BOOK OF ABSTRACTS

SEAWHEAT FINAL CONFERENCE

ULVA: TOMORROW'S "WHEAT OF THE SEA", A MODEL FOR AN INNOVATIVE MARICULTURE

BREMERHAVEN, GERMANY

2ND TO 4TH SEPTEMBER 2025

TABLE OF CONTENTS

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Funded by the European Union

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
Funded by the European Union

SEAWHEAT COST ACTION CA20106
SEAWHEAT BEYOND 2025: BUILDING A SUSTAINABLE *ULVA* FUTURE

SHPIGEL, MUKI [1,2,3]
[1] SeaWheat COST Action Chair
[2] The Leon H. Charney School of Marine Sciences
[3] University of Haifa, Israel

The COST Action “SeaWheat” (CA20106, 2021–2025) aimed to promote a pan-European, interdisciplinary approach to the sustainable cultivation and application of *Ulva* spp. (sea lettuce). *Ulva* is a promising green macroalga with potential uses in aquaculture, food systems, bioactive products, and environmental services.

SeaWheat addressed this challenge by establishing a strong, coordinated network of scientists, industry stakeholders, and policymakers. The final conference, held at the Alfred Wegener Institute in Bremerhaven showcased 4 years of work and collaboration by our members.

SeaWheat brought together 448 participants from 53 countries, including 17 Inclusiveness Target Countries and 17 Small and Medium-sized Enterprises (SMEs). Structured around seven Working Groups, spanning biology and aquaculture to food, bioactive compounds, ecosystem services and regulatory frameworks, SeaWheat delivered significant advances along the *Ulva* value chain.

The initiative supported 24 Short-Term Scientific Missions (STSMs), five training schools, and four workshops, promoting hands-on collaboration and training for early-career researchers. Its scientific output included over 30 peer-reviewed publications and four major review articles. In addition, a database of more than 200 *Ulva*-related publications authored by network members was compiled.

SeaWheat COST Action initiated the launch of E*ULVA*, a collaborative initiative focused on the taxonomy and standardization of *Ulva* cultivation.

Public outreach was a key strength of the Action. SeaWheat produced three animated films (in 14 languages), a multilingual *Ulva* recipe book, and 16 widely attended “Lunch with *Ulva*” webinars. These initiatives helped raise awareness among the public and policymakers about the value and potential of *Ulva*.

A notable achievement of SeaWheat was the empowerment of early-career researchers and the promotion of inclusive participation across Europe. The results of the Action have been integrated into academic programs, industrial R&D, and policy discussions, setting the stage for a thriving *Ulva*-based bioeconomy.

By effectively uniting research, innovation, and outreach, SeaWheat advanced the science and applications of *Ulva*. Its legacy will continue through ongoing collaborations, the E*ULVA* initiative, and the vibrant community it has fostered.

There is no doubt that the success of the SeaWheat COST Action is due to the dedicated collaboration of the Working Group leaders and Core Group members, who voluntarily led and organized all our activities over the past four years.

Funded by the European Union

CONSIDERATION OF THE NUTRITIONAL AND TOXICOLOGICAL ASPECTS OF *ULVA* SPP. FOR ALIMENTARY AND ZOOTECHNICAL APPLICATIONS

ANGIONI A.[1], ADDIS P.[1], PASQUINI V.[1]

[1] Department of Life and Environmental Science, University of Cagliari, Italy
E-mail: aangioni@unica.it

Abstract

The genus *Ulva* (Ulvophyceae, Chlorophyta), also known as sea lettuce, is the most common, widely distributed green alga [1]. These algae can adapt to a variety of habitats and environmental factors (e.g. light, nutrients, temperatures, etc.) and reproduce in various ways, including parthenocarpy and asexual reproduction via biflagellate zoospores [2]. There are many recognised commercial applications of *Ulva* spp., including use as a fertiliser, nutraceutical, biomaterial, biofilter, human food (e.g. "aonori") and animal feed (e.g. abalone, shrimp and sea urchin). This makes them a valuable seaweed. [3, 4]. Researchers have extensively analysed the biochemical composition of *Ulva* spp., showing that it is rich in proteins, dietary fibres, minerals, vitamins and bioactive secondary metabolites. This indicates that it is suitable for human consumption and has applications in the feed industry [1]. In addition, sea lettuce is regarded as a potent attractant and feeding stimulant, capable of augmenting the feeding intake and promoting the conversion rate of marine herbivores [5, 6].

Although researchers are familiar with the nutritional potential of *Ulva* spp., they have not thoroughly investigated its toxicological aspects or potential risks to human and animal health.

Depending on the environmental conditions, chemical and microbiological contamination can occur on wild and cultivated seaweed.

It is known the capacity of seaweeds to uptake and concentrate environmental pollutants, such as those belonging to the family of persistent organic pollutants (POPs), heavy metals and metalloids [7]. Several studies have been carried out on the bacterial diversity in brown (Phaeophyceae), green (Chlorophyta), and red (Rhodophyta) macroalgae (henceforward: seaweed). Seaweed is home to a variety of bacteria, including Proteobacteria, Actinobacteria, Bacteroidetes (CFB group), Cyanobacteria, Firmicutes, Planctomycetes, Verrumicrobia, Chloroflexi, Deinococcus-Thermus, Fusobacteria, and Tenericutes. Among these, Gammaproteobacteria are the most prevalent bacterial clade [8]. However, only a few studies have clarified the prevalence of human pathogens in edible seaweed, and further research is needed [9].

This in-depth study aims to show the two sides of the coin so as not to create false myths and unwarranted alarmism.

References

[1] Mantri, V.A. et al. Concise review of green algal genus *Ulva Linnaeus*, J Appl Phycol 2020, 32 2725–2741, https://doi.org/ 10.1007/s10811-020-02148-7.

[2] Balar, N.B. et al. Insights into life cycle patterns, spore formation, induction of reproduction, biochemical and molecular aspects of sporulation in green algal genus *Ulva*: implications for commercial cultivation, J Appl Phycol 2020, 32 473–484, https://doi.org/10.1007/s10811-019-01959-7.

[3] Karthik, T. Systematic study on the effect of seaweed fertilizer on the growth and yield of *Vigna radiata* (L.) *R. Wilczek* (mung bean). J Agric Food Res 2023, 14, 100748, https://doi.org/10.1016/j.jafr.2023. 100748.

[4] Marareni, M. The effect of incorporating dietary green seaweed (*Ulva* sp.) on growth performance, blood parameters, and carcass and meat quality characteristics of jumbo quail.

Heliyon 2023, 9, 19603. https://doi. org/10.1016/j.heliyon.2023.e19603.
[5] Shpigel, M., *Ulva lactuca* biofilter from a land-based integrated multi-trophic aquaculture (IMTA) system as a sole food source for the tropical sea urchin *Tripneustes gratilla elatensis.* Aquaculture 2018, 496, 221–231. https://doi.org/10.1016/j. aquaculture.2018.06.038.
[6] Prato, E., et al. Influence of a prepared diet and a macroalga (*Ulva* sp.) on the growth, nutritional and sensory qualities of gonads of the sea urchin *Paracentrotus lividus.* Aquaculture 2018, 496, 240–250. https://doi.org/10.1016/j.aquaculture.2018.05.010
[7] Corrias, F., et al. Integrated environmental evaluation of heavy metals and metalloids bioaccumulation in invertebrates and seaweeds from different marine coastal areas of Sardinia, mediterranean sea. Environmental Pollution 2020, 266(2), 115048. https://doi.org/10.1016/j.envpol.2020.115048
[8] Selvarajan, R., et al. Distribution, Interaction and Functional Profiles of Epiphytic Bacterial Communities from the Rocky Intertidal Seaweeds, South Africa. Sci. Rep. 2019, 9, 1–13.
[9] Lytou, A.E., et al. Quality and safety assessment of edible seaweeds *Alaria esculenta* and *Saccharina latissima* cultivated in Scotland. Foods 2021, 10, 2210.

Acknowledgments

We acknowledge the support of the COST Action CA20106 “Tomorrow's wheat of the sea’: *Ulva*, a model for an innovative mariculture”, supported by COST (European Cooperation in Science and Technology, www.cost.eu).

Short Biography of the speaker

Prof. Alberto Angioni is a full professor of food chemistry at the University of Cagliari, teaching food chemistry, technology, and analysis. He is responsible for the Laboratory of Chemical Analysis of Food, which is included in the list of regional laboratories. President of the Italian Group of Plant Protection Products and the Environment (GRIFA), Past-president of the Italian Group of Food Chemistry (ItaChemFood), member of the National Committee for Food Safety (CNSA) of the Ministry of Health, and reference person for the University of Cagliari for the evaluation of Dossiers on plant protection products for the Ministry of Health. Prof. Angioni is a member of the Technical Scientific Committee of the “Phytopathological Days” and of the Technical Scientific Committee of the Montiferru Olive Oil Award.

EFFECTS OF DIFFERENT CULTURE MEDIA ON GROWTH, COMPOSITION AND QUALITY OF THE GREEN ALGAE *ULVA* SP. CULTIVATED IN CYLINDRICAL PHOTOBIOREACTORS

ARRU N.[1], ADDIS P.[1], PASQUINI V.[1]

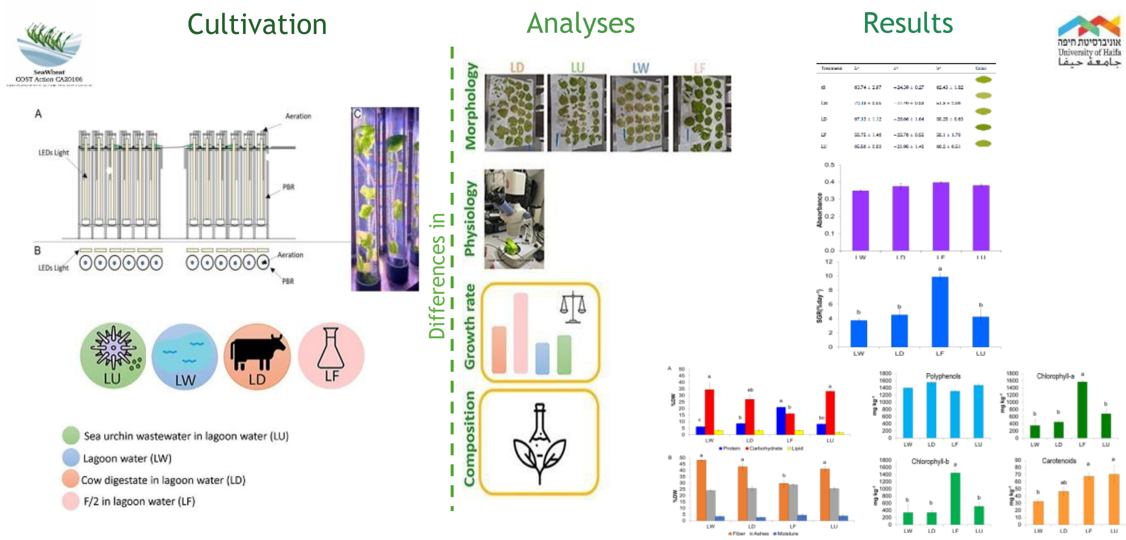
[1] Department of Life and Environmental Science, University of Cagliari, Italy
E-mail: nicola.arru@unica.it

Abstract

Ulva spp. have been identified as an effective and sustainable biomass source. They are macroalgae with high growth capacity and high nutritional content, which have gained considerable importance in the food and feed sector, as well as in ecosystem services and green technologies [1, 2].
The growth rate, morphology, physiology and biochemical characteristics of *Ulva* sp. produced by an indoor vertical cylindrical photobioreactor (PBR) system were evaluated using four different culture media such as lagoon water, lagoon water enriched with f/2 synthetic media, sea urchin wastewater and bovine digestate [3].
It was found that the media influenced all the parameters examined, the lagoon water enriched with f/2 synthetic media biomass weight was double compared to the other treatments and showed a slightly higher absorbance. Colorimetric analyses reported a significant darker color in *Ulva* sp. grown under enriched media. *Ulva* sp. showed higher nutrient removal potential in lagoon water enriched with f/2 synthetic media. The lipid content did not vary (2–3 % dry weight, DW), while the protein content ranged from 21 % in f/2 synthetic media to 6–9 % in the other treatments. Carbohydrates and fiber content were significantly lower in f/2 synthetic media (16 % and 30 %) compared to the other treatments, 27–34 %, and 41–48 %, respectively. Pigment content significantly varied, being higher in biomass grown in lagoon water enriched with f/2 synthetic media and sea urchin wastewater. This study shows how different nutrient sources affect the biochemical composition, growth and quality of *Ulva* sp. The PBR system tested here proved to be efficient in ensuring significant biomass growth in a short time frame, ensuring controlled growing conditions, gas and nutrient exchange and adequate amounts of light. Moreover, it was highlighted how the different media used determines important variations regarding growth rate, morphology and biochemical composition of the biomass.

