MIRACLES
SPECIALTIES FROM ALGAE

Newsletter

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Editorial

by Hans Reith (Wageningen University), Work Package 8 and Project Coordinator

Microalgae are a promising and sustainable source of raw materials for both food and non-food products. Instead of taking up arable land, microalgae can be grown on seawater using residual nutrients and CO_2 from flue gas. Algal cultures have high areal productivity, and the biomass they produce is rich in oils, proteins, carbohydrates and other valuable compounds. Despite their potential, little use has been made so far of algae as a biomass production platform because of the need to reduce production costs and increase output in order to improve profit margins. Another way of improving economic feasibility is to refine the algae into many different value products that can increase revenue. All these issues are addressed in MIRACLES.

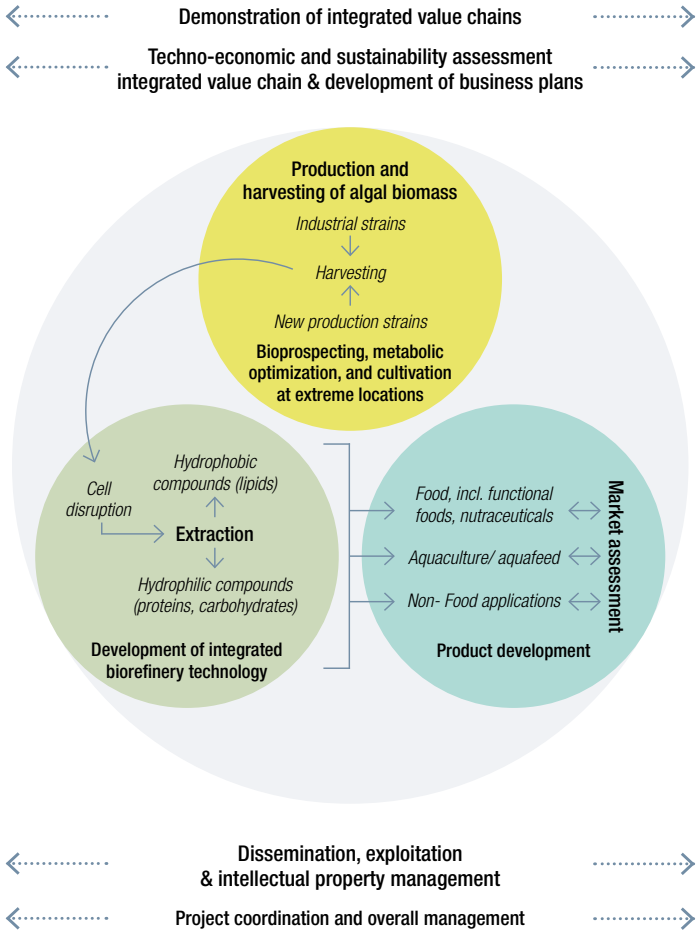

Image 1: MIRACLES Diagram

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Editorial

The overall aim of the MIRACLES project is to develop mild and environmentally friendly, integrated biorefinery technologies for the production of algae-based specialties that can be used in food, aquaculture and selected non-food products. The project will develop products for these markets and also aims to make significant, groundbreaking improvements in cultivation and harvesting techniques to boost productivity, reduce costs, and lower the environmental footprint by recycling and saving energy.

New tools will be developed to monitor farming processes and optimize algal biomass target products. New industrial strains for extreme locations will be selected using bioprospecting, and atmospheric CO_2 levels will be developed to facilitate cultivation in remote areas. This will allow the developing algae industry to grow, and the technology used may be beneficial for regions with limited biomass availability, extreme climatic conditions, and land that is unsuitable for agriculture, including desert areas. The activities will be supported by techno-economic and socio-economic evaluations, Life Cycle Assessment, assessment of market opportunities and business plan development. The project includes demonstrations to prove the techno-economic feasibility of biorefinery concepts, and project results will be widely published.

The MIRACLES consortium includes 26 partners from 6 EU countries plus Norway and Chile, each with highly complementary expertise and facilities (details can be found on the project website, http://miraclesproject.eu/). All 11 Universities and Research Organizations involved are international leaders in their fields. Strong industrial leadership of the project is guaranteed by the participation of 3 multinational end user companies that are world leaders in the target markets, and 12 SME's with activities in algae cultivation, separation technology and product development as well as business development. The first 6 months of the project have been promising, and partners have actively cooperated. I am looking forward to further developments in this exciting area.

Image 2: MIRACLES Partners

1. Production and harvesting of algal biomass, by Bert Lemmens (Vlaamse Instelling Voor Technologisch Onderzoek N.V.), Work Package 1 Coordinator

The goal of algal biomass production and harvesting is twofold: to produce sufficient quantity and quality; this is a crucial aspect, as without biomass no other work can be done; and secondly is to optimise algal production in terms of cultivation, harvesting and growth medium recycling, alternative CO_2 sourcing, and the development of a novel photobioreactor design. The overall objective of these activities is to significantly bring down cultivation costs, and can be summarised as:

1. Optimising algal production: It is important to produce not only large quantities of biomass, but above all large amounts of the valuable target component in the algal biomass. Due to changing conditions in outdoor cultivation (light, temperature, etc.) it is very difficult to consistently produce a quality end product. The goal of this research is to develop ways to monitor and regulate cultivation to optimise target molecule production. In this project, advanced molecular monitoring tools and strategies are used to gain better insight into physiological pathways and thereby optimize the concentration of target biomolecules in the algal biomass during cultivation.
2. Algae need a good supply of CO_2. As large-scale algae cultivation is envisioned in wasteland located far from industrial activity and thus CO_2, other sources of CO_2 are needed. In this research, breakthrough technology for concentrating atmospheric CO_2 will be developed to enable cultivation in remote areas such as deserts. This will greatly facilitate the planning of large algal installations. The aim is to be competitive using current pure CO_2 supplies.
3. Algae cultivation is still expensive. Open pond systems are associated with low production and high harvesting costs. Although photobioreactors are expensive, they do manage to bring down harvesting costs. In this project, a novel low-weight Photo Bio Reactor (PBR) capable of high density algae production will be developed in order to significantly reduce initial investment costs, energy and harvesting cost.
4. Last but not least, novel algae harvesting and growth medium recycling technologies will be developed. When algae are grown on a large scale, growth medium recycling will be essential. For example, in order to cultivate 1000 tons of algae DM/year in a photobioreactor, around 60 m³/h of growth medium must be processed, and this is only possible with recycling. To achieve this, membrane technology and analytical methods capable of saving water, nutrients, energy and costs will be developed.

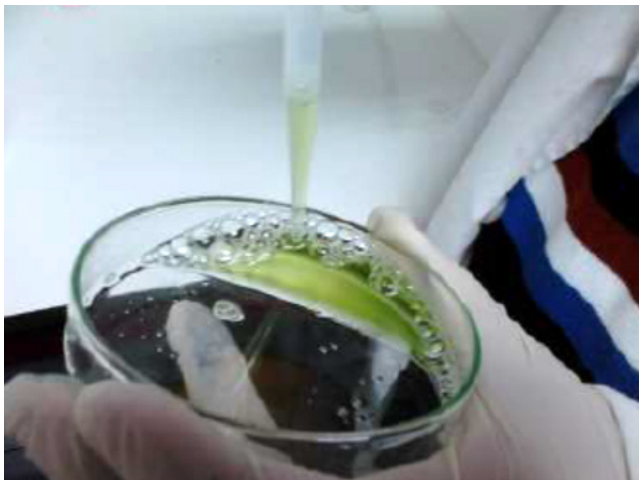


Image 3 and 4: Sample analysis at the University of Huelva

2. Bioprospecting, metabolic optimization and cultivation at extreme locations, by Hans Kleivdal (Uni Research), Work Package 2 Coordinator

The overall objectives of bioprospecting, metabolic optimization and cultivation at extreme locations are to perform bioprospecting to identify novel robust, highly productive algal strains with appropriate product profiles and biomass characteristics, to develop metabolic models to optimize productivity parameters, and to evaluate outdoor cultivation under different climatic conditions. The aim is to enable cultivation of microalgae in areas with limited potential for agriculture in order to broaden the resource base of the developing microalgae industry.

The specific activities include:

1. Exploring biodiversity by establishing a sampling plan and a harmonized screening program for novel microalgae isolates. Project partners in Norway, the Canary Islands (Spain) and Chile sample and screen the diversity of unique, local strains for biochemical properties suitable for industrial application. In this context, it is also important to discover how the biochemical properties of the algal cells vary throughout the growth cycle, and how they relate to variations in environmental conditions. Partners involved in this activity are: FCPCT, working in a subtropical climate in the Canary Islands (Spain); UiB and UniRes, working in a Nordic climate in Bergen (NO); and UA in the Atacama Desert in Chile.

2. Outdoor cultivation of selected algal strains that are adapted to extreme climatic conditions will be evaluated. Selected microalgal strains with suitable properties will be scaled up and cultivated in standardized small-scale outdoor cultivation facilities set up at each partner location. The different climatic and environmental conditions will be monitored and evaluated in relation to growth, biochemical profile and commercial potential. This will help us assess cultivation in areas with limited potential for agriculture, and broaden the resource base and product portfolio of the algae industry.

3. Metabolic modelling and optimization studies to enhance production of target products in the algal *Nannochloropsis gaditana* platform. This will focus on yield optimization and increased productivity of target products, particularly lipids, in the industrial *Nannochloropsis gaditana* algal platform through metabolic modelling and optimization studies. The first task is to screen the model strain to study the influence of different conditions on productivity and yield of *N. gaditana* target products.

Image 5: Bioprospecting partners from Chile, Spain and Norway at a joint sampling event in May 2014 at Charca Maspalomas, Canary Islands.

3. Development of integrated biorefinery technology, by Lolke Sijtsma (Stichting Dienst Landbouwkundig Onderzoek), Work Package 3 Coordinator

The main objective of integrated biorefinery technology is to develop processing technologies based on mild disruption, green extraction and fractionation/purification technologies to produce multiple specialty products from microalgae biomass by evaluating all biomass components.

Specific tasks include:

1. Characterization of biomass components and cell wall structure.
2. Screening of mild cell disruption, extraction and fractionation purification technologies for selected species.
3. Optimization and integration of selected biorefinery value chains.
4. Knowledge and data transfer of activities to demonstrate integrated value chains, techno-economic and sustainability assessment, and the supply of materials for product development and market assessment RTD.

Currently, the focus of the project is on the first two activities, as algae composition, disruption and extraction methods must be understood before the other tasks can be undertaken.

Key findings during the first six months:

1. Analytical methods have been inventoried and discussed.
2. The overall biochemical composition of the selected algal strains for the project has been established.
3. In order to estimate the protein content, nitrogen-to-protein conversion factors have been determined on the basis of the amino acid composition.
4. Cell weakening and destruction technologies have been developed.
5. Preliminary extraction technologies have been tested.

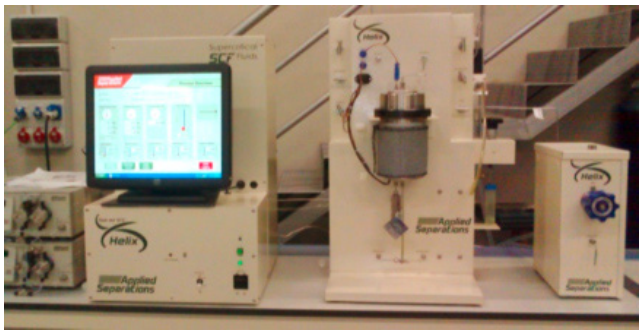

Image 6: Semi-pilot scale system for supercritical extraction and subcritical water extraction

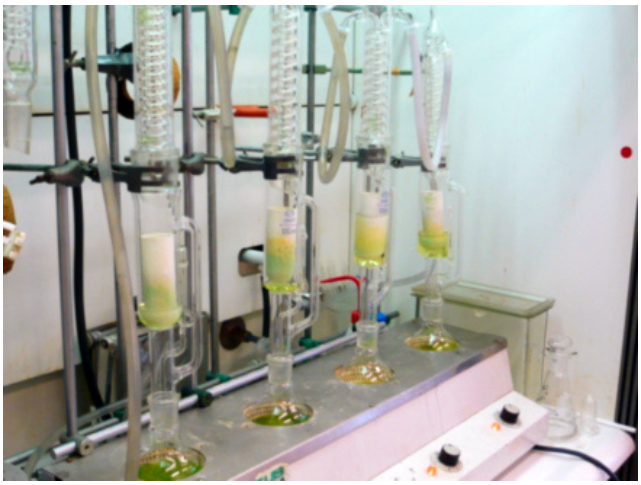

Image 7: Oil extraction from algae

4. Product development and market assessment, by Philippe Willems (Value for Technology BVBA), Work Package 4 Coordinator

The objective of product development and market assessment is to develop, validate and document the use of microalgae-derived products in food, feed and materials.

Specific tasks include:

1. Assessment of different product/market combinations for the target market sectors based on algae components.
2. Together with application research tasks, market data to position microalgae products against existing reference products will also be developed.
3. Ultimately, a fully documented marketing plan for a microalgae biorefinery will be developed. To reach this goal, optimal bi-directional interaction with other activities is essential: supply of algae fractions, purity requirements, selection of the most promising fractions, etc.

All these tasks are scheduled to start in month 12, since basic input from other project activities is needed as a basis for the planned research activities. Therefore, only some preparatory work (analytical tools, literature study, etc.) has been completed so far.

5. Demonstration of integrated value chains, by Carlos Unamunzaga (Fitoplancton Marino), Work Package 5 Coordinator

The biorefinery concept involves the development and optimization of technological processes to exploit a range of selected bioactive compounds produced by microalgae. MIRACLES will focus on producing microalgae in multiple-product biorefineries to obtain valuable specialties for use in food, aquafeeds and non-food products. In this scenario, the main aim of the activities designed to demonstrate selected integrated value chains is to deliver proof-of concept and to demonstrate techno-economic feasibility, mainly based on the findings of activities involving the production and harvesting of algal biomass, the development of integrated biorefinery technology, product development and market assessment. Therefore, activities to demonstrate the existence of integrated value chains will focus on biorefinery process chains, from microalgae biomass to biorefinery and the final validation of product application.

More specifically, the objectives and activities include:

1. Pilot-scale production of optimized algae batches. Once the different technologies for product optimization in selected microalgae strains have been developed by producing and harvesting algal biomass, bioprospecting, and optimizing metabolism and cultivating at extreme locations, they will be produced at pilot- and full-scale at a partner's facilities.
2. Pilot-scale validation of selected processes developed during the creation of integrated biorefinery technologies, product development and market assessment. The extraction conditions of target compounds will be tested to validate lab-scale results. Process feasibility and optimized extraction processes will be determined at pilot-scale. Scaled-up processes for aquafeed production, bio-polymers and resins will also be tested. Additionally, cosmetics prototypes will be developed and tested.
3. Selection of value chains for demonstration. This process will be based on a matrix system that requires proof-of-concept of each chain, at least at lab-scale. Thus, results and data from production and harvesting, development of integrated biorefinery technology, product development and market assessment, as well as techno-economic assessment of the value chain under consideration are needed to justify further demonstration.
4. Demonstration of selected integrated value chains. All lessons learnt during the project will be finally integrated in the demonstration activities, including optimization of biomass composition, optimized, integrated biorefinery technology (disruption, extraction, fractionation/purification), functionality testing and product formulation. Furthermore, designs and other data from the techno-economic and sustainability assessment will be used. All these demonstration activities will be monitored and managed as they are carried out. To achieve maximum integration, a register will be set up to record relevant parameters,

the aim being to generate complete mass and energy balances to be included in the final report on the demonstration and modelling work done during the techno-economic and sustainability assessment. This will consist of a thorough evaluation and final report of the demonstration carried out.

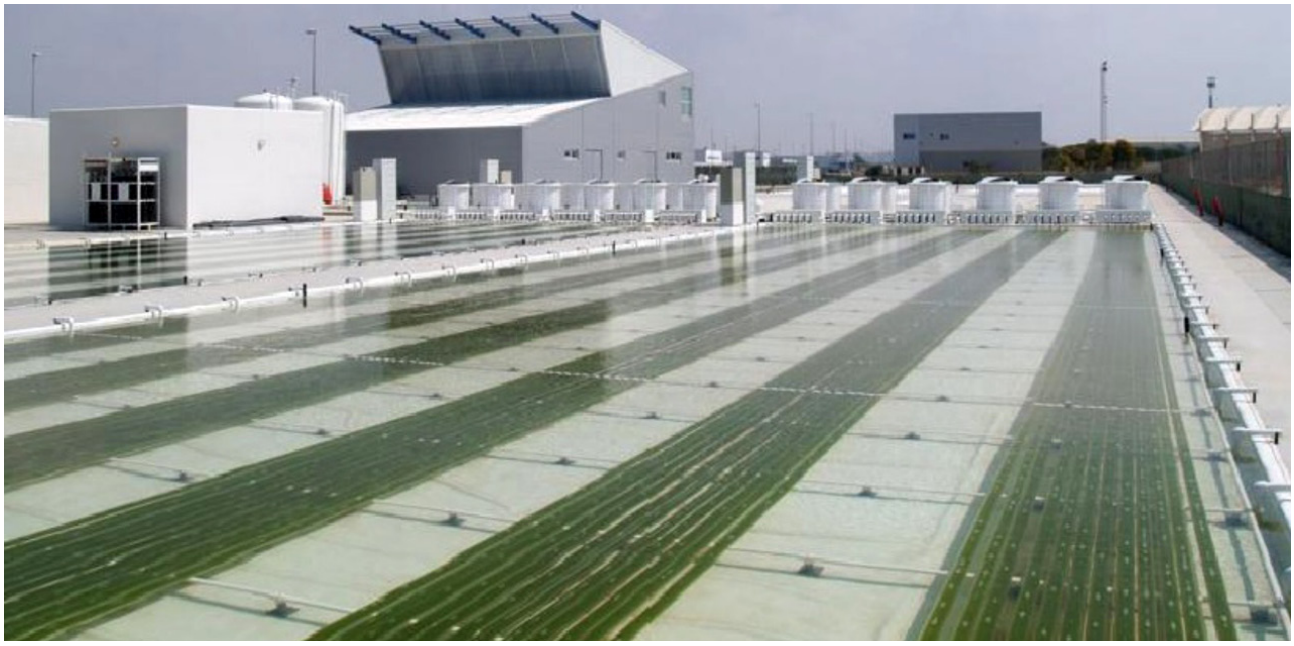

Image 8: Algae cultivation facilities at Fitoplancton Marino SA (SPAIN)

At the end of the project, at least four integrated value chains are expected to be demonstrated.

6. Techno-economic and sustainability assessment integrated value chain & development of business plans, by Lara Dammer (Nova- Institut Fur Politische und Okologische Innovation GMBH), Work Package 6 Coordinator

Techno-economic and sustainability assessment evaluates the processes designed at the previous stages of the project. The main concern in this stage of the project is to describe the processes and prepare data collection.

The conceptual biorefinery design models (technical models) serve as a basis for the evaluation of the value chain, Techno-Economic Assessment (TE), Life Cycle Assessment (LCA) and Social Life Cycle Assessment (S-LCA). The objectives at this stage are to specify and describe the process units, and to organise/harmonise the data for partners.

The progress made during the first six months can be summarized as follows:

1. The process units for each processing step have been identified from the Description of Work. The processes will first be modelled until the compounds are separated. Further processing is similar to the current practice applied to reduce bulk products to specific products. Harvesting, dewatering and disruption has been itemised and described. Extraction and purification processes will be studied at the next stage.

2. An inventory table will be used to gather the data necessary for all analyses. The framework of the inventory table will be drawn up and data will be gathered from all partners during the project duration. This information will be valuable for deciding the value chain scenario. During the project meeting in Cadiz the following conclusions about the inventory

table currently being designed were reached: side streams are important for the LCA, but also for TE (value, processing costs of waste). Side streams will probably complement the main stream and determine whether the overall concept is feasible. Correct definition of the streams (components, purity, concentration) is necessary to determine their value. Two inventory tables will be created: one will include reported experimental data (supplemented with literature and model data), while the other will report large-scale estimates. Thus, analyses will be performed on a 'virtual plant'.

3. Technical models provide information on the quantities and composition of both main and side streams. Mass and energy balances will be the basis for these models. The output of process unit 1 influences that of the next process unit. The models use processing conditions and inflow/concentration to determine yields, energy use and stream composition. At the next stage, existing models for processing algae will be adapted to new data inputs/outputs to include all cell components. Models for new techniques such as pulsed electric field disruption will be developed.

4. The business plan development is partially combined with market analysis. The primary goal is to perform an initial market/TE analysis to describe viable scenarios

5. Many techniques are still at a developmental stage. Lab-scale results have to be extrapolated to large-scale systems. This will have to be done in collaboration with the research partners involved. Work on lower and upper boundaries ranges will also be undertaken.

7. Dissemination, exploitation & intellectual property management, by Macarena Sanz (IDConsortium), Work Package 7 Coordinator and Dissemination Officer

The main aim of the dissemination of MIRACLES is to communicate project results to a wide audience, fostering the adoption of the results and their impact, facilitating information pooling and both internal and external interaction with other projects and with stakeholders. Dissemination activities also include basic tasks: creating and updating the website, managing social networks, creating and distributing articles for scientific journals, organizing workshops, conferences, exhibitions and training activities. We also plan to go a step further by focusing on industry stakeholders engaged in specific activities to facilitate the implementation of project results.

So far, the following dissemination activities have been carried out.

1. Creation of the MIRACLES, Facebook, Twitter, profiles and Linkedin group.

2. Development of dissemination materials: general presentation, roll up and leaflet, in which a general description of the project's consortium, objectives and activities is available for public access.

3. Definition of target audiences and content. As MIRACLES has a strong industrial component with major industry participation, most stakeholders are either SMEs or industrial corporations, although other important groups such as researchers working on related subjects, EU project consortia with a similar focus, public authorities, public and private investors, NGO's, the media and the public in general are also involved in the project.

Important upcoming activities include:

1. Training of young researchers (BSc, MSc, PhD), industrial employees, SMEs and entrepreneurs in algae biotechnology in order to foster knowledge pooling between the industrial and scientific partners. This will be spearheaded by participating universities and research organizations that will disseminate project information and results in national and international training courses.

2. Tours of MIRACLES sites for industry representatives. These visits will take place during the fourth year of the project in order to give stakeholders a first-hand experience of the different innovative technologies developed and used by MIRACLES.

During this period, the project has been presented in the following events (all presentations are available on the project website):

Event	When & Where	Partner	Summary of poster/ presentation	website
Young Algaeneers Symposium	3-6 April 2014 Montpellier- Narbonne (France)	Agnes Janoska et al, WU	Production and harvesting of algal biomass first conclusions on Foambed Photobioractor	http://yas2014.sciencesconf.org/
VLAG Research School of Wageningen: PhD week	14-17 April 2014 Wageningen University (The Netherlands)	Agnes Janoska et al, WU	Production and harvesting of algal biomass first conclusions on Foambed Photobioractor	No
VLAG Research School of Wageningen: PhD week	14-17 April 2014 Wageningen University (The Netherlands)	Jorijn Janssen, WU	Oral presentation "Metabolic modelling of *Nanochloropsis gaditana*" showed the approach of Jorijn`s PhD project on Metabolic modelling	No
CIAL Forum, I Jornadas Científicas	5 June 2014, Madrid (Spain)	J.A. Mendiola	Introduction poster to MIRACLES project	http://www.cial.uam-csic.es/CIALforum2014/
Flucomp, VII Reunión de Expertos en Fluidos Comprimidos	10-13 June 2014 Barcelona (Spain)	M- Herrero, J.A. Mendiola, A.L. Cediel, L. Montero, I. López-Expósito, E. Ibáñez, CSIC	Oral presentation entittled "New Green Technologies to Extract Bioactives from *Isochrysis galbana* Microalgae"	http://www.flucomp.es/eventos/flucomp-bcn-2014
International course Microalgae Process Design From cells to photobioreactors	11-18 July 2014, Wageningen (The Netherlands)	Organised by the Graduate School VLAG, in cooperation with Bioprocess Engineering (Wageningen University) and BioSolar Cells	This course teaches the essential skills needed to designing optimal microalgae-based production processes, for both research and commercial purposes.	http://www.vlaggraduateschool.nl/courses/algae-design.htm

MIRACLES has also been invited to participate in the following events:

Event	When & Where	Organised by	Summary of poster/ presentation	website
The 4th International Bielefeld-CeBiTec Research Conference "Prospects and challenges for the development of algal biotechnology"	21-24 September 2014, Bielefeld University, Germany	Center for Interdisciplinary Research (ZiF)	María Vázquez (University of Huelva), will present a poster on Production of stable microalgae-enriched foam	http://www.cebitec.uni-bielefeld.de/index.php/events/conferences/392-2014-09-21-int-bielefeld-cebitec-research-conference

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