applications are possible, the cascading fractionation was mainly tailored to meet requirements of cosmetics and feed applications.

Cosmetics represent a higher value application where rather small amounts of biomass are required to start a production process, but there are more strict requirements related to odour, colour and composition. The oil fractions of the different algae species were extracted using solvent extraction and supercritical fluid extraction, and were subsequently further processed to remove odour and colour to acceptable levels. The composition of the total and free fatty acids was examined. Defatted algae biomass, was subsequently characterised to evaluate its application in feed, and especially as bioactive ingredients. Compared to nutritional ingredients, bioactive ingredients have a higher value and smaller amounts are required to start up a production process. The salt concentration in the fractions was identified as a point of attention. Also other cascading fractionation processes were considered. The fractionations were performed at lab scale and most promising concepts were also performed at small pilot scale. The latter allowed to produce fractions for in vitro and in vivo application trials.

This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains In North-West Europe).

4.4 E-POSTER SESSION 4: APPLICATION POTENTIAL OF & FORMULATIONS WITH ALGAE BIOMASS (FRACTIONS)

Abstract No. 4

Bio-Stimulans IsoAgensò

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An extracted fraction from Isochrysis galbana (IsoAgensÒ) appeared to have some specific effects on a range of plants/crops as demonstrated in selected bioassays:

1. Increased Nitrogen efficiency at low supply rates of nitrate and or ammonium by increasing the affinity of nitrate uptake and after 48 hours by a higher capacity of the uptake system.
2. Stimulation of the net chlorophyll synthesis
3. Delay of leaf senescence
4. Increased stress tolerance to abiotic factors

Practice validation confirmed the bioassay results through testing:

1. Two pot plants, Schefflera and Coleus, for their ornamental and survival value in the sales channel
2. Several juvenile plants of kitchen herbs, mint, caraway, parsley and basil, for their vigour and survival value during transport simulation
3. Increased N-efficiency in grasslands at low manure application rates; less nitrate leakage and GHG-emission

From this we entered a few co-developments:

1. Bringing IsoAgensÒ in a matrix of biodegradable biopolymers and by this creating a slow release source for several horticultural and agricultural applications; *it has been verified on bioassay level*
2. Absorbing IsoAgensÒ in different types of paper and by this creating a slow-release source for several horticultural and agricultural applications, however having a shorter lifetime than 1.; *it has been verified on bioassay level*

Some general technical data:

1. Applied concentrations IsoAgensÒ: M-6—M-9.
2. Duration of action after a single addition: at least 12 weeks
3. Storage at 5°C. at least for 6 months

Use of microalgae in the development of enriched, bioactive foods and assessment of their acceptance by consumers.

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Microalgae are a known source of bioactive compounds with potential benefits for human health. As part of the IDEA project, microalgae were incorporated into recipes for jelly sweets and biscuits. Anti-oxidative, anti-hypertensive, immunomodulatory, anti-cancer, hepato-protective, and anticoagulant activities have been attributed to specific microalgal compounds including bioactive peptides. Bioactive peptides are sequences of between 2-30 amino acids in length that when released from the parent protein may exert a beneficial health effect to the consumer. *Spirulina* sp., and *Nannochloropsis* sp. supplied by VITO were used in this study as a source of protein and for the development of bioactive peptide-rich protein hydrolysates that were subsequently incorporated into biscuits. A bioactive peptide containing *Spirulina* sp. hydrolysate was generated using proteolytic enzymes and bioactivities assessed using an *in vitro* Angiotensin-I-converting enzyme (ACE-1) inhibitory assay. The hydrolysate inhibited ACE-1 by 59.13% ±2.76. Furthermore, protein extracted from the microalga *Nannochloropsis* sp. was also found to inhibit ACE-1 significantly compared to the commercial control Captopril© when assayed at a concentration of 1 mg/ml. Bioactive hydrolysates were characterised for their peptide content using mass spectrometry and subsequently used in the formulation of biscuits. Biscuits were made by including the hydrolysate at 4% of the dry weight of the biscuit and using a whey hydrolysate at the same inclusion rate as a positive control. Biscuits were analysed for their protein content. The *Spirulina* sp. biscuit had a protein content of 9.04%/g biscuit ±0.13. The protein content was significantly greater than the protein content of the positive control biscuit which had a protein content of 6.48%/g biscuit ±0.18. *Spirulina* sp. biscuits were re-made and an acceptance test was carried out to determine the acceptability of the formulations by potential consumers. Sensory panels were carried out on a team of 18 untrained panellists. The parameters analyzed included appearance, aroma, flavour, texture and overall impression. A nine-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) was used. Purchase intention was evaluated with a 5-point scale, ranging from 5 (I would certainly buy it) to 1 (I would certainly not buy it). Values of between 5 and 2 were obtained for each test respectively. *Spirulina* sp. hydrolysate biscuits presented the highest sensory scores similar to the control biscuit and provide a potential heart health benefit to the consumer.

Acknowledgement: This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains in North-West Europe).

Nutritional profiling of five micro-algae strains cultivated in Northwest Europe

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This study aimed to map the nutritional profile of five microalgae that can be grown in Northwest Europe or areas with similar cultivation conditions. Next to the biochemical composition, the *in vitro* digestibility of carbohydrates, proteins, and lipids was studied for *Chlamydomonas nivalis*, *Porphyridium purpureum*, *Chlorella vulgaris*, *Nannochloropsis gaditana*, and *Scenedesmus* biomass. Large differences in organic matter solubility after digestion suggested that a cell disruption step is needed to unlock the majority of the nutrients from *N. gaditana* and *Scenedesmus* sp. biomass. Significant amounts of free glucose were detected after digestion of *C. nivalis*, *P. purpureum*, and disrupted *Scenedesmus* species. The fatty acid profiles showed major variations with particularly high Ω-3 fatty acid levels found in *N. gaditana* (5.5 ± 0.5 g/100 g dry algae) while lipid digestibility ranged from 33.3 ± 6.5% (disrupted *N. gaditana*) to 67.1 ± 11.2% (*P. purpureum*). *C. vulgaris* and disrupted *N. gaditana* had the highest protein content (45-46% of dry matter), a nitrogen solubility after digestion of 65-71%, and the degree of hydrolysis was determined as 31% and 26%, respectively. These data can assist algae growers and processors in selecting the most suitable algae species for food or feed applications.

This research was funded by NORTH-WEST EUROPE INTERREG as part of the IDEA project (NWE 639).

Value chain for n-3 LC-PUFA from microalgae for food applications

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There is a need for an alternative source of n-3 LC-PUFA due to the reducing fish stock. In addition, the daily intake of n-3 LC-PUFA is not reached in Western countries. Microalgae could provide such an alternative. Therefore it is useful to enrich food products with n-3 LC-PUFA from microalgae.

Different routes can be followed from the green water to the health conscious consumer: after harvesting and possibly drying, the whole biomass can be added to food products, the lipids can be extracted from the biomass and added to food products or the biomass can be added to the feed of laying hens to enrich their eggs with n-3 LC-PUFA. In each case a cell disruption step may be appropriate to increase the bioaccesibility or extractability of the n-3 LC-PUFA.

Given the food application, it is very important to study the lipolytic and oxidative stability of the lipids during the whole value chain, an aspect that is quite often overlooked. Furthermore, it is important to not only look at the triglycerides but also the polar lipids, which also contain N-3 LC-PUFA.

This presentation / poster will give an overview of the obtained results by different projects of Food & Lipids KU Leuven in this respect in the past years and the current research focus. Attention will be paid to lipolytic stability during wet storage and cell disruption and also to the effect of cell disruption on lipid extractability and how to best study this. Oxidative stability during storage, extraction and processing of algae containing food products will be another important topic. Comparison between photoautotrophic and heterotrophic microalgae (as biomass or as extract) and fish oil will be made and the importance of endogenous carotenoids of photoautotrophic microalgae for the higher oxidative stability of these microalgae will be demonstrated.

Finally, the importance of using correct analytical methods will be touched upon.

Microalgae as a protein source and beneficial health ingredient for use in pet treat production.

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There is a growing demand for functional health ingredients and novel proteins in pet feeds. These ingredients should have increased health or nutritional benefits in terms of general wellness or address specific health concerns such as digestion, joint and cartilage function, immune system strength or dental health. Microalgae offer potential for use as protein-rich ingredients in pet treats as they produce ingredients via conversion of CO2, nutrients and light, and offer potential as a renewable source of protein.

Spirulina sp. (purchased and processed by Teagasc) and *Nannochloropsis* sp. (Grown in Sunbuilt-Belgium, processed by VITO) were characterized for their nutritional (protein, ash and lipid content) and their potential heart health benefits for pets. High blood pressure in dogs is systolic blood pressure exceeding 150 mm Hg. Blood pressure above 150 mm Hg can cause negative effects in dogs and signs of hypertension relate to the eyes, heart, central nervous system and kidneys. Microalgae were screened for their ability to inhibit the enzyme Angiotensin-I-converting enzyme (ACE 1; EC 3.4.15.1). This enzyme is central to the control of salt-water balance and blood pressure in humans but also in several mammals including dogs. The nutritional and bioactive content of microalgae was determined. Spirulina protein hydrolysates and defatted *Nannochloropsis* were used to manufacture dog treats due to their observed ACE-1 enzyme inhibition activities.

Dog treats were made with the microalgae in a recipe formulated at Teagasc Ashtown and were subsequently used in a non-invasive dog feeding trial. Ten senior dogs aged between 8-13 years old were fed over a period of 28 days in a "matched design" trial where the four different treat recipes were assessed for their palatability, digestibility, blood pressure reducing effects and acceptability. Blood pressure was measured every second day in the experimental period. Systolic and diastolic blood pressure recordings were taken. Weight gain was also determined. At the end of the trial, it was found that dogs fed the *Spirulina* sp. treat gained weight but had less acceptance in terms of palatability compared to treats made using defatted *Nannochloropsis* sp. When fed to the dogs, both treats caused a reduction in blood pressure in elderly dogs when assessed over a 28-day period. These prototype products show promise for use as functional foods for the prevention of hypertension in dogs.

Acknowledgement: This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains in North-West Europe).

Abstract No. 30

Use of dry and wet micro algae in feeds

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Performing an application test with dry and wet micro algae in pig feed in the pilot plant of Feed Design Lab was executed in November 2018 and January 2019 as part of the INTERREG IDEA project. Chlorella Vulgaris in powder form (Phycom) was used in a pelleting experiment with temperatures of 60, 70 and 80 degrees Celsius. The same meal with 2% Chlorella Vulgaris was used in a similar test using and expander before pelleting. Samples of meal and pelleted products were analysed.
In another test micro algae from IDEA partner Forzungs Zentrum Juelich (FZJ) in Germany were used. A frozen amount of mixed cultured micro algae was used as wet algae product to be dosed in the conditioner, just before extruding the feed. The same products was also used to spray during vacuum coating of extruded pig feed. The dry Chlorella Vulgaris was dissolved and also used in the vacuum coater.

Results of analysis showed:

- The physical quality of the produced feeds was fine. The microbiological analysis showed safe products. The chemical analysis was partly performed. Levels of ash and protein were fine. The levels of lysine and available lysine were very different and not as expected.
- Because of the missing of these parameters, the conclusions on the maximum level of processing during pelleting and extruding was not possible to draw.
- Missing that, makes that we can only go for the safe known level of 75 degrees Celsius for maximum temperature during processing for proteins in general.
- Alternative for using the micro algae in the heated process is to use the products during vacuum coating. This post pelleting application of micro algae prevents the bio-active substances to be affected by the heating process.

This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains in North-West Europe).

Effect of micro algae in dogs on immune system

Van der Lee A.1, J. Verspreet [2], M. Hayes [3] and L. Bastiaens [2]

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Health is important for dog owners. Producing a feed that improves the immune system of the dog is desired. By measuring the faecal IgA the effect on the immune system in dogs can be judged. One way to positively influence the dogs health are micro algae, this new upcoming ingredient is said to improve health, and has already proven positive results in many species. In the INTERREG NWE IDEA project many organisations are working together to prove that micro algae could be the future in many sectors including feed. VITO provided the processed micro algae (grown by Thomas More) and performed analyses in this project, TEAGASC analysed algae and feeds and Feed Design Lab produced the dog feed and coordinated the dog trial. The goal of this study was to measure the effect of the micro algae *Chloromonas* and *Porphyridium* in dog feed on immunity, measured in faecal IgA.

The three extruded feeds that were used in this study were produced at Feed Design Lab using a basal meal from Vobra Special Petfoods, with the micro algae added during mixing. The study was performed on thirteen midsized dogs of multiple breeds, ages and genders that live together at the same research facility in the Netherlands. The general feed intake of the dogs was calculated for each period, and the manure was collected and weighed during the last two days of each period. The manure was frozen and at the end of the trial send to Gent University to be analysed for faecal IgA using a Elisa method, used on dog faeces.

The IgA was the highest in the group with the *Chloromonas* feed, showing a trend compared to the control feed. *Porphyridium* did not show a significant difference when compared to the control feed. Other variables that had a significant effect on the IgA were breed and gender.

This means that adding *Chloromonas* in feed has a positive effect on the immune system of a dog. *Porphyridium* did not show an effect, with 0.5% added in feed, but it would be recommended to perform a dose response study. Using small amounts of micro algae in feed can also be useful for other animals as livestock because health is important in livestock farming as well.

This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains in North-West Europe).

Algae Based Bio Compound for Prevention and Treatment of Inflammation, Pain and IBD (ALGAE4IBD)

Avni D.

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Algae4IBD's mission is to develop commercial products for Inflammatory Bowel Disease (IBD) prevention and treatment using aquatic natural biological resources. With the emerging developments in natural product, notable success has been achieved in discovering natural products and their synthetic structural analogues with anti-inflammatory activity. However, global biodiversity remains a largely unexploited resource for natural bioactive molecules with an enormous potential for developing commercial products with public health benefits. Micro and macroalgae, found in marine and freshwater, have been identified as promising sources of bioactive compounds including small molecules and secondary metabolites with a wide range of bioactivities as an antioxidant, anti-inflammatory and cancer preventive. Consumption of algae could, therefore, provide defence against chronic inflammatory diseases such as IBD, that until date have no effective cure. This project offers nature to bedside approach, using an entire development along the value chain for a new biodiscovery therapeutic approach by developing and examining algae-based compounds for IBD patients while guaranteeing algae's biodiversity preservation. We propose innovative solutions for increasing the use of algae-based ingredients and to ensure the science-based improvement of nutritional quality and its effect on public health. The researchers, companies and hospitals involved in the different stages of the project will use the biodiversity of algae, both micro and macro, as a wide source for bioactive compounds using state-of-the-art cultivation and extraction technologies for obtaining sufficient amounts of the bio-active molecules together with novel processing protocols. It will result in novel algal based, high-quality bioactive compounds at GMP grade and lower costs for dual purposes – IBD prevention and treatment in relevance to the food as well as the pharmaceutical industries.

Algae4IBD
Health from aquatic resources

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grand agreement N°101000501¶

4.5 E-POSTER SESSION 5: ALGAE VALUE CHAINS

Abstract No. 1

An integrated techno-sustainability assessment framework for algae-based technologies

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A better understanding of the drivers of the economic, environmental, and social sustainability of emerging biobased technologies and products in early development phases can help decision-makers to identify sustainability hurdles and opportunities. Furthermore, it guides additional research and development efforts and investment decisions, that will, ultimately, lead to more sustainable products and technologies entering a market. To this end, this study developed a novel techno-sustainability assessment (TSA) framework. The integrated TSA compares the potential sustainability performance of different scenarios and helps to make better-informed decisions by evaluating and trading-off sustainability impacts in one holistic framework. The TSA combines methods for comprehensive indicator selection and integration of technological and country-specific data with environmental, economic, and social data. Multi-criteria decision analysis (MCDA) is used to address data uncertainty and to enable scenario comparison if indicators are expressed in different units. A hierarchical, stochastic outranking approach is followed that compares different weighting schemes and preference structures to check for the robustness of the results. The integrated TSA framework is demonstrated on an application for which the sustainability of a production and harvesting plant of microalgae-based food colorants is assessed. For a set of scenarios that vary with regard to the algae feedstock, production technology, and location, the sustainability performance is quantified and compared, and the underlying reasons for this performance are explored. The results show that stimulating algae growth leads to productivity gains, positively affecting the overall sustainability. Moreover, company management choices such as the degree of recycling and the level of transparency can influence the relative sustainability performance.

This research was funded by NORTH-WEST EUROPE INTERREG as part of the IDEA project (NWE 639).

MooV – decision support for optimal value chain design - The IDEA algae case

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Figuring out the best design (or configuration) of a value chain is hard. For each value chain activity; such as production, storage, pre-processing, transport and final processing; decisions need to be made regarding location, capacity, transport modes, process types,… However, freedom of choice is often limited as specific conditions related to quantity, quality, location, planning and costs need to be met simultaneously. What is more, each decision made has impact elsewhere in the chain.

The impact of these strategic design decisions needs to be thoroughly investigated as they have a long-term impact on the chain's performance and cannot be easily reversed in time. MooV is a service specifically designed to **investigate the impact of decisions and events and support the design of robust and optimal value chain configurations**. The MooV service is based on the MooV model, a smart merger of proprietary linear programming code and Python-based advanced (geo-)data analytics, and professional software packages such as GUROBI Optimizer and ESRI ArcGisPro. To be able to apply the MooV service to all kinds of value chains, the MooV model is designed as a central core enveloped by a shell. The MooV-core is generic and captures the universal value chain logics. The MooV-shell is customizable and captures the specifics of each specific case.

To **apply MooV to a specific case**, three steps are distinguished:

1. DEFINE: definition of the case specifics such as; all relevant value chain activities, products and flows in its geographic context, as well as all key decision parameters (cost, quantity, quality, time, etc.); and define specific client needs into scenarios.
2. DESIGN: design of the customized MooV-shell; translating the case specifics, needs and scenarios into linear programming code.
3. DELIVER: scenario analysis, sensitivity analysis and delivery of the results; running the scenarios and comparing the results side-by-side; assessing the impact of critical decisions on the performance of the overall chain. MooV results are presented either as static graphs and maps in a report or as a dynamic online dashboard.

As a **proof-of-concept and demonstration** of this MooV approach, the poster presents the implementation within IDEA to analyse and optimize the algae-based value chain. The model is used to investigate the impact of different algae cultivation strategies, the impact of centralized or decentralised downstream processing of algae and the impact of the geographic region on the total cost of the chain as well as the configuration of the algae-based network.

This research was co-funded by NORTH-WEST EUROPE INTERREG as part of the IDEA project (NWE 639).

MAGNIFICENT Value chain for the production of sustainable ingredients from microalgae

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There is presently a large production capacity for a limited number of microalgae strains in Europe. However, the number of concrete products and market applications is still limited.

MAGNIFICENT is a European project (2017-2021) sponsored by the Bio Based Industries Joint Undertaking (BBI-JU; H2020) to expand the range of commercial products and their market volume in a sustainable manner. The overall objective is to develop and validate a sustainable and economically feasible new value chain based on algae cultivation and processing. The aim is to transform microalgae biomass into valuable ingredients for food, aquafeed and cosmetics.

To achieve this, optimization was done: 1) Upstream, cultivation related processes via adaptation and selection of algae varieties, improvement of growing conditions and target product concentration in the cell and 2) downstream process steps (separation, extraction, purification) in order to achieve the overall aim to maximize the production of compounds of interest (phospholipids rich in omega-3 fatty acids EPA and DHA and fucoxanthin as main molecules). Development and validation of new product formulations are included in the project. The work is supported by chain evaluation, market assessment, socio-economic impact assessment and LCA. Specific attention is paid to the requirements of the existing EU regulatory framework.

The MAGNIFICENT consortium has 15 partners from 6 EU countries incl. 10 SME's, 2 LE's, 1 University and 2 RTO's, and comprises commercial partners in the entire value chain and the 3 target markets. MAGNIFICENT started in 2017 and the main results to date will be presented.

Keywords:

Fucoxanthin, omega-3 fatty acids, autotrophic, aquaculture, cosmetics, biomass production, biorefinery

Inventory of stakeholders needs in the algae value chain

Monagheddu M[1] , L. Bastiaens [1], with inputs from the IDEA consortium

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Within the Interreg NWE IDEA project, thanks to its holistic approach, the links of the value chain, the stakeholder types, their needs, concerns and ambitions were analysed. The general aim was to identify the main points of attention that prevent full implementation of algae value chains in (NW)Europe.

To do so, 234 individual stakeholder entries were collected across the value chain and categorized by geography, position in the chain and business model. Out of the 134 entities located in North West Europe a representative sample of each category was interviewed leading to collecting > 80 observations that were then grouped in ~40 individual needs.

Analysis of these needs highlighted that algae farming is perceived as risky investment due to the uncertainty on costs, market and the technology challenges of scale up. The last element has a strong effect on processing industry, that feels threatened by insecurity of supply, to the point that integration of upstream and downstream parts of value chain becomes more and more common. End users realize the opportunity of algae based products, but require product standardization, reproducibility and certification in order to fulfil regulations and address consumer that are growing more and more demanding.

There is a general consensus that innovation is required to serve large scale markets expecting a competitive market price, being for instance 0.5-0.75 euro/kg for nutritional feed/food compounds.

Based on the identified points of attention, the following drivers of algae value chain implementation were identified:

- Clearly defined applications, that guide 1) algae growers to select relevant algae species and growth conditions, and 2) the processing industry to produce relevant product ingredients.
- Innovation should have short time to market and a focus on: manufacturing engineering, strain optimization and product standardization.

This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains inNorth-West Europe).

IDEA roadmap towards implementation of economic viable algae value chains in NWEurope

***Bastiaens, L.*[1] & IDEA consortium [2]**

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The Interreg NWEurope project IDEA envisions the development and enrolment of economic viable value chains based on micro-algae in NWEurope. More particularly, Belgium, Germany, France, The Netherlands and Ireland are represented by the IDEA consortium, which are countries exposed to a similar climate that is significantly different from the south-European climate. The project focusses on phototrophic algae growth in closed reactors targeting higher value applications of the algae biomass (feed, food, cosmetics).

IDEA envisioned to formulate concepts of an algae value chain implementation plan. This implies interlinking the different parts of the value chain, taking into account (1) the needs of different actors along the value chain comprising algae growth, algae processing and formulating industry of algae-based ingredients, (2) the reality of spatial distributions (logistic aspect), (3) quantities of biomass (fractions) to be processed, (4) product specific requirements, and (5) economic aspects.

The IDEA roadmap serves two purposes. First and foremost it is a plan or strategy intended to achieve a particular goal. It gives an overview of challenges and opportunities and explains which routes to be followed. It includes the steps to be taken or milestones to be met and hurdles to be overcome in order to reach the goal. Further, the roadmap is also a communication tool and articulates the strategy behind the goal and the way to reach it. The most updated version of the IDEA roadmap will be presented and will be finalised lateron with feedback received during the IDEA final event.

This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains In North-West Europe)

Potential concepts of an algae federation

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The last 2 decades the interest in algae farming for other uses then biofuel has risen very rapidly. The numbers of algae growers is also increasing, as is the need for information (like market information and information about algae growth) and the need to cooperate.

The Interreg NWEurope project IDEA envisions the development and enrolment of economic viable value chains based on micro-algae in NWEurope. Within this project a desktop study was performed to find out what kind of co-operations are used in the agricultural sector to get more market power by combining the strengths of farmers and or other chain players.

Two types of grouping were considered, notably, federations and cooperatives. For each type we described: definition, what are the differences and what is their specific use? We also described for both practical aspects like: getting started, investments, good collaboration, staffing, dangers and examples. For this we took a look at initiatives in the wine and brewing industry and the milk, insect, pig and algae farming.

Based on this information, possible scenarios for start-ups were elaborated, as well as ideas about the collection and processing of algae, the need and setup of knowledge centres and trading possibilities.

This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains In North-West Europe).

Identification and evaluation of potential 'platform' concepts to facilitate offer and demand of algae based biomass

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The last 2 decades the interest in algae farming for other uses then biofuel has risen very rapidly. The numbers of algae growers is also increasing, as is the need for information (like market information and information about algae growth) and the need to find customers or suppliers to trade with.

The Interreg NWEurope project IDEA envisions the development and enrolment of economic viable value chains based on micro-algae in NWEurope. An important aspect in value chain enrolment is the interaction between offer and demand, which for algae is related to algae species, the way of processing, and the quality/purity as well as the quantity of the biomass.

Within this project, firstly, a desktop study was performed to find out what kind of platform concepts are used in the agricultural sector to connect farmers with their clients. Eight already existing platforms and initiatives trading in agricultural products in Europe and the US were examined and for each platform the goal and functioning was described as well as its pros and cons.

Next, based on these examples, different platform types were defined and their possible role for algae biomass was evaluated in terms of possible expectations of the platform users. A differentiation was made between 1) platforms that takes up the roll of only informing the platform users and 2) platforms that take up the role of informing and trading. For each platform type pros and cons were defined. The most suitable platform is to be selected based on the role the platform should take up and the users expectations.

This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains In North-West Europe).

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