Funded by the European Union

Graphical Abstract



References

[1] Mantri, V.A. et al. Concise review of green algal genus *Ulva Linnaeus*, J Appl Phycol 2020, 32 2725–2741, https://doi.org/ 10.1007/s10811-020-02148-7.

[2] Hofmann, L. C., Strauss, S., Shpigel, M., Guttman, L., Stengel, D. B., Rebours, C., … Meléndez-Martínez, A. J. (2024). The green seaweed *Ulva*: tomorrow's "wheat of the sea" in foods, feeds, nutrition, and biomaterials. Critical Reviews in Food Science and Nutrition, 1–36. https://doi.org/10.1080/10408398.2024.2370489

[3] Gnayem, N.; Unis, R.; Gnaim, R.; Chemodanov, A.; Israel, Á.; Gnaim, J.; Golberg, A. Fatty Acid Content and Profile in *Ulva* lactuca in Response to Exposure to Variable Growth Conditions in Indoor Photobioreactors. Life 2025, 15, 57. https://doi.org/10.3390/life15010057

Acknowledgments

We acknowledge the support of the COST Action CA20106 "Tomorrow's wheat of the sea': *Ulva*, a model for an innovative mariculture", supported by COST (European Cooperation in Science and Technology, www.cost.eu).

Short Biography of the speaker

Nicola Arru is a PhD student at the Department of Life, Environmental and Pharmaceutical Sciences of the University of Cagliari. His doctoral project "BIO-Bank: catalog of behavioural, biochemical and physiological responses of marine organisms conditioned in mesocosms", has as its objective the evaluation of the chemical and biochemical characteristics of lagoonal and marine model species of the Sardinian coast.

The study of these species will also be able to provide useful information regarding the diffusion of pollutants in the marine environment and in transition waters and, furthermore, be able to identify the sources of pollution. He obtained a master's degree in Chemical Sciences at the University of Cagliari. His studies concern food chemistry and nutrition.

ULVA, AN EMERGING GREEN SEAWEED MODEL FOR MOLECULAR BIOLOGY

BLOMME J.[1,2,3], COULEMBIER VANDELANNOOTE E.[1,2,3], SEBIANI A.[1,2,3], JACOBS T.[2,3], DE CLERCK O.[1]

[1] Department of Biology, Phycology Research Group, Ghent University, Ghent, Belgium
[2] Department of Plant Biotechnology and Bioinformatics, Ghent University, Ghent, Belgium
[3] VIB-UGent Center for Plant Systems Biology, Ghent, Belgium
E-mail: jonas.blomme@ugent.be

Abstract

Green seaweeds exhibit a wide range of morphologies and occupy various ecological niches, spanning from freshwater to marine and terrestrial habitats. These organisms, which predominantly belong to the class Ulvophyceae, showcase a remarkable instance of parallel evolution toward complex multicellularity and macroscopic thalli in the Viridiplantae lineage. Within the green seaweeds, several *Ulva* species ("sea lettuce") are model organisms for studying carbon assimilation, interactions with bacteria, life cycle progression, and morphogenesis. *Ulva* species are also notorious for their fast growth and capacity to dominate nutrient-rich, anthropogenically disturbed coastal ecosystems during "green tide" blooms. From an economic perspective, *Ulva* has garnered increasing attention as a promising feedstock for the production of food, feed, and biobased products, also as a means of removing excess nutrients from the environment.

We propose that *Ulva* is poised to further develop as a model in green seaweed research. In this talk, I will focus on *Ulva mutabilis/compressa* as a model species and highlight the molecular data and tools that are currently available or in development. I will focus on our efforts in improving *Ulva* genomic data. The use of our molecular tools will be demonstrated with a case study on the carbon concentrating mechanisms of *Ulva*. Here, we combined large-scale gene-tagging with targeted characterisation of proteins in vivo, in vitro and at the structural level. Our spatial model for inorganic carbon capture in *Ulva* reveals unique Rubisco condensation mechanisms in the pyrenoid.

References

[1] Blomme, J. et al. *Ulva*: An emerging green seaweed model for systems biology. *J Phyc*. 2023, 59 (3), 433-440.
[2] Blomme, J. et al. Consolidating *Ulva* functional genomics: gene editing and new selection systems. *New Phyt*. 2025, 246 (4), 1710-1723.
[3] Blomme, J. et al. A molecular toolkit for the green seaweed *Ulva mutabilis*. *Plant Phys*. 2021, 186 (3), 1442-1454.

Short Biography of the speaker

Jonas Blomme is a molecular biologist. My PhD focused on understanding land plant growth and development using mutant studies and systems-biology approaches. Then, from my postdoc onwards, I have focused on -omics research and molecular tool development in the green seaweed *Ulva* (vectors available at https://vectorvault.vib.be/*Ulva*-mutabilis). I generated the first stable transgenic seaweed lines with tagged transgenes and one of my core activities is to further improve these molecular tools to allow a better understanding of seaweed developmental biology.

For example, in an ongoing FWO ERC starting grant runner up project, I am determined to enable CRISPR screens in *Ulva*. My ambition is to develop and use system-biology approaches to understand *Ulva* growth and development. In an FWO-funded research project we use automated phenotyping, generation of mapping populations and ecological genomics to understand the growth potential of *Ulva*. Doing research at the intersection of (population) ecology, genomics and molecular biology in an ecological and economical relevant organism holds promise to further translate academic results into industrial applications. In total, I have (co-)authored 23 publications (h-index 13; 706 citations), eight during my PhD and fifteen during my postdoc. Since September 2024 I have obtained an associate professorship position at Ghent University.

LAB SCALE FEASIBILITY STUDY INVESTIGATING THE POTENTIAL USE OF THE SHELLFISH TOWER DESIGN FOR OPEN OCEAN CULTIVATION OF *ULVA COMPRESSA* IN DIFFERENT SALINITY ENVIRONMENTS

BÖHME C.[1,2], MILIA M.[3], HOFMANN L.C.[1,2]

[1] Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany
[2] Bremerhaven University of Applied Sciences, Bremerhaven, Germany
[3] University of Cagliari, Italy
E-mail: cboehme@studenten.hs-bremerhaven.de

Abstract

Low trophic aquatic food provides the potential to reduce food and nutrition insecurity and tackle malnutrition, while simultaneously posing little stress on the climate and environment, thereby delivering essential ecosystem services and enabling the achievement of the UN SDGs. The Shellfish Tower is an Innovative system design for open ocean aquaculture of shellfish, a low trophic aquatic food. In the current study, we examined the feasibility of using the Shellfish Tower for cultivation of *Ulva compressa*. *Ulva compressa* is widespread in the Baltic and North Seas and can exhibit two different morphologies: a tubular form, most common in the Baltic, and a foliose form, most common in the North Sea. Therefore, we tested the hypotheses that the Shellfish Tower could be used to cultivate *Ulva compressa* in different salinity environments, and that the morphology, physiology and biochemical properties of *U. compressa* would differ in the Baltic and North Sea salinity scenarios. Nets were seeded with *U. compressa* gametes after fertility induction and incubated for one month at 15°C, 30 PSU and 100 µmol photons m^{-2} s^{-1} light intensity. Once the *U. compressa* reached 2-3 cm in size, the nets were wrapped around the outer frame of 20 miniature Shellfish Towers, which were constructed based on the original frame design. The frames with seeded *U. compressa* were distributed to four different salinities: 10, 15, 30 and 35 PSU. Growth rates, photosynthetic efficiency and cell size were monitored weekly for 5 weeks. Biochemical properties (protein, carbohydrate, fiber, ash and chlorophyll and carotenoid content) were measured at the end of the experiment. *Ulva compressa* successfully grew on the miniature Shellfish Towers at a lab scale (Figure 1). Significant differences in growth rates and photosynthetic efficiency were observed between the low and high salinities (Figure 2). Differences in cell size and biochemical properties will be discussed, but we did not observe the foliose morphology of *U. compressa* in any salinity treatment. This study shows that the Shellfish Tower can be used to cultivate *U. compressa* in different salinity environments, but the success in an open ocean environment must still be evaluated, as well as the impact of the vertical distribution of light and its impact on seaweed growth.

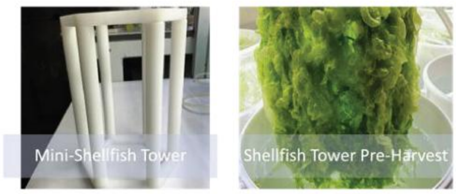


Figure 2 Miniature Shellfish Tower before seeding and directly prior to harvest

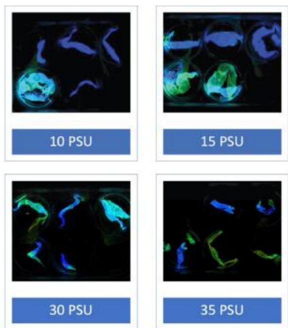


Figure 1 Visualization of maximum photosynthetic efficiency (Fv/Fm) of U. compressa exposed to different *salinities*.

Short Biography

Clarissa Böhme is a Master's student in the Biotechnology program at Bremerhaven University of Applied Sciences. Her research focuses on microbiology and aquatic biotechnology, with a focus on sustainable aquaculture and the cultivation of macroalgae. She presented the results of her bachelor's thesis at the international AQUA 2024 conference in Copenhagen. She is currently deepening her knowledge of marine biotechnology and is aiming for a scientific career in the field of sustainable aquatic systems.

NOVEL EXTRACTION OF BIOACTIVES FROM ALGAE AND PLANTS: A SEQUENTIAL APPROACH WITH PEF, ASE AND SFE

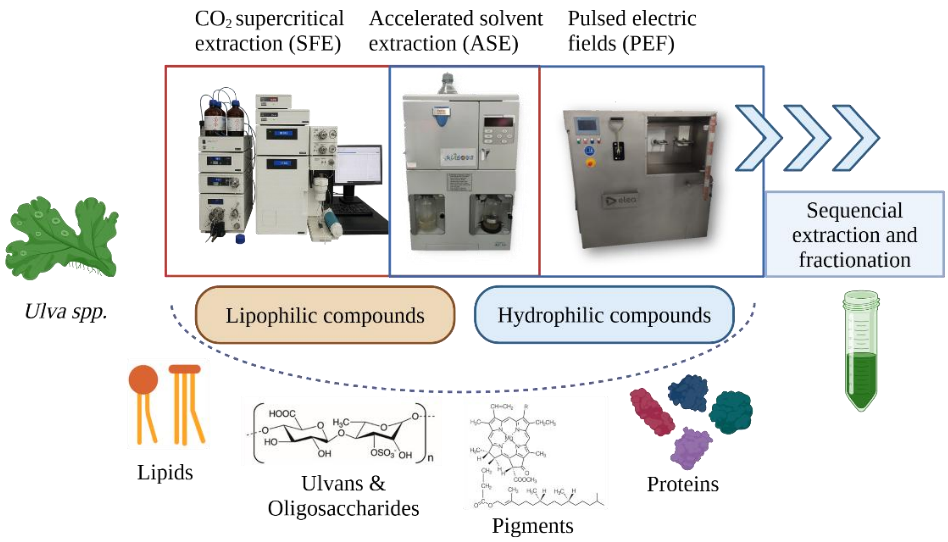
CALLEJA-GÓMEZ M.[1], BARBA FJ.[1], MARTÍ-QUIJAL FJ.[1], MOREIRA A.[2], SEBASTIÀ A.[1], MARQUES F.[2], DOMINGUES R.[2]

[1] Research Group in Innovative Technologies for Sustainable Food (ALISOST), Department of Preventive Medicine and Public Health, Food Sciences, Toxicology and Forensic Medicine, Faculty of Pharmacy and Food Sciences, Universitat de València, Avenida Vicent Andrés Estellés s/n, 46100, Burjassot, València, Spain
[2] CESAM - Centre for Environmental and Marine Studies, Department of Chemistry, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
E-mail: mara.calleja@uv.es

Abstract

Sustainable and innovative extraction technologies such as pulsed electric fields (PEF), accelerated solvent extraction (ASE), and supercritical fluid extraction (SFE) have significantly advanced the recovery and preservation of bioactive compounds from complex food matrices like *Ulva spp*. Nevertheless, sequential extraction approaches offer a powerful strategy for fractionating and concentrating target compounds based on their chemical affinities, thereby maximizing the valorization potential of marine biomass. In this study, sequential extractions combining SFE, ASE, and PEF were applied to obtain both hydrophilic and lipophilic fractions from *Ulva* spp., followed by comprehensive chemical characterization. Carbohydrates were analyzed by GC-FID and colorimetry, proteins via elemental nitrogen analysis, fatty acids by GC-MS, and total pigments (chlorophylls and carotenoids) were quantified spectrophotometrically. Results revealed that aqueous ASE extracts were particularly enriched in sugars (25–51%) and proteins (~10%), with a notable presence of uronic acids and rhamnose associated with *Ulva*ns. In contrast, ethanolic extracts from ASE and SFE showed low sugar content but were rich in fatty acids. PEF-treated samples exhibited the highest antioxidant capacity and pigment concentration compared to ASE. Overall, the integration of these three technologies in a sequential manner enhanced both the yield and selectivity of bioactive compound recovery, offering a viable and scalable approach for the sustainable exploitation of *Ulva* spp. and similar marine-derived matrices.

Graphical Abstract



Acknowledgments

The authors are grateful for funding from the EU. The results showed in the presentation were obtained during the STSM of Ana Moreira, Francisca Marques and the collaboration with Prof. Martí-Quijal supported by the Cost Action No. CA20106 "Tomorrow's 'Wheat of the Sea': *Ulva*, a Model for an Innovative Agriculture (SEAWHEAT)". Mara Calleja-Gómez is a beneficiary of the predoctoral grant from the Conselleria d'Educació, Universitats i Ocupació of Generalitat Valenciana (CIACIF/2022/391). Albert Sebastià Duque acknowledges the program "Atracció de Talent" (UV-INV-PREDOC-1916102) by Universitat de Valencia. Authors would also like to acknowledge Generalitat Valenciana (Spain) for the financial support (IDIFEDER/2018/046—Procesos innovadores de extracción y conservación: pulsos eléctricos y fluidos supercríticos) through the European Union ERDF funds (European Regional Development Fund).

Funding

This work was supported by COST Action (European Cooperation in Science and Technology) No. CA20106.

Short Biography of the speaker

Mara Calleja is a PhD candidate in Food Science at the University of Valencia, affiliated with the Department of Preventive Medicine and Food Science. As a member of the research group Innovative Technologies for Sustainable Food (ALISOST), her work focuses on promoting sustainable food production through the application of advanced preservation strategies and the valorization of agri-food by-products. In this context, her research integrates a range of emerging technologies such as pulsed electric fields (PEF), supercritical fluid extraction (SFE), accelerated solvent extraction (ASE), and ultrasound (USN), with the aim of improving the recovery bioactive compounds while maintaining the nutritional and sensory integrity. Additionally, her work explores the *in vitro* therapeutic potential of the recovered compounds and the evaluation of contaminants and associated risks in both food and soil matrices.

SCALING UP EMISSION CAPTURE AND UTILIZATION WITH *ULVA*: A THREE-PHASE APPROACH

CHRISTIANSEN E.R.[1]

[1] Pure Algae Denmark
E-mail: info@purealgae.dk

Abstract

The potential for macroalgae to play a transformative role in carbon and nutrient capture is significant, yet largely untapped. *Ulva* species, in particular, offer fast growth, high biomass yields, and valuable compounds for food, feed, and biotech applications. This presentation outlines Pure Algae's three-phase approach to industrializing *Ulva* cultivation with a focus on emissions capture and circular resource use [1].

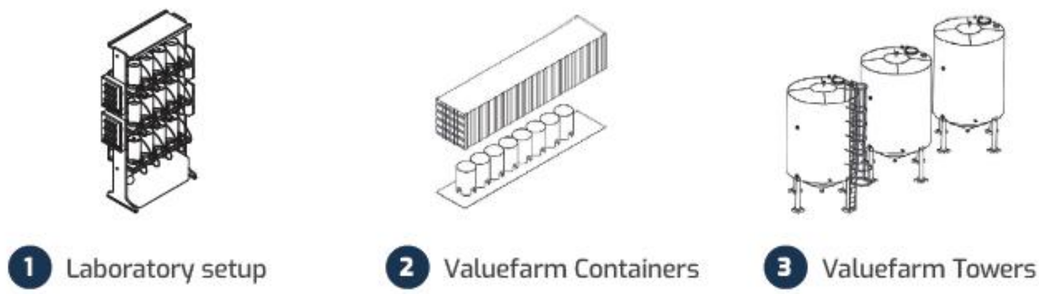
Phase 1 begins with laboratory-verified productivity of *Ulva* in controlled environments, where precision cultivation enables reliable data on growth performance, nutrient uptake, and strain selection. With the use of Pure Algae's Laboratory Setup, early-stage feasibility studies help determine optimal species and conditions, supporting data-driven decisions for larger-scale installations.

Phase 2 focuses on medium-scale production in VALUEFARM Container systems. These plug-and-play cultivation units are CE-certified and deliver stable yields of 5–13 kg fresh weight per PBR per week. Integrated with recirculating aquaculture systems (RAS), they utilize CO_2 and dissolved nutrients from fish production, creating a low-impact IMRAS (Integrated Multitrophic Recirculating Aquaculture System) model that converts emissions into high-value biomass.

Phase 3 targets full industrial scalability through the VALUEFARM Tower platform. Each modular tower holds 5,000 to 10,000 liters and is optimized for automation, nutrient cycling, and real-time monitoring. These units enable emission-intensive industries to integrate carbon and nitrogen utilization directly into their infrastructure – reducing emissions while generating new bio-based value streams.

Results from ongoing trials demonstrate that *Ulva* cultivation in these systems can outperform state-of-the-art land-based models, with productivity reaching up to 15.6 kg fresh weight/m^3/week at 10% dry weight. The systems are designed to scale modularly, adapt to site-specific parameters, and produce consistent outputs for both local and export markets.

This phased approach allows for rapid deployment, learning, and scale-up, facilitating climate-positive growth in aquaculture, biotech, and land-based emissions-heavy sectors. It combines science, engineering, and entrepreneurship to turn a global emissions challenge into a green economic opportunity.



References

[1] Kristoffer Larsen-Ledet, Teis Boderskov, Birgit Olesen, Martin Mørk Larsen, Nina Simonsen, Esben Rimi Christiansen, Lasse Hornbek Nielsen, Lan-Anh T. Tran, Sofie D'Hondt, Olivier De Clerck, Annette Bruhn. Strain selection and temperature responses of *Ulva* and *Ulva*ria (Chlorophyta) for application in land-based cultivation systems. Algal Research, Volume 85, 2025. https://doi.org/10.1016/j.algal.2024.103858.

Short Biography of the speaker

Esben R. Christiansen is the founder and CEO of Pure Algae, a Danish company pioneering land-based seaweed cultivation. With a background in biotechnology and bioremediation, he has developed scalable systems that convert emissions from aquaculture and industry into high-value biomass. Esben has played a central role in advancing EU-supported innovations in aquaculture, turning Pure Algae into a trusted provider of emission-utilizing cultivation solutions

SOME LESSONS LEARNED FROM ONLAND CULTIVATION OF SELECTED SEAWEEDS INCLUDING MANAGEMENT TECHNIQUES

CRITCHLEY A.T.[1]

[1] Verschuren Centre, Sydney, Nova Scotia, Canada
E-Mail: Alan.critchley2016@gmail.com

Abstract

The history of cultivation of a few, select seaweeds, at scale, is but a few centuries old. More recently, advanced and applied techniques have evolved to reach an equivalency to terrestrial farming that has been called "phyconomy". Some open water farmed seaweeds cannot be cultivated without at least a seeding/seedling stage on land, in a nursery (e.g., laver, kelps). The commercial volumes and economic values of seaweeds produced are regularly documented by the Food and Agriculture Organisation of the United Nations, the data from which were queried (see Buschmann et al. for an early warning call) and were also re-evaluated recently by the World Bank as investment opportunities. It is of great concern that the production of some cultivated seaweeds is falling, particularly in some surprising traditional, key areas. A number of issues arising will be presented.

An even smaller group of selected, and bespoke seaweeds (i.e., strains and variants) are currently farmed entirely on land for (hopefully) high-value applications and this has been coined as "precision phyconomy". These practices can be traced from using earthen ponds with co-cultivation of seaweeds and fish (e.g., agarophytes and milk fish), but generally the practice of on land (unialgal) seaweed cultivation for high-value production of biomass, is only a few decades old.

Sadly, all is not well in the seaweed garden and there are pressing issues facing the future of economically successful phyconomic activies - either in open water, or on land. Not least the very small number of currently (reliably) cultivatable seaweeds and their cultivars, plus increasing pest and diseases. Some of these issues are made worse by rapid climate change, especially is shallow waters. These are red flag warnings as to a clear and present danger to the future of the industry. The status quo is no longer an option. Resiliency of applied techniques and types of farmed seaweeds have to be established by urgent current research. There is little room for delay. Management of seaweeds in cultivation is a combination of science and evolving art and practice. Keep on keeping on, growing the "same old, same old" and responses of: "we have always done it that way" will no longer "work". This presentation will highlight some selected issues which it is hoped will evoke discussion and urgently needed directions for research.

Short Biography of the speaker

Dr Alan T. Critchley (**https://orcid.org/0000-0003-1704-458X**) is an adaptive phyconomist with 20 years' experience as an academic in southern Africa focused on seaweeds. He moved to sustainable and industrial-scale applications of commercial seaweeds in early 2001. He has helped co-edit two books on Tropical Phyconomy and currently two volumes on Temperate Phyconomy are in preparation for Springer.

He is Research Fellow at the Verschuren Centre, Canada and a consultant working on aspects of industrial-scale production of selected seaweeds, their biomass conversion and value-added applications.

MANIPULATING FISH GUT BACTERIA FOR IMPROVING *ULVA* NUTRITIONAL VALUE IN AQUAFEEDS

<u>DAKE A.[1,2]</u>, GUTTMAN L.[2,3]

[1] Marine Biology and Biotechnology Program, Ben-Gurion University of the Negev, Eilat, Israel 8811201.

[2] Israel Oceanographic and Limnological Research, The National Center for Mariculture, Eilat, 8811201, Israel.

[3] The Leon H. Charney School of Marine Sciences, University of Haifa, Sdot Yam, 38805, Israel.

E-mail: dake@post.bgu.ac.il

Abstract

The incorporation of *Ulva* sp., a nutrient-rich green macroalga, into aquafeeds offers a sustainable approach to reducing the aquaculture industry's dependence on fishmeal [1]. Still, the high presence of indigestible fibers, such as non-starch sulfated polysaccharides, limits *Ulva's* digestibility and nutritional value in aquafeeds for finfish species [2]. To address this challenge, the present study investigates the feasibility of manipulating the gut microbiota of gilthead sea bream (*Sparus aurata)* through probiotic supplementation as a strategy to enhance the utilization of *Ulva*-rich diets. For this aim, a preliminary feeding trial was performed over 12 weeks in which fish were fed commercial aquafeed with different inoculation rates of the probiotic bacterium of $1x10^8$, $1x10^{10}$, and $1x10^{12}$ CFU/Kg compared to a probiotic-free diet control. Fish growth rate, digestibility, immune response, and microbial community composition were measured throughout the culture period. Sequentially, trials to examine feed digestibility and fish resilience when challenged with pathogenic *Streptococcus agalactiae* were conducted using identical diets. Results indicated no effect of probiotic treatment on fish growth performances, but protein and lipid digestion were improved when the probiotic was supplemented at $1x10^{10}$ CFU/Kg, proposing an improved absorption of these macronutrients. Such a level of the probiotic supplement also induced antiprotease activity and led to a more stable gut microbial community in terms of its diversity. Last but not least, the probiotic treatment improved fish survival after challenging them with *S. agalactiae*, with highest survival rate of 70% in the probiotic supplementation level of $1x10^{12}$ CFU/Kg. Overall, the probiotic bacterium appears to be efficient in culture of *Sparus aurata* by improving fish resilience and enhancing its nutrition via improved protein and lipid uptake and digestibility.

References

[1] Shpigel, M. et. al. *Ulva lactuca* from an integrated multi-trophic aquaculture (IMTA) biofilter system as a protein supplement in gilthead seabream (*Sparus aurata*) diet. *Aquaculture*, 2017, *481*, 112-118.

[2] Wassef, E. A. et. al. Evaluation of *Ulva lactuca* and *Pterocladia capillacea* as dietary ingredients for juvenile gilthead seabream (*Sparus aurata*). *Aquaculture Research*, 2005, 36(13), 1348-1357.

Short Biography of the speaker

Ajit Dake working as a Ph.D. student in Prof. Lior Guttman's lab at the IOLR- National Center for Mariculture in Eilat, Israel, with a keen interest in microbiology, molecular biology, and aquaculture. His current project focuses on the use of novel probiotics to enhance growth, health, and feed digestibility in gilthead seabream. His academic journey reflects a commitment to research excellence and innovation. He actively engages in both national and international conferences, contributing to the dissemination and exchange of knowledge within his field.

Funded by the European Union

YEAR-ROUND CULTIVATION OF *ULVA* SP. ASSOCIATED WITH A RAS FISH FARM: BIOMASS PRODUCTIVITY AND ITS VALORISATION POTENTIAL

DUARTE A.M. [1,2], PINTO H. [4], PINHEIRO T. [1], MARTINS I. [1], SILVA I. [5], SOUSA PINTO I. [1,2], COSTA I. [1,2,3]

[1] Interdisciplinary Centre of Marine and Environmental Research (CIIMAR), Av. General Norton de Matos s/n, 4450-208 Matosinhos, Portugal
[2] Faculty of Sciences of University of Porto, University of Porto, Rua do Campo Alegre s/n, 4169-007 Porto, Portugal
[3] ICBAS—Instituto de Ciências Biomédicas Abel Salazar, University of Porto, Rua Jorge Viterbo Ferreira 228, 4050-313 Porto, Portugal
[4] Aquacria Piscícolas S.A., SeaEight group, Rua do Lavadouro, Quintas do Sul 3870-304, Torreira, Portugal
[5] S2AQUAcoLAB | EPPO- IPMA, Avenida Parque Natural da Ria Formosa, s/n 8700-194 Olhão Portugal
E-mail: airesmduarte@gmail.com

Abstract

Recirculating aquaculture systems (RAS) can reduce impacts on the environment, however the nutrient-rich water produced by RAS can still affect both local wildlife and the water quality which the industry depends on [1]. Integrating a seaweed cultivation close-by to these systems could be an effective approach to reduce nutrient levels and produce biomass for further use, supporting sustainability and the circular economy [2,4]. *Ulva* spp. are a fast-growing green macroalgae, rich in proteins, pigments, polysaccharides and other. These traits make *Ulva* species an ideal organism not only to bioremediate fish aquacultures but also as a source of food, feed, and bioproducts [3].

The work presented here demonstrates the feability of cultivating *Ulva* sp. in association to a land-based intensive aquaculture of *Solea senegalensis* operating in RAS (Aquacria Piscícolas S.A., from the Sea8 group), showing its biomass productivity, its biochemical characterization and its nutrient removal potential over a year-round experiment.

The cultivation conditions of *Ulva* sp. were optimized by testing different stock densities (1, 2, and 3 kg·m²) and water flows (LF – 45 $L \cdot h^{-1}$ and HF – 180 $L \cdot h^{-1)}$ during a year-round. Physico-chemical parameters (salinity, temperature and pH) and growth performance (growth rate and productivity) were monitored weekly, whereas bioremediation performance (carbon and nitrogen) and biochemical characterization (pigments, proteins, ashes, polysaccharides, phenols and antioxidant capacity) was assessed monthly. The nutrient concentration of the RAS water (inlet water) was followed every 15 days.

In a nutshell, environmental conditions in the HF tanks were closer to those in the fish farm water, showing more stable temperatures and lower pH compared to the LF tanks. Salinity was not influenced by the cultivation conditions. Growth performance and nutrient removal increased steadily for all conditions, peaking in summer. The highest growth rate (25%d^{-1}), productivity (4.5 kg FW m^{-2} wk^{-1}) and carbon/nitrogen removal (210 g C/ 29 g N g DW m^{-2} wk^{-1}) was achieved at 1kg m^{-2} and 180 $L \cdot h^{-1}$. A variation was observed, for both cultivation conditions over the year, for total pigments (4.8-11.1 mg /g DW), proteins (17.2-25.8%), ashes (12.9-25.8 %), polysaccharides (9.6-41.4 %), phenols (0.6-2.6 mg /g DW) and antioxidant capacity (14-86 mg TE/ g DW).

This presentation will explore the influence of the cultivation conditions and the seasonal effect on the growth, bioremediation performance and biochemical composition of the produced biomass, assessing its potential valorization.

References

[1] Ebeling, J. M., & Timmons, M. B. *Recirculating aquaculture*. Cayuga Aqua Ventures Ithaca. 2002

[2] Bolton, J., Robertson-Andersson, D., Shuuluka, D., & Kandjengo, L. Growing *Ulva* (Chlorophyta) in integrated systems as a commercial crop for abalone feed in South Africa: a SWOT analysis. *Journal of Applied Phycology.* 2009, *21*, 575-583

[3] Hofmann, L. C., Strauss, S., Shpigel, M., Guttman, L., Stengel, D. B., Rebours, C., Gjorgovska, N., Turan, G., Balina, K., & Zammit, G. The green seaweed *Ulva*: tomorrow's "wheat of the sea" in foods, feeds, nutrition, and biomaterials. Critical Reviews in Food Science and Nutrition. 2024, 1-36.

[4] Shpigel, M., Guttman, L., Ben-Ezra, D., Yu, J., & Chen, S.. Is *Ulva* sp. able to be an efficient biofilter for mariculture effluents? *Journal of Applied Phycology*. 2019, *31*, 2449-2459.

Short Biography of the speaker

Aires M. Duarte holds a bachelor's degree in Biotechnology from the University of Évora (2013) and a master's degree in Functional Biology and Biotechnology of Plants from the University of Porto (2017). He is currently a PhD candidate in Marine Biotechnology and Aquaculture at the Interdisciplinary Centre of Marine and Environmental Research (CIIMAR) and the Faculty of Sciences, University of Porto (FCUP). His research focuses on macroalgae cultivation, particularly *Ulva* species, and their integration into aquaculture systems to improve water quality, as well as the valorisation of biomass from a circular economy and biorefinery perspective.

Funded by the European Union

BIODEGRADATION AND TRANSFORMATION OF BISPHENOLS IN *ULVA*

HARDEGEN J.[1], KNIPS M.[1], DÄUMER J.[1], KRETZER S[1], WICHARD T.[1]

[1] Institute for Inorganic and Analytical Chemistry, Friedrich Schiller University Jena, Jena, Germany
E-mail: maximilian.knips@uni-jena.de, thomas.wichard@uni-jena.de

Abstract

Anthropogenic xenoestrogens represent a significant threat to both human health and the environment due to their endocrine-disrupting effects [1]. The green macroalga *Ulva* (Chlorophyta), known for its ability to thrive across a wide range of salinities and to form large green tides in polluted and eutrophic waters, shows strong potential for applications in wastewater treatment and bioremediation.

In this study, we examined the removal of various bisphenols and ethinylestradiol, focusing on the underlying mechanisms involved, using the tripartite community of *Ulva mutabilis* - *Roseovarius* sp. (MS2) - *Maribacter* sp. (MS6) [2]. The model organism *Ulva* demonstrated over 99% removal efficiency for bisphenols A, B, E, F, P, and Z, with partial removal observed for bisphenol S. Notably, complete removal occurred even under axenic conditions, indicating that associated bacteria *Roseovarius* sp. (MS2) and *Maribacter* sp. (MS6) played no significant role. A concentration of 6.6 mg L^{-1} of bisphenol A was entirely removed within two days, with a half-life of 1.85 hours [3].

Stable isotope labeling combined with high-resolution mass spectrometry revealed that bisphenol A underwent a range of transformation reactions including bromination, sulfation, iodination, and radical cleavage. In total, 20 transformation products were identified, with radical cleavage being the dominant removal mechanism. Bioaccumulation was minimal, suggesting that chemical transformation, rather than storage, drives pollutant removal [4].

The results demonstrate that *Ulva* is not only effective at removing xenoestrogens but also degrades them into less harmful byproducts. These findings highlight the potential of *Ulva* as a scalable and sustainable tool for bioremediation, particularly in wastewater treatment systems. Future applications could integrate *Ulva* into aquaculture or coastal treatment facilities, offering a nature-based solution to persistent organic pollutants.

References

[1] Michałowicz, J. Bisphenol A − sources, toxicity and biotransformation. *Environmental Toxicology and Pharmacology*. 2014, 37, 738-758.

[2] Wichard, T. From model organism to application: Bacteria-induced growth and development of the green seaweed *Ulva* and the potential of microbe leveraging in algal aquaculture. *Seminars in Cell & Developmental Biology*. 2023, 134, 69-78.

[3] Hardegen, J. et al. Lifecycle-dependent toxicity and removal of micropollutants in algal cultures of the green seaweed *Ulva* (Chlorophyta). *Journal of Applied Phycology*. 2023, 35, 2031-2048.

[4] Hardegen, J. et al. Biodegradation of Xenoestrogens by the Green Tide Forming Seaweed *Ulva*: A Model System for Bioremediation. *ACS ES&T Water*. 2025, 5, 1195-1206.

Acknowledgments

This research was funded by the Friedrich Schiller University Jena (Germany) through the “Landesgraduiertenstipendium” of the Free State of Thuringia and by the Deutsche Forschungsgemeinschaft (DFG) through the SFB 1127 ChemBioSys (No# 239748522). The project was also supported as part of the "Clusters 4 Future" initiative of the German Federal Ministry of Education and Research (BMBF) within the Thuringian Water Innovation Cluster (ThWIC, project VANAPLA, 03ZU1214BB).

Short biography of the speaker

Maximilian Knips is a PhD candidate in chemistry at the Friedrich Schiller University of Jena in Germany. He holds a bachelor's degree in Chemistry and a master's degree in "Chemistry – Energy – Environment". He is investigating the ability of *Ulva* to biodegrade anthropogenic micropollutants and its application in wastewater treatment plants. His research is funded by the Deutschen Bundesstiftung Umwelt (German Federal Environmental Foundation).

DOES MORPHOLOGICAL INSTABILITY IN THE CROP *ULVA FENESTRATA* RESULTS FROM POLYPLOIDY?

HELLIGE, I.[1], STEINHAGEN, S.[1,2]

[1] Department of Marine Sciences, University of Gothenburg, Tjärnö Marine Laboratory
[2] Department of Natural History, University Museum of Bergen
E-mail: inga.hellige@gu.se

Abstract

Ulva fenestrata is gaining attention as a promising future crop for aquaculture in the Northern Hemisphere, sparking interest in methods to improve its growth and maintain morphological consistency. One potential strategy involves selecting fast-growing “giant” individuals. However, it remains unclear whether this distinctive trait —enabling them to outcompete others in growth— emerges randomly or is associated with polyploidy. Here, we sampled 30 individuals of *Ulva fenestrata* along the Swedish west coast and further included 5 long-term cultivated crop strains. All algae were incubated to induce fertility, swarmers were isolated and cultured to generate an F1 generation. This generation was screened for individuals displaying the giant phenotype. Selected F1 gametophytic giants will be parthenogenetically propagated and the inheritance of the trait will be assessed while in parallel, we aim to determine ploidy levels in giant individuals.
Our findings may inform strain selection in future *Ulva* aquaculture by clarifying the role of polyploidy in morphological stability and genetic diversity. This knowledge is essential for identifying robust traits in cultivated strains and advancing our understanding of *Ulva* biology at both molecular and physiological levels.

Acknowledgments

We would like to thank Elena Schroffner-Brunner from University of Gothenburg, Department of Marine Sciences for her help with *Ulva* sampling and setting up of experiments, as well as Annelous Oerbekke from Nordic SeaFarm for providing cultivation strains. We acknowledge invaluable support from the Blue Bio Boost Project (grant number: SBEP2023-476), as well as the European Cooperation in Science and Technology.

Short Biography of the speaker

Inga is a postdoctoral researcher at the Steinhagen lab at University of Gothenburg, Tjärnö Marine Laboratory, working on the cultivation and selection of green algae *Ulva* for aquaculture purposes. Prior she obtained her PhD in marine glycobiochemistry at MARUM Center for Environmental Research at University of Bremen and Max-Planck Institute for Marine Microbiology, Bremen, focusing on the potential of brown algae as a carbon sink.

SeaWheat COST Action CA20106

University of Haifa

MORPHOGEN-INDUCED METABOLIC SHIFTS IN *ULVA*

HOLBL H.[1], DUNGER N.[1], KÜHNEL B.[1], WICHARD T.[1]

[1] Department for Inorganic and Analytical Chemistry, Friedrich Schiller University Jena
E-mail: hermann.holbl@uni-jena.de

Abstract

The green macroalga *Ulva mutabilis* (conspecific with *Ulva compressa*) serves as a valuable model for the investigation of algal development, particularly due to its reliance on the symbiotic marine bacteria *Roseovarius* sp. MS2 and *Maribacter* sp. MS6 [1]. The bacteria excrete algal-growth and morphogenesis-promoting factors (AGMPFs) essential for the normal development of the alga [2, 3]. *Roseovarius* sp. promotes cell division, while *Maribacter* sp. induces morphogenesis and proper cell wall formation in axenic gametes. The AGMPF from *Maribacter* sp. has been identified as (−)-thallusin [4] and successfully synthesised [5, 6], whereas the corresponding factor from *Roseovarius* sp. is still unidentified.
We demonstrated the axenic callus derived from *Ulva* gametes is a suitable model for investigating the metabolic effects of AGMPFs [7]. After two weeks of exposure to AGMPFs, treated calli showed visible signs of regeneration and significant metabolic shifts compared to untreated controls using metabolomics. Targeted fatty acid profiling also revealed pronounced alterations in the fatty acid profiles compared to untreated controls. Particularly ω3 and ω6 fatty acids were affected [7]. In addition, we analysed the monosaccharide profiles of *Ulva* treated with bacteria or AGMPFs for three months to compare their carbohydrate composition to that of the axenic calli control cultures. Notably, treatments with *Maribacter* sp. or (−)-thallusin revealed clear differences compared to control conditions. Overall, our poster illustrates how omics approaches can elucidate the mechanisms of morphogen-induced signal transduction. The findings underscore the crucial role of bacterial-derived compounds in regulating metabolic and developmental processes in *Ulva*, highlighting their potential utility in interfering with algal–microbe interactions for aquaculture applications.

References

[1] Wichard, T., et al. The green seaweed *Ulva*: a model system to study morphogenesis. *Front. Plant. Sci.*, 2015, 6, 72.

[2] Spoerner, M., et al. Growth and thallus morphogenesis of *Ulva mutabilis* (*Chlorophyta*) depends on a combination of two bacterial species excreting regulatory factors. *J. Phycol.*, 2012, 48, 1433-1447.

[3] Wichard, T. From model organism to application: Bacteria-induced growth and development of the green seaweed *Ulva* and the potential of microbe leveraging in algal aquaculture. *Semin. Cell Dev. Biol.*, 2023, 134, 69-78.

[4] Alsufyani, T., et al. Macroalgal-bacterial interactions: Identification and role of thallusin in morphogenesis of the seaweed *Ulva* (*Chlorophyta*). *J. Exp. Bot.*, 2020, 71, 3340-3349.

[5] Dhiman, S., et al. Stereoselective total synthesis of (-)-thallusin for bioactivity profiling. *Angew. Chem. Int. Ed.*, 2022, 61, e202206746.

[6] Wienecke, P., et al. Enantioselective total synthesis of the morphogen (-)-thallusin and mediated uptake of Fe(III) into the green seaweed *Ulva*. *Chemistry*, 2024, 30, e202304007.

[7] Holbl, H., et al. Bacteria-released algal growth and morphogenesis factors regenerate axenic calli derived from the macroalga *Ulva (Chlorophyta)* and change the fatty acid profile. *Bot. Mar.*, 2025, DOI: doi:10.1515/bot-2024-0101.

Acknowledgments

This research was funded by the Friedrich Schiller University Jena (Germany) ('Landesgraduiertenstipendium' of the Free State of Thuringia) and by the Deutsche Forschungsgemeinschaft (DFG) through the SFB 1127 ChemBioSys (No# 239748522).

Short biography of the presenter

Hermann Holbl is a PhD candidate in chemistry and a member of the Collaborative Research Centre 1127 Chembiosys at the Friedrich Schiller University Jena in Germany. He holds a bachelor's degree in chemistry and a master's degree in "Chemistry – Energy – Environment". He studies the symbiotic relationships between *Ulva* and its associated bacteria, *Roseovarius* sp. and *Maribacter* sp., focusing on the algal growth- and morphogenesis-promoting factor thallusin released by *Maribacter* sp.

SEAWEED CULTIVATION AND COMMERCIAL EFFORTS IN DENMARK

HOLDT S.L.[1], CHRISTIANSEN S.L.[2], MOURITSEN L.[2], BODERSKOV T.[3], NIELSEN M.M.[4], SCHMEDES P.S.[4], HOU X.[5], THOMSEN M.[6], BRUHN A.[3]

[1] The National Food Institute, The Technical University of Denmark
[2] Kattegatcentret, Denmark
[3] Department of Ecoscience, Aarhus University, Denmark
[4] DTU Aqua, Nykøbing Mors, Denmark
[5] Bioresources, Danish Teknological Institute, Denmark
[6] Food Institute, University of Copenhagen, Denmark
E-mail: suho@food.dtu.dk

Abstract

Over the past two decades, Denmark has witnessed the emergence of a seaweed sector transitioning from historical hydrocolloid processing based on imported or wild-harvested biomass, to a small but growing ecosystem of seaweed cultivation, processing, and product innovation. While Denmark lacks extensive intertidal zones and large native seaweed forests, pioneering efforts since 2007 have driven both sea-based and land-based cultivation of species such as *Saccharina latissima*, *Ulva* spp., and *Palmaria palmata*.

This presentation outlines the development of the Danish seaweed industry with a focus on cultivated species, commercial applications, and the evolving network of small- and medium-sized enterprises. We present results from three national SWOT analyses (2012, 2021, 2023) capturing stakeholder perspectives, and summarize trends in funding, peer-reviewed research output, and industry consolidation. A particular emphasis is placed on the role of formalized science-industry networks—such as Tangnetværket, AlgaeCenter Denmark, and the Danish Seaweed Organization—in supporting knowledge exchange and enabling collaboration. Despite positive developments, challenges remain related to funding structures, regulatory clarity, and the shift from enthusiastic entrepreneurship to economically sustainable business models. The Danish case offers valuable insight into how coordinated national efforts can support the emergence of a blue bioeconomy sector in a European context.

Acknowledgments

The authors thank Nordic Algae Network (SWOT1) supported by the Nordic Council of Ministers, Tang.nu supported by VELUX FOUNDATIONS (SWOT2), Norddjurs Municipality (SWOT3), AlgaeCenter DK2.0, network project supported by GUDP (Grønt Udviklings og Demonstrations program, Danish Ministry of Food, Agriculture and Fisheries), and Joint Nordic Seaweed Innovation Network supported by the Nordic Council of Ministers.

Short Biography of the speaker

Susan Løvstad Holdt, Associate Professor at DTU Food is expert in research within seaweed composition, bioactives and technologies for extraction and processing. Furthermore, she is involved in research on seaweed as a food, legislation, standardization, retaining the qualities of seaweed, but also having focus on reducing the contaminant found in seaweed. SLH is Vice President of the International Seaweed Association and chair of the Seaweed Network in Denmark. SLH's list of publications incl. FAO reports and book chapter, and with more than 40 peer-reviewed publications counting the highly cited (>1350) review on Bioactive compounds in seaweed: functional food applications and legislation (Holdt and Kraan, 2011).

A SALINE WATER SOURCE FOR *ULVA* LAND-BASED CULTIVATION: FROM SPA TO BIOMASS FOR *ULVA*N AND BIOPLASTIC PRODUCTION

ISRAEL, Á.[1]

[1] Israel Oceanographic & Limnological Research, The National Institute of Oceanography. Tel Shikmona, Haifa, Israel
E-mail: alvaro@ocean.org.il

Abstract

Ulva biomass is typically produced in land-based settings using seawater and attempts to establish sea-based cultivation strategies are under way [1,2,3]. Further, only a handful studies using saline water sources to explore seaweed culture have been reported, and they include *Ulva* [4,5,6]. This talk presents a compilation of a 1-y experimental trials in which the growth rates of *Ulva* (likely a combination of the morphologically similar *U. rigida* and *U. ohnoi*) were measured in 1,000 L PVC tanks using a saline (i.e. thermo-mineral water) source chemically resembling natural seawater, with temperatures ranging between 25-28 °C. The experiments run from August 2024 through July 2025. During an initial period of several weeks the thermo-mineral water source tested was highly nuisance for algal growth, apparently related to high Fe levels and alkalinity, resulting in calcite deposition, very low or negligible growth, triggering several sporulation events. This may reflect a stress response to acclimation to a new cultivation environment. A set of filters down to 5 µ were of significant benefit and towards the coming fall and winter seasons growth rates ranged between 50-150% per week. Altogether, the biomass quality was arbitrarily ranged as "low" or average" compared to similar cultures in seawater, yet *Ulva*n estimates were c.a. 10% on a DW basis. This study provides an encouraging option for land-based *Ulva* cultivation in saline environments, other than seawater, specially when looking at on-going climate changes and alarming anthropogenic global pollution occurring in the marine environment.

References

[1] Zertuche-González, JA. et al. Seasonal and interannual production of sea lettuce (*Ulva* sp.) in outdoor cultures based on commercial size ponds. *J World Aquac. Soc.* 2021, https://doi.org/10.1111/jwas.12773

[2] Steinhagen, S. et al. Harvest time can affect the optimal yield and quality of sea lettuce (*Ulva fenestrata*) in a sustainable sea-based cultivation. *Front. Mar. Sci*. 2022. 9:816890. doi: 10.3389/fmars.2022.816890.

[3] Zollmann, M. et al. Effects of season, depth and pre-cultivation fertilizing on *Ulva* growth dynamics offshore the Eastern Mediterranean Sea. *Scientific Reports.* 2023 13.1, 14784.

[4] Fricke, A. et al. Study on the nutritional composition of the sea vegetable *Ulva compressa* in a brine-based cultivation system. *Front. Mar. Sci.* 2023. 10:1292947. doi: 10.3389/fmars.2023.1292947.

[5] Fricke, A. et al. A proof of concept for inland production of the "sea-vegetable" *Ulva compressa* in Brandenburg (Central Europe) using regional saline groundwater. Algal Research. 2023. 74, 103226. https://doi.org/10.1016/j.algal.2023.103226.

[6] Denisova, V. et al. Sea vegetables for brine-based inland cultivation. *Front. Mar. Sci*. 2025. 12:1630093. doi: 10.3389/fmars.2025.1630093.

Funded by the European Union

Short Biography of the speaker

Álvaro Israel is a senior scientist at Israel Oceanographic & Limnological Research, Ltd. The National Institute of Oceanography, Haifa, Israel. During his career he engaged in studying photosynthesis, carbon fixation and ecology of marine macroalgae, acquiring a vast experience in seaweed aquaculture and strain selection intended for the production of food and valuable molecules. Seaweed taxonomy using molecular tools, seaweed invasions and issues related to global change are also under current investigation in his lab.

FROM LAB TO SEA: EXPLORING *ULVA* SPORULATION AND GROWTH DYNAMICS FOR OPEN-WATER AQUACULTURE ON GRAN CANARIA

JACOB J.[1], ORTIZ CORTES J.[2], FERNÁNDEZ-MÉNDEZ M.[1,2]

[1] Department of Bioeconomy, Alfred-Wegener-Institute
[2] Macrocarbon
E-mail: jan.jacob@awi.de

Abstract

Seaweed cultivation in coastal areas is often limited by spatial constraints and environmental variability. To support the expansion of seaweed farming, it is necessary to explore alternative regions with suitable environmental parameters. Gran Canaria is particularly promising due to its abundant sunlight and stable, warm water temperatures.

This study presents the first trials of open water cultivation of *Ulva* in nearshore waters off Gran Canaria, aiming to assess whether the local environmental conditions support its growth. The experiments were conducted over a period of approximately one month between March and May. Two cultivation approaches were employed: cage and rope-based systems. A biomass of exactly 50 g (wet weight) of young *Ulva* specimen was placed in each cage (n=3) at two different depths: the surface and 1.5 meters. Adult *Ulva* was attached to ropes fiddling the specimen into the twine (n=4 + one control without any biomass) and grown under three treatments. Attached to a frame without a net, with a net and submerged at 1 m with a net.

Cage cultivation achieved growth rates of up to 12.5% wet weight (WW) per day during the first week. Growth at 1.5 m depth led to significant higher RGR ($p = 0.014$, Post hoc tukey test) then the cages kept floating at the surface, potentially due to reduced biofouling and lower irradiance or photoinhibition effects at depth. Despite increasing biotic stressors, including grazing and biofouling, the biomass doubled twice during the experimental period. Further in contrast, the rope-based system faced significant challenges due to heavy biofouling, which hindered the algae's development and resulted in total decay of the biomass. Additionally, the age of the used biomass might have impacted the growth potential. Adjustments to this system are planned for future trials to mitigate fouling and grazing impacts.

Additionally, sporulation experiments using a local *Ulva* species offered preliminary insights into reproductive timing and potential regulatory factors, setting the stage for future reproductive studies. These findings underline the importance of refining cultivation techniques and understanding biotic interactions for sustainable *Ulva* aquaculture in nearshore environments.

References

[1] Balar, N. B., & Mantri, V. A. (2019). Insights into life cycle patterns, spore formation, induction of reproduction, biochemical and molecular aspects of sporulation in green algal genus *Ulva*: implications for commercial cultivation. Journal of Applied Phycology, 32(1), 473-484. https://doi.org/10.1007/s10811-019-01959-7

[2] Bikker, P., van Krimpen, M. M., van Wikselaar, P., Houweling-Tan, B., Scaccia, N., van Hal, J. W., Huijgen, W. J., Cone, J. W., & Lopez-Contreras, A. M. (2016). Biorefinery of the green seaweed *Ulva* lactuca to produce animal feed, chemicals and biofuels. J Appl Phycol, 28(6), 3511-3525. https://doi.org/10.1007/s10811-016-0842-3

Funded by the European Union

[3] Carl, C., de Nys, R., Lawton, R. J., & Paul, N. A. (2014). Methods for the induction of reproduction in a tropical species of filamentous *Ulva*. PLoS One, 9(5), e97396. https://doi.org/10.1371/journal.pone.0097396
[4] Change, I. P. O. C. (2007). Climate change 2007: the physical science basis. Agenda, 6(07), 333.
[5] Duarte, C. M., Wu, J., Xiao, X., Bruhn, A., & Krause-Jensen, D. (2017). Can Seaweed Farming Play a Role in Climate Change Mitigation and Adaptation? Frontiers in Marine Science, 4. https://doi.org/10.3389/fmars.2017.00100
[6] Gao, G., Clare, A. S., Rose, C., & Caldwell, G. S. (2017). Intrinsic and extrinsic control of reproduction in the green tide-forming alga, *Ulva* rigida. Environmental and Experimental Botany, 139, 14-22. https://doi.org/10.1016/j.envexpbot.2017.03.016
[7] Titlyanov, E. A., & Titlyanova, T. V. (2010). Seaweed cultivation: Methods and problems. Russian Journal of Marine Biology, 36(4), 227-242. https://doi.org/10.1134/s1063074010040012
[8] van den Burg, S. W. K., Koch, S. J. I., Poelman, M., Veraart, J., Selnes, T., Foekema, E. M., & Lansbergen, R. (2023). Seaweed as climate mitigation solution: Categorizing and reflecting on four climate mitigation pathways. WIREs Climate Change, 15(2). https://doi.org/10.1002/wcc.868
[9] Xiao, J., Zhang, X., Gao, C., Jiang, M., Li, R., Wang, Z., Li, Y., Fan, S., & Zhang, X. (2016). Effect of temperature, salinity and irradiance on growth and photosynthesis of *Ulva* prolifera. Acta Oceanologica Sinica, 35(10), 114-121. https://doi.org/10.1007/s13131-016-0891-0

Acknowledgments

I acknowledge the Alfred Wegener Institute (AWI) for funding this research, the Spanish Bank of Algae for their support and provision of laboratory infrastructure, and Macrocarbon for their financial contributions, which not only supported this study but also enabled access to their boat and barrier system, making the fieldwork possible.

Short Biography of the speaker

I began my academic journey with a Bachelor's degree in Biology at Leibniz University Hannover, specializing in plant genetics and completing a thesis on Arabidopsis thaliana mutants under abiotic stress. I then earned a Master's in Marine Environmental Sciences from the University of Oldenburg, conducting my thesis research at Aarhus University on the responses of sub-Arctic benthic macrophytes to warming. In early 2023, I worked at the Department of Ecoscience in Aarhus and later completed a research stay at the Greenland Institute of Natural Resources in Nuuk. Since March 2024, I have been a research assistant at Macrocarbon, designing and running experiments to optimize *Ulva* cultivation and managing aquaculture systems such as photobioreactors. In January 2025, I began my PhD at the Alfred-Wegener Institute as part of the INNOva project, which focuses on sustainable open-water *Ulva* farming and its climate and social benefits. These experiences have given me a strong foundation in marine plant research and applied aquaculture. I'm especially interested in the role of seaweed in climate change mitigation and sustainable resource use. My work is driven by a commitment to bridging marine science with practical environmental solutions.

USE OF SEAWEEDS, EXTRACTS AND INGREDIENTS FROM SEAWEEDS TO IMPROVE HEALTH AND WELLBEING IN LIVESTOCK.

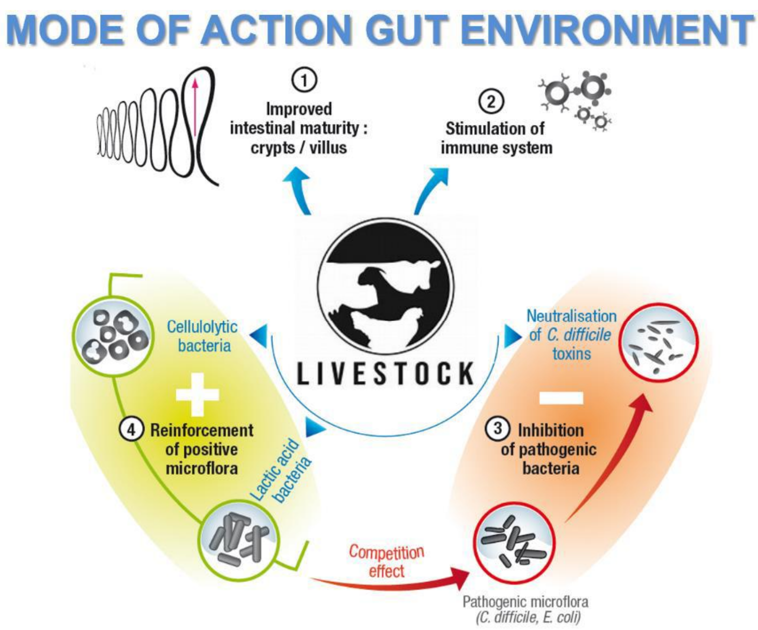
KRAAN S.[1]

[1] Oceana Organic Products Ltd, Headford Co Galway H91 E09X Ireland
E-mail: Stefan@theseaweedconsortium.com

Abstract

There are about 1200 chlorophytes or green algal, 1750 phaeophytes or brown algal and 6000 rhodophytes or red algal species. These macroalgal species or more popular called seaweeds, contain a plethora of secondary metabolites that play a role in a variety of metabolic processes in plants, animals and humans. Seaweeds possess several bioactive molecules that are studied for their prebiotic, anti-microbial, antioxidant, anti-inflammatory and immunomodulatory effects.
Seaweed benefits are related to their content of sulfated polysaccharides, phlorotannins, diterpenes, omega-3 polyunsaturated fatty acids, minerals and vitamins. Modern agricultural and farming practices depend heavily on chemicals to control pests such as a variety of parasitic organism either internal or external in animal farming and crop production. Unique biochemical compounds from algae have been applied as potential biocides against these parasitic organisms. This presentation as part for the final COST action "*Ulva* Wheat of the Sea" will place specific emphasis on *Ulva* as feed ingredient for livestock in agriculture.
Over the last decades several chemical biocides have become less effective and many chemicals currently used have a negative environmental impact (e.g., Zinc Oxide, bromoform) and have possible side effects to humans and other non-target organisms. Marine algae have a demonstrated potential to act as environmentally friendly biocides with no negative side effects and could fulfill the need of alternative and safe supplements to increase health and welfare in livestock. This presentation reviews the effects of seaweeds (*Ulva* in particular) and seaweed extracts in farmed animals as prebiotics, anti-microbial, antioxidant, anti-inflammatory and immune-modulatory effects, promoting intestinal well-being and improving digestibility. Special focus will be on the green seaweed *Ulva.*

Graphical Abstract



Funded by the European Union

Short Biography of the speaker

Obtained his PhD on phylogenetics and aquaculture of edible seaweeds at the National University of Ireland, Galway in 2001, while in parallel managed of the Irish Seaweed Industry Organisation and established the Irish Seaweed Centre in 2001, a dedicated R&D centre for seaweed-based research and development at the University of Galway Ireland. Resigned from University life and established Ocean Harvest Technology Ltd to pursue and develop some commercial ideas using seaweeds for functional food ingredients for fish farming and livestock. After 8 years he resigned and co-founded The Seaweed Company in 2018. A company with complete horizontal integration developing the whole seaweed value chain from cultivation to biostimulant feed, food, and biomaterials with as highlight SeaMeat™, a processed meat replacement ingredient. Stepped out of the Seaweed Company in December 2024. Currently he is developing seaweed cultivation in India and Indonesia, producing agarose, biostimulant and works on biopaper and bioplastics. In his position for Blaaker AS, Norway is also involved in developing and applying biodegradable rope and materials for seaweed cultivation and aquaculture in general. He was President of the International Seaweed Association (2016- 2019) and is currently President for the International Society for Applied Phycology (2024- 2027). He was business coach of 14 Indonesian seaweed companies under the Dutch Ministry of Economics and Climate Policy’s development program (CBI/RVO) to help diversify and increase export to Europe. Main fields of expertise are aquaculture of seaweeds, sustainable development of algal resources, industrial applications of seaweeds and usage of seaweeds in animal feed, aquaculture, biotechnology and biomedicine

HOW COLLABORATIONS WITHIN THE SEAWHEAT NETWORK ALLOWED FOR AN HOLISTIC APPROACH OF TEMPERATURE EFFECTS ON *ULVA* BIOMASS QUALITY AND YIELD.

LARSEN-LEDET K.[1, 2, 3], BODERSKOV T.[1, 2, 3], OLESEN B.[4], SIMON C.[5], ROSIGNOLI S.[5], SULPICE R.[5], ENGELEN A.[6], VAN DER LOOS L.[7], D'HONDT S.[7], DE CLERCK O.[7], NIELSEN L.[8], VON STEIN L.[9], BRUHN A.[1, 2, 3].

[1] Department of Ecoscience, Aarhus University.
[2] Centre of Circular Bioeconomy, Aarhus University.
[3] Algae Centre Denmark.
[4] Department of Biology, Aarhus University.
[5] School of Biological & Chemical Sciences, University of Galway.
[6] Centre of Marine Sciences, University of the Algarve.
[7] Phycology Research Laboratory, Ghent University.
[8] Pure Algae Denmark.
[9] Department of Food Science, Copenhagen University.
E-mail: kll@ecos.au.dk

Abstract

The wonders of *Ulva* biology are being researched in all corners of the world with every research group having special expertise and niches. The SeaWheat COST Action has provided incredible opportunities for early-career researchers to learn from several research groups through training schools, workshops, and short-term-scientific-missions (STSM). All these opportunities allow young researchers to gain a more holistic and nuanced approached to their own research.

Several questions arise, as the research and development of *Ulva* cultivation systems is being investigated in Denmark: "Which *Ulva* species are we working with?", "How does it grow?", "What can it be used for?". To answer these questions, the expertise of several *Ulva* research groups is needed, as the dynamics of *Ulva* biology often vary among *Ulva* strains and cultivation conditions.

In this study, the effect of temperature on a single German *Ulva compressa* strain was investigated across a temperature gradient (10 – 31 ℃) in a steady-state, high-nutrient pilot setup. The examined parameters included: growth rates, oxygen release, nitrogen uptake, microbiome composition, and biochemical composition. To complete this study an early-career researcher travelled between several SeaWheat member institutes to learn methods of molecular biology, seaweed cultivation, and biochemistry.

Temperature affected growth rates, with high growth rates being observed (19 ± 2% FW day^{-1}) up to 19 ℃, and gradually reduced growth above 22 ℃ (0.2 – 12% FW day^{-1}). *Ulva*n content was highest at 10 – 13 ℃ (148.5 ± 34.2 mg g^{-1} DW), while amino acid content was higher at the temperature extremes (10, 28, and 31 ℃). Nitrogen uptake potential was highest at 10 - 19 ℃ and accounted for 60 - 80% of added inorganic nitrogen. The results document effects of cultivation temperature on the biomass yield and quality of a single *U. compressa* strain at pilot scale. Furthermore, these results present a prime example of how international cooperation within the COST Action framework have promoted learning, networking, and increased the quality of research caried out by young scientists.

Acknowledgments

The authors would like to acknowledge the technical and academic staff of Aarhus University, Ghent University, and the University of Galway who were essential to this work. Additionally, the authors would like to thank everyone involved in hosting and organising the SeaWheat COST Action training schools, workshops, and STSMs for their dedication and inspirational discussions.

Short Biography of the speaker

Kristoffer Larsen-Ledet
PhD student, Department of Ecoscience, Aarhus University, Denmark
Originally from the West coast of Denmark, Kristoffer grew up with a curiosity for marine life and coastal ecosystems. Kristoffer is passionate about the mitigation of anthropogenic effects on natural ecosystems and educated as an artic and marine ecologist he aims to quantify the ecosystem services and disservices of *Ulva* cultivation in Danish waters.

ULVA IN LAND-BASED INTEGRATED AQUACULTURE WITH ABALONE IN SOUTH AFRICA: AN UPDATE AFTER 25 YEARS OF COMMERCIAL CULTIVATION

MACEY B.M.[1,2], BOLTON J.J.[2], BRINK-HULL M.[1,2]

[1] Department of Forestry, Fisheries and the Environment, South Africa
[2] Department of Biological Sciences, University of Cape Town, South Africa
E-mail: Bmacey@dffe.gov.za

Abstract

The land-based abalone farming industry in South Africa developed rapidly in the 1990s. By the early 2000s the first commercial IMTA systems were initiated, using *Ulva* grown in abalone effluent to produce feed for cultivated abalone. All the farms feed formulated feed to the abalone, with some providing additions of freshly harvested kelp (*Ecklonia maxima*) and/or cultivated *Ulva*. In 2006 the first integrated recirculating system was developed using *Ulva* to bioremediate the effluent enabling partial recirculation of water. Bolton et al. (2009) carried out a SWOT analysis of this initial system. Since then national abalone production has increased from 1100t to 2600t yr^{-1}, and *Ulva* production, predominantly on 4 large farms, has increased from 1000t to ca. 2400t yr^{-1}. Two of these farms were built a little over a decade ago and designed to operate fully on 50% recirculation: Bufflejags Abalone and Diamond Coast Abalone. The ASTRAL project (2021-4: https://www.astral-project.eu/) 'IMTAlab South Africa' carried out detailed research on the recirculating IMTA system at Buffeljags Abalone Farm. The farm (Figure 1) is designed in 'clusters' consisting of 42 ca. 5m-long abalone tanks linked to a D-ended ca. 30m long paddle raceway producing *Ulva lacinulata*. The latter propagates vegetatively in the system, as demonstrated by continual production without thallus deterioration and the lack of attached foliose *Ulva* sporelings on the raceways.

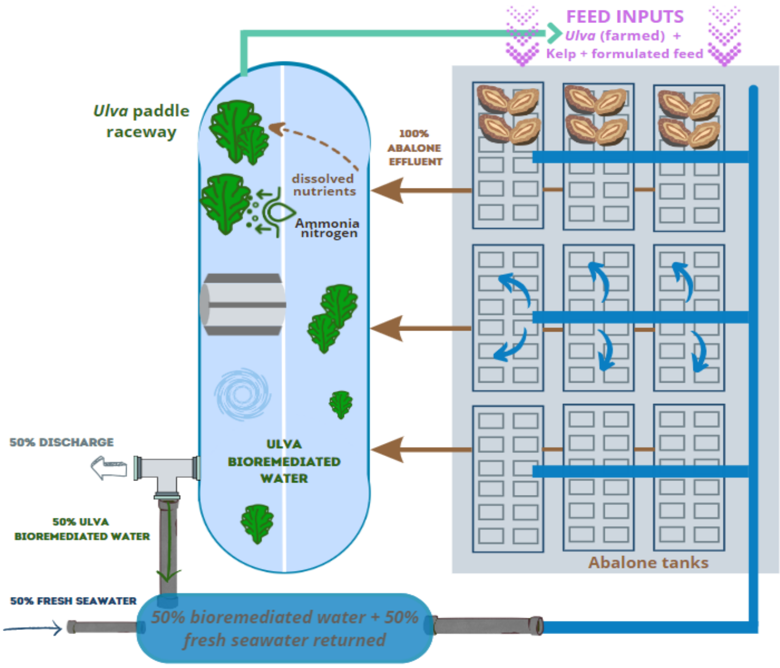


Fig. 1
Single cultivation cluster at Buffeljags abalone farm. From Macey et al. (2024)

Ulva has a remarkable list of benefits apart from additional feed provision and enabling partial recirculation. These include: providing feed when formulated feed causes difficulties at high summer temperatures/ improved abalone health through the addition of fresh feed/ feeding stimulation leading to increased consumption reducing use of protein-rich formulated feed/ significant reduction in nutrient release to the environment/ potential to increase recirculation rates to 75% with no apparent adverse effects/ potential to run on 100% recirculation for a few days - a benefit in the event of a short-term Harmful Algal Bloom/ and modulation of microbiome in the system including reduction in potential opportunistic pathogens. Despite the demonstrated benefits, only ca. 35% of South African abalone farms grow seaweeds. As previously highlighted (Bolton et al. 2009), main barriers to IMTA development in South Africa are: biosecurity concerns with refeeding seaweed grown in effluent/ use of costly land-space for seaweed rather than abalone cultivation/ concerns over potential for reduced growth or health of abalone with increasing recirculation/ and the extra input necessary to grow a second aquaculture species. An additional threat is the recent price reduction for the high-value abalone, sold predominantly to Asia.

References

Bolton, J.J., Robertson-Andersson, D.V., Shuuluka, D., Kandjengo, L. (2009). Growing *Ulva* (Chlorophyta) in integrated systems as a commercial crop for abalone feed in South Africa: a SWOT analysis. *J. Appl. Phycol.*, 2009, 21, 575-583

Macey, B.M., Brink-Hull, M., Bolton, J.J., Cyrus, M.D., de Vos, B., Loubser, N., Fourie, S., Loubser, M. Land based, pump ashore IMTA production manual. *EU H2020 project 'ASTRAL'*. 2024, 99pp. https://www.astral-project.eu/training-education-materials

Acknowledgments

This study received funding from the EU Horizon 2020 Research & Innovation Programme ASTRAL Project under Grant Agreement No. 863034.

Short biography of the speaker

Dr Brett M Macey is a specialist scientist in the South African Department of Forestry, Fisheries and the Environment (DFFE). He conducts inter- and transdisciplinary research to tackle nutritional and sustainability challenges of marine aquaculture, focusing specifically on advancing the health and sustainability of farming systems, the development of disease prevention strategies and fostering a better understanding of the role microorganisms play in the health of aquatic animals and farming practices. Current research encompasses the creation of probiotics/immuno-stimulants, establishment of innovative molecular methods for diagnosing new and emerging pathogens, and the formulation of functional feeds—such as probiotic and seaweed-supplemented diets—with emphasis on culture technologies aimed at enhancing the health and sustainability of aquaculture systems and nutritional content of farmed species, particularly through the integration of low trophic species and seaweeds.

PILOT SCALE *ULVA* BIOREMEDIATION OF DIFFUSE SOURCE NUTRIENTS IN A NEW ZEALAND ESTUARY

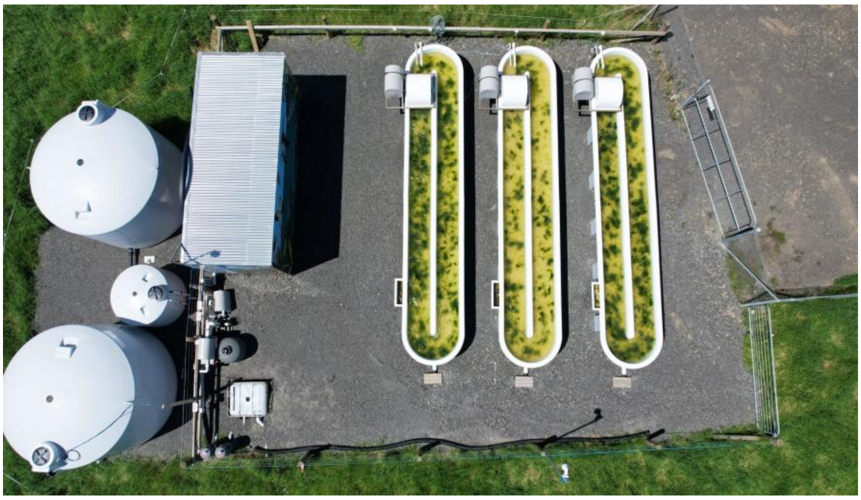
MAGNUSSON M.[1], GLASSON C.[1]

[1] Te Aka Mātuatua - School of Science, University of Waikato, New Zealand
E-mail: marie.magnusson@waikato.ac.nz

Abstract

Terrestrial run-off has resulted in nutrient (e.g. nitrogen and phosphorus) enrichment of rivers and adjacent marine ecosystems in New Zealand, with risk of significant environmental harm. However, an opportunity exists to recover and re-use some of these nutrients using a land-based algal bioremediation strategy. Seaweed based bioremediation is used commercially for point-source discharges elsewhere, e.g. from land-based aquaculture, but there is limited evidence of the efficacy of this approach for remediating diffuse source nutrients in a warm-temperate climate.

To test this, we designed and commissioned a pilot-scale aquaculture pond system suitable for the land-based cultivation of *Ulva* seaweed (sea lettuce) for the bioremediation of diffuse source nutrients from the Waihou River estuary on the North Island of New Zealand. We isolated and scaled up a locally present species of *Ulva*, *Ulva australis*, at our University farm, where we maintained broodstock and scaled up biomass for inoculating the three 10m raceway ponds at the test site. We then quantified seasonal performance of biomass productivity and bioremediation capacity (nutrient removal) over seasonal growth periods during 2022-2023. The ponds were managed with weekly harvests at stocking densities of 0.5, 1.0, and 1.5 g fresh weight *Ulva* L-1, and water flow rates of 2.4, 3.6, and 4.8 pond volumes day-1 using a 2-level 2-factor blocked design with replicated centre points. On average per seasonal block, seaweed ponds removed 70% to 86% of the dissolved nitrogen (NOx-N) and up to 70% of dissolved phosphorous (as PO4-P) from the in-flow water taken from the Waihou River. Productivities (seaweed growth) were excellent during the warmer months, producing over 100kg of seaweed from this relatively small pilot system per month, with somewhat lower growth in the cooler months, as expected. Overall, the project demonstrated the potential for year-round land-based seaweed production and continuous nutrient removal in conditions of ambient sunlight, water temperatures, and availability of nutrients for growth in a rural setting.


.

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
Funded by the European Union

Acknowledgments

This project was a collaboration between the University of Waikato and AgriSea Ltd. who also provided funding, supported by the Ministry for Primary Industries Sustainable Food and Fibre Futures fund (MPI SFFF), the Agricultural and Marketing Research and Development Trust (AGMARDT), and the Hauraki & Thames-Coromandel District Council, Te Waka, Veolia, and PWC, with the blessing of local Iwi.

Short Biography of the speaker

I am a phycologist and lead a multidisciplinary research group at the University of Waikato's Tauranga campus, delivering fundamental and applied science underpinning NZ's emergent seaweed aquaculture sector. I have a passion for using science and seaweed to develop practical and sustainable solutions for communities and diverse environmental and primary industry sectors. I led the commissioning of our University pilot scale recirculating algal aquaculture farm licensed for commercial transfers of seaweed stock to support the research and its technology transfer. My team and I have developed and established seaweed hatcheries, farming methods for local species, and a culture collection of key seaweed aquaculture targets for NZ. Current work focusses on seaweed microbiomes, and the application of seaweed sulfated polysaccharides as elicitors of plant immunity to develop horticultural crop protection products.

Funded by the European Union

PHOTOSYNTETIC AND GROWTH ACCLIMATION OF *ULVA LACINULATA* TO EUTROPHIC THESSALONIKI BAY (GREECE): AN INTEGRATED, MULTILEVER ANALYSIS

MALEA L.[1], NAKOU K.[1], SEITIDOU O.[1], LACHANIDOU G.[1], PAPADIMITRIOU A.[1], ORFANIDIS S.[1]

[1] Fisheries Research Institute (ELGO-DIMITRA), 640 07 Nea Peramos, Kavala, Greece
E-mail: sorfanid@elgo.gr

Abstract

Seaweeds acclimate their photosynthesis and growth to environmental factors to optimize their performance under predictable, seasonal, and unpredictable extreme weather variations [1]. Heat waves and heavy storms will likely become more frequent and intense under the human-induced climate crisis, changing nutrient loadings in coastal habitats [2] and further testing seaweed acclimation potential. Among the seaweeds, fast-growing *Ulva* species can thrive in shallow eutrophic conditions worldwide, with their utility in bioremediation and as a source of valuable products [3]. Understanding the underlying biological mechanisms controlling *Ulva*'s life cycles in nature is fundamental to developing cultivation protocols for these economically important species [4].

We studied *Ulva lacinulata* (Kützing) Wittrock in the eutrophic Thessaloniki Bay, Greece, between June 2019 and March 2021, to study photosynthetic and growth responses to understand species' acclimation strategies at different integrated biological levels, to develop species' sea or land-based mass cultivation protocols. At each sampling effort, while temperature and salinity were recorded by a WTW LF330 portable conductivity meter, 2 l of seawater was collected and transferred by a portable refrigerator in plastic containers to analyze its nutrient content. From each sampled material 18 pieces of *U. lacinulata* thalli were carefully cleaned of epiphytes and selected as replicates (n = 6) for the experiments in the simulation laboratory. While temperature and salinity have been adjusted to field measurement, nutrients (6 µmol/L $N\text{-}NO_3^-$ and 0.06 µmol/L $P\text{-}PO_4^-$) and irradiance (100 µmol photons m^{-2} s^{-1}; 12 h light per 24 hours) were kept constant.

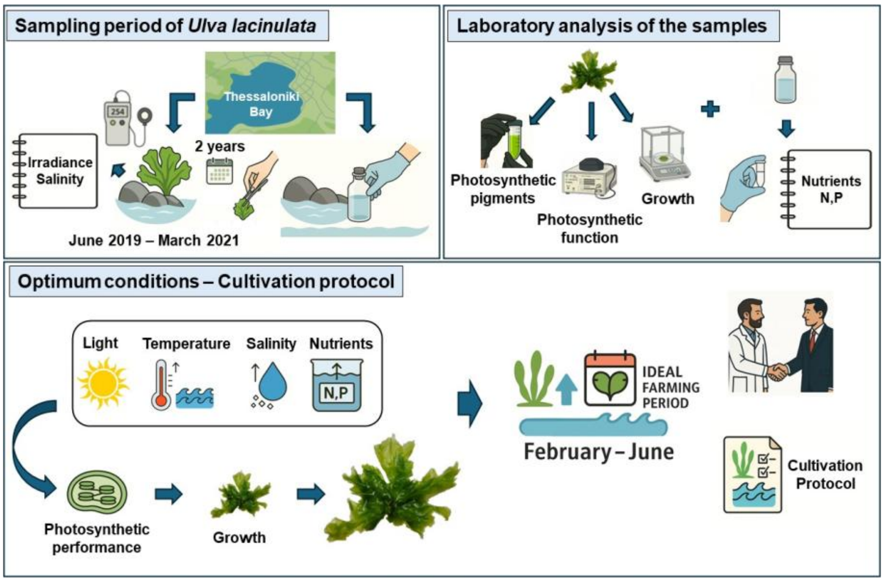
Critical seawater variables were analyzed by using one-way ANOVA and were correlated with biochemical (photo-pigment content), physiological (fast-term JIP-test and slow-term Rapid Light Curve photosynthesis protocols), and organismal (Relative Growth Rate-RGR) species variables by using multivariate analysis (RDA).

In order, nitrates, temperature, and phosphates were the abiotic factors most significantly affected *Ulva*'s photosynthesis and growth, in agreement with other studies [5]. While extreme temperatures during September 2029 triggered photosynthetic changes in PSII structure (photon absorption and trapping), function (electron transport from QA^- to QB), and photopigments composition (chl/carotenoids ratio), heavy rainfall during June 2019 reduced salinity and increased nitrates, lowering *Ulva lacinulata*'s photosynthetic efficiency (alpha), quantum yield (ΦP_0), and active PSII centers (RC/ABS) and increasing energy dissipation (DI_0/RC). Variations in winter-summer temperature and nitrogen-to-phosphate ratio affected photosynthetic performance ($rETR_{max}$, E_k) and productivity (ETR_{max}/NPQ_{max}). As expected [1], seasonal changes and extreme events significantly drove *U. lacinulata*'s physiology. However, they operated on different timescales (fast vs. short photo-acclimation), eliciting different responses.

Unimodal is the typical pattern of *Ulva* spp. [6] and *Ulva lacinulata* [7] growth in temperate coastal waters. It involves a period of biomass accumulation starting in winter or early spring as water temperatures rise and light availability increases, leading to a peak in biomass, usually occurring in late spring or early summer. Late winter and early spring conditions supported the highest

relative growth rates, primarily due to increased nitrogen availability despite moderate irradiance and low temperatures.

Graphical Abstract



References

[1] Hurd, C.L., et al. Seaweed ecology and physiology. *Cambridge University Press*, 2014.
[2] Temino-Boes, R., et al. Future trends of dissolved inorganic nitrogen concentrations in Northwestern Mediterranean coastal waters under climate change. *Journal of Environmental Management*, 2021, *282*, 111739.
[3] Hofmann, L.C., et al. The green seaweed *Ulva*: tomorrow's "wheat of the sea" in foods, feeds, nutrition, and biomaterials. *Critical reviews in food science and nutrition*, 2024, 1-36.
[4] Charrier, B., et al. Furthering knowledge of seaweed growth and development to facilitate sustainable aquaculture. *New Phytologist*, 2017, *216.4*, 967-975.
[5] Kim, K.Y., et al. Physiological ecology and seasonality of *Ulva pertusa* on a temperate rocky shore. *Phycologia*, 2004, *43.4*, 483-492.
[6] Teichberg, M., et al. Eutrophication and macroalgal blooms in temperate and tropical coastal waters: nutrient enrichment experiments with *Ulva* spp. *Global Change Biology*, 2010, *16.9*, 2624-2637.
[7] Orfanidis, S. et al. Deliverable. Research program "Production of bioactive polysaccharides of high added value from macroalgae of the Greek seas and their utilization in the development of innovative biofunctional foods - Bioalgafood". *Technological Development & Innovation "RESEARCH - CREATE - INNOVATE"*, 2022,1- 209.

Acknowledgments

This study was supported by the BIOALGAFOOD project (code: T1EΔK-00232) co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH—CREATE—INNOVATE.

Short Biography of the speaker

Dr. Sotiris Orfanidis, Research Director, is a Marine Botanist with expertise in seaweed ecophysiology and cultivation. His expertise includes the ecology and ecophysiology of macroalgae for their usage as bioindicators of water quality of coastal and transitional waters, the cultivation of macroalgae independently or within multi-trophic aquaculture systems (IMTA), and marine forest restoration. Participated in more than 40 national and European projects and has more than 150 publications, 79 of them in peer-reviewed international journals, one in Nature Communications, as listed in Google Scholar database (h-index = 31, i-10 = 61). He is also a reviewer for international journals and conferences and a member of the editorial board of Mediterranean Marine Science, Water and Frontiers in Marine Science.

REGULATION OF *ULVA* SPORULATION AS PART OF A CULTIVATION STRATEGY: WHAT DO WE KNOW?

MALTA E.-j.[1], ASNAGHI V.[2], BOLTON J.J.[3], CARDOSO I.[4], CASTELAR B.[2], REBOURS C.[5], SULPICE R.[6], BERMEJO R.[7], PEREIRA R.[8]

[1] Department of Applied Research, Aquaculture Technology Centre, CTAQUA, El Puerto de Santa María, Spain
[2] DiSTAV, Department of Earth, Environment and Life Sciences, University of Genoa, Genoa, Italy
[3] Department of Biological Sciences, University of Cape Town, South Africa
[4] Seaweedland, Heerhugowaard, The Netherlands
[5] Møreforsking AS, Ålesund, Norway
[6] School of Biological and Chemical Sciences, University of Galway, Galway, Ireland
[7] Facultad de Ciencias, Universidad de Málaga, Málaga, Spain
[8] A4f Algafuel Sa, Lisbon, Portugal
E-mail: e.malta@ctaqua.es

Abstract

One of the principal conclusions of the Seawheat workshop “From *Ulva* aquaculture to food and feed production: state-of-the-art, bottlenecks, risks and gaps” (Lisbon, 23-24 May 2023) was that one of the main challenges preventing the development of *Ulva* cultivation in Europe is its financial cost. This relates to all parts of the production phase and all types of production systems (e.g., monoculture, integrated) at sea or on land. Sporulation is one of the key parts of the production cycle.

In land-based cultivation systems using vegetative propagation (currently the dominant commercial cultivation model), spontaneous sporulation, fragmentation or protoplast formation might result in important loss of biomass, depending on the species or strain. For sea-based cultivation on longlines, sporulation is essential in developing a labour extensive cultivation process. In addition, sporulation is important in the process of strain selection and to maintain genetic diversity in vegetatively growing material. Hence, achieving control of the sporulation process, or the production of other initial phases of individuals, such as biomass is of great importance for upscaling commercial *Ulva* cultivation.

The life-cycle of *Ulva* is typical for many green algae (alternance of gametophytes and sporophytes), however, many short-cuts and alternative routes have been observed in laboratory situations. The plasticity in the reproduction mode is species or even strain specific and the triggers are largely unknown. In this presentation, the state of the art of knowledge for reproduction control of *Ulva* will be summarised and discussed. Main focus will be on the role of sporulation inhibiting factors, their chemical identification, and how they regulate the reproduction process.

Based on this knowledge, developed in the last two decades, a general protocol for sporulation has been developed and some specific methods have been identified for individual species or strains, which is part of the objective for task 2.2 of WP2 “*Ulva* in Aquaculture” of this COST action. In addition, potential alternatives to sporulation, such as protoplast development (incl. spontaneous events of protoplast development) will be discussed.

Acknowledgments

CR: Research Council of Norway (319577).

Short Biography of the speaker

Erik-jan Malta PhD, is Chief Scientific Officer and researcher seaweed cultivation and sustainable aquaculture at the Aquaculture Technology Centre (CTAQUA), Spain. A biologist by training, Erik has more than 25 years of international research experience in marine ecosystem and seaweed ecology, seaweed cultivation and applications and sustainable aquaculture systems as Integrated Multitrophic Aquaculture (IMTA). He has been PI of several research projects in Spain and Portugal and is coordinator of the Interreg Atlantic Area project AQUAFISH0.0 and collaborator and in various other past and present EU funded projects. He has published >25 papers in peer-reviewed journals (H-index = 19) as well as contributions to book chapters and various technical reports. He is research topic co-editor of the journal Frontiers in Marine Science and member of the Scientific Committee of the European Algal Biomass Association (EABA).

MACROALGAE-DERIVED COMPOUNDS AGAINST CARDIOVASCULAR AND NEURODEGENERATIVE DISEASES

MARTENS N.[1, 2], ZHAN N.[1, 3], YAM S.C.[1], LEIJTEN F.P.J.[1], PALUMBO M.[4], CASPERS M.[5], TIANE A.[2, 6], FRIEDRICHS S.[7], LI Y.[1, 8, 9], VAN VARK-VAN DER ZEE L.[1], VOORTMAN G.[1], ZIMETTI F.[4], JAARSMA D.[10], VERSCHUREN L.[5], JONKER J.W.[11], KUIPERS F.[11, 12], LÜTJOHANN D.[8], VANMIