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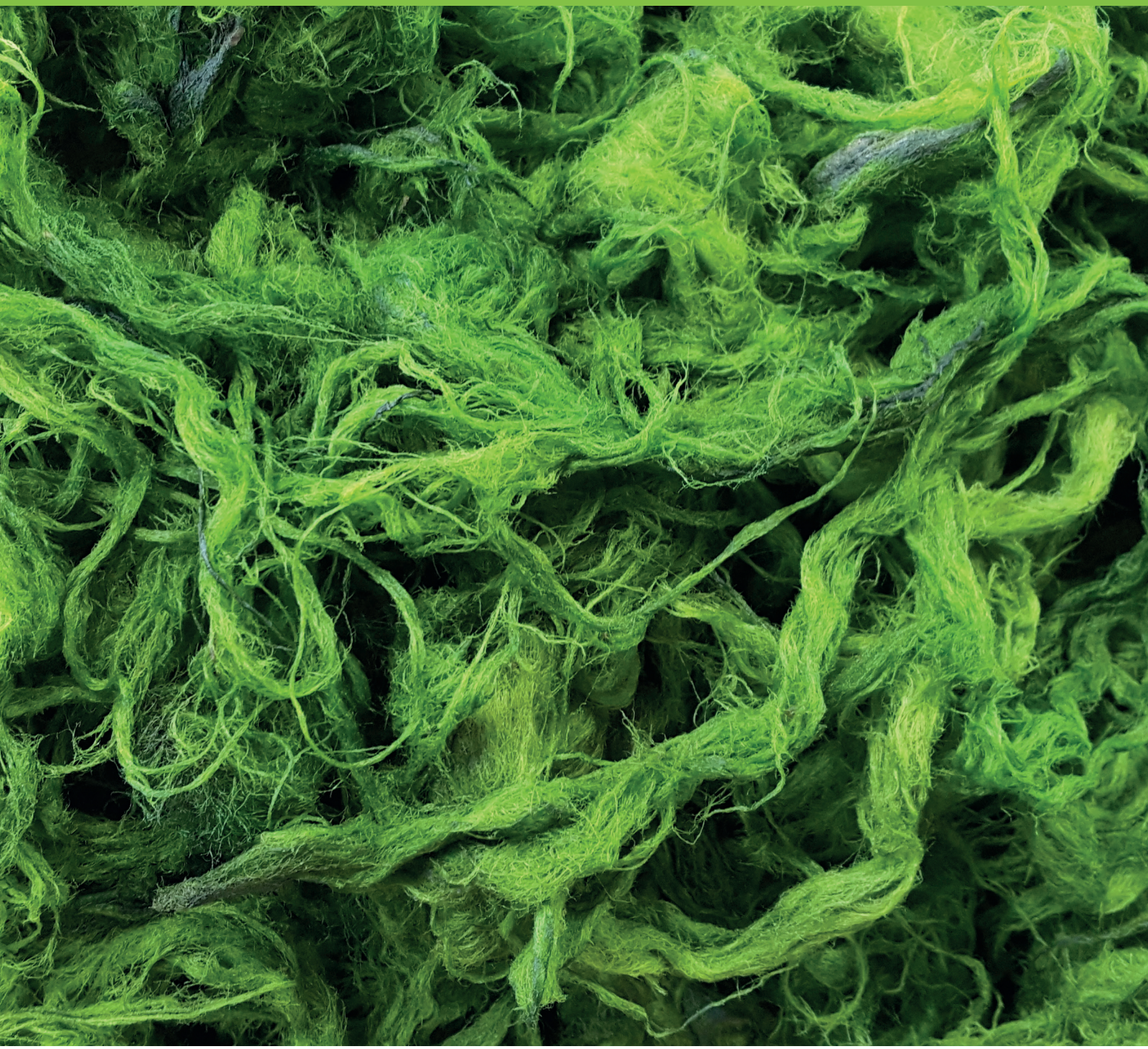

PUFA Chain

This project is funded by the European Union

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Impact Objective

- Develop a robust scientific and technological basis for substantiating strategic and technical decisions for the industrial development of high value products from algae

A sustainable and synergic biotechnology value chain

*The leaders of the **PUFAChain** consortium, **Professor Thomas Friedl**, **Dr Vitor Verdelho**, **Martin Sova** and **Gabriele Seitz**, reveal what makes their R&D a groundbreaking project in biotechnology*

Professor Thomas Friedl

Dr Vitor Verdelho

Martin Sova

Gabriele Seitz

The PUFAChain consortium has brought together the efforts of different teams in order to develop a value chain from microalgae to polyunsaturated fatty acids (PUFAs). In what ways has each team contributed to the project's success?

GS: Originally, the project was kick-started by EurA AG where the idea was developed in the EurA Algae-Network. At that time, all network partners were looking for high priced final products which could be produced by microalgae, in contrast to the already established approaches that were mainly aiming at the development of biofuels. As result of the networking efforts, the partners established an excellent international value chain and defined omega-3 fatty acids as ideal final product. Since omega-3 fatty acids are valuable components for pharma and food applications, they provide the potential to make microalgae production economical at an industrial scale.

Thanks to the European Commission which is funding this research, the microalgae world will take a big step forward towards economic production. At the end of the project, pharma and food industry will, for the first time, have a new raw material source from microalgae for high value products.

TF: Each of the six companies and three research institutes in the consortium was vital to evaluate and develop PUFAChain's innovative technologies by exchanging knowledge in different areas every step of the way. Because my field of scientific expertise is basic research, it was of utmost importance to reach out and establish these partnerships, so we could learn more about the needs of applied biotechnology. Only then could we convert the research's results into a practical, biotechnological application that met our project's goals.

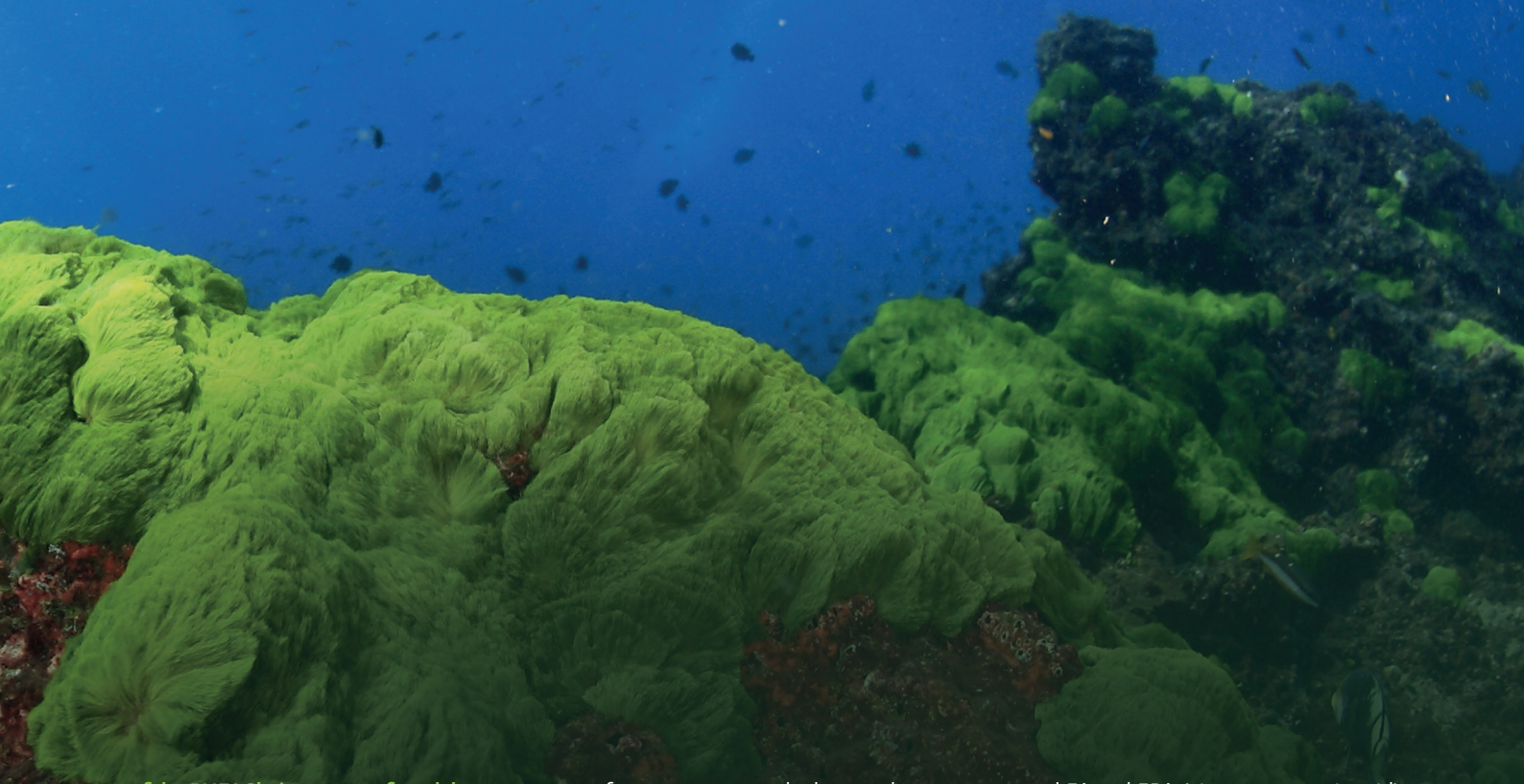
How are you aiming to upscale the process of PUFA extraction?

MS: The overall goal is to develop a sustainable and easy way to extract these valuable fatty acids from the algae biomass we work with, with the lowest energy expenditure possible. Our pursuit led us to examine the effectiveness of different biomass preparation treatments in terms of breaking the algae cell structures, as well as making the released oil available to the extracting solvent. We selected two alternatives for study within the PUFAChain consortium. One of the processes is already applied at an industrial level, for production of specialty chemicals used in the cosmetic and nutrition industries. This process, called supercritical fluid extraction, requires CO_2 to collect fatty acids. However, there is a need to dry the biomass before the extraction, which may account for a higher energetic cost. The alternative to this is fatty acid extraction from wet biomass using propane. At this stage, we are working to identify which one gives the highest yield and best quality oil while at the same time being more energetically favourable.

Can you share the improvements that the PUFAChain project has led to in the production of microalgae?

VV: The PUFAChain project involved testing different technologies to grow microalgae including airlifts, tubular reactors, green wall panels and cascade raceways, both indoor and outdoor. The use of different technologies for different strains pushed the boundaries for these technologies, harbouring relevant results for the future scale-up of different microalgae species. The future implementation of new pumps and materials has already been tested at pre-market level, so we can integrate them into diverse industries.

What do you consider to be the major challenges posed during the scale-up



of the PUFAChain process, from lab to production scale?

GS: In the earlier stages, the main issue was engaging potential project partners and fuelling their interest about algae and algae products. This is still an ongoing process, due to the huge variety of microalgae available and possible applications for these microalgae. The three main challenges for microalgae production today are: to find applications with high value creation to make production economic; to gain access to corporates in pharma, food, feed and life science industries to develop, produce and bring microalgae-based products into market; and, in the case of food applications, to qualify the product as a novel food. As this accreditation process is very complex and expensive, European financial support for these novel food accreditations would accelerate the market entrance for many new algae products.

MS: From a more technical aspect, the major challenges in adapting these processes into higher scales of functionality are mainly related to the variability among algae species we can use. Since we're manipulating a biologic compound, there is the need to shift between different techniques to separate different cellular components within algae, in order to successfully retrieve the target substances. Think, for example, about structural differences in cell membranes. Algae have high variability in terms of these structures, which requires new cell disruption methods and equipment depending on the scale involved. Cell size is also an important aspect, as cell particles smaller than 100µm tend to shift the extraction performance curve to the lower values, making it harder to apply and homogenise at complex stages. Furthermore, how the enzymatic and molecular instability naturally present in these cells is affected by higher temperatures, oxygen levels, and light availability is a key step to consider.

VV: We worked around these issues as we have successfully grown several microalgae on a 1000-litre scale instead of a few millilitres within our laboratory. This was a major achievement because it was necessary to solve a wide range of issues related to the culture media and microalgae sensitivity in order to scale up the process from laboratory scale to prototype and then to pilot scale.

How can the processes you have designed for PUFAChain be applied to other bioengineering processes?

MS: So far, the applicability of extraction using supercritical CO_2 is limited by water content in the available biomass. Extraction with propane provides new opportunities for fractionating these materials. This means that the extraction challenges we encountered in all water-based raw materials, like fermentation broths, aqua cultures, cell cultures, and even materials with thermolabile substances that cannot be dried easily (e.g. fractionation of eggs), will be removed with this technique.

TF: The technology we have been developing and testing within PUFAChain will be available to other applications, not only in algal biotechnology, but in a broader scope of industries as well. Examples include new membrane filtration modules; total FA and EPA (eicosapentaenoic acid) extraction from fresh algal biomass with high efficacy using liquid and supercritical CO_2; improved photobioreactor technology; and differentiated upscaling protocols.

In what ways is the PUFAChain process environmentally and economically sustainable?

TF: The crucial point is that the rising demand for PUFAs cannot be met by fish oil or any other marine source such as krill any more. Fishing quotas of the respective fisheries are at their limits and cannot be increased without risking severe damage or even a collapse of populations of marine organisms. Algae can fill this gap and help to save fish populations and thus the marine environment. It has to be said that any alternative requires more efforts than just clearing the oceans of fish and separating fish oil from fish meal. The sustainability assessment that accompanies the project by PUFAChain partners IFEU (Institute for Energy and Environmental Research Heidelberg), Wageningen University and Research and IOI Oleo greatly helps to identify and optimise drivers of environmental impacts, costs and further aspects such as the energy demands and material requirements of certain processes in algae cultivation and extraction. We are successfully working on reducing these impacts. As increased fishing is not an option, we are convinced that the health benefits of PUFAs for the consumers are worth the efforts put into algae-based PUFA production.

Naturally therapeutic

*Since 2013, the highly experienced researchers behind the **PUFAChain** project have been developing upscaling processes for the extraction of compounds with pharmaceutical and nutritional value from algae*

In a society where nutritional supplements are a growing trend, there is the need to adjust industrial responses accordingly, and in a sustainable and cost-effective way. The high demand for oils and supplements that are rich in omega-3 fatty acids, which are types of polyunsaturated fatty acids (PUFAs), is draining the natural sources of these substances. As PUFAChain Project Coordinator Professor Thomas Friedl of Göttingen University explains, 'PUFAs, in particular docosahexaenoic (DHA) and eicosapentaenoic (EPA) acid, are recognised as important players supporting human health. They play beneficial roles in the prevention and/or treatment of coronary heart diseases, cancer, and diabetes.'

The PUFAChain project is focused on creating a biorefinery-based model capable of extracting and producing highly purified omega-3 fatty acids from microalgae at an industrial level, thus averting the exhaustion of natural resources. Friedl reiterates the importance of the evolution of the algae biomass sector worldwide: 'PUFAChain is one of several European projects aiming to valorise and accelerate the commercialisation of algae-based products with pharmaceutical and nutritional potential and it is important to expand what is still considered a niche in pharmaceutical industry.'

AIMING HIGH

After establishing a solid partnership with two renowned research institutes – Göttingen University and the Fraunhofer Institute for Cell Therapy and Immunology's Bioanalytics and Bioprocesses Branch (Fraunhofer IZI-BB), researchers within the PUFAChain consortium paired their novel biorefinery concept with specific culture techniques devised to optimise PUFA yields within the immense biodiversity of microalgae. The method was tested on algae strains capable of growing in either warm or cold seasons, in order to scale up the process from lab to industrial scale.

Successfully demonstrating the functionality of this method at a larger scale required joining efforts with Dr Vitor Verdelho's team at A4F – Algae for Future and Martin Sova's team at Natex Prozesstechnologie GesmbH. This enabled the building of a pilot plant where growth conditions for different algae strains could be met and adapted for a viable and efficient treatment of the cultured biomass. Most importantly, the team focused on re-evaluating and investigating further each stage of the extraction process, having successfully defined two pathways to extract the oils from the dried biomass.

A HELPING HAND

Efforts to introduce PUFAChain's model to industries in the near future have been made not only within the four walls of the laboratory. Alongside the dissemination activities of EurA, PUFAChain partners IFEU (Institute for Energy and Environmental Research Heidelberg) and Wageningen University and Research have conducted comprehensive economic and environmental assessments of the technique's influence in different industrial fields, opening intense discussions on the fine-tuning of the scaling-up process, with the possibility of establishing new partnerships in sight. 'Discussions are relevant to explore not only investment costs related with the scaling-up process, but also consumers' perceptions of algae-based PUFA products,' Friedl adds. The viewpoints and interests of both consumers and potential investors are critical for the project's progression, therefore the team opts to maintain close contact with universities, industries, and the public in general through regular newsletter releases, attending conferences such as the International Algae Congress, networking workshops, and social media.

Overview of the multilayer horizontal tubular photobioreactors (front to back: growing Chloridella, Nannochloropsis, Thalassiosira *and* Dunaliella*) in operation at A4F Lisbon Experimental Unit, July, 2016*

Project Insights

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PARTNERS

Göttingen University (Germany) • A4F – Algae for Future (Portugal) • MAHLE InnoWa GmbH (Germany) • Natex Prozesstechnologie GesmbH (Austria) • IOI Oleo GmbH (Germany) • Fraunhofer IZI-BB (Germany) • IFEU Heidelberg (Germany) • Wageningen University and Research DLO (Netherlands) • EurA AG (Germany)

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PROJECT COORDINATOR BIO

Professor Thomas Friedl is Head of the Experimental Phycology Department at Göttingen University and Director of the renowned SAG (Culture Collection of Algae at Göttingen University). His main research field is the biodiversity of microalgae and cyanobacteria and is closely linked to the SAG, an important resource of reference cultures. Another expertise of Friedl's is in the identification of algal strains/species by employing a variety of molecular markers. Additional research activities include screening of algal strains for commercial metabolites with expert input into process development and upscaling, as well as developing genetically stable stocks of algal cultures through cryopreservation.

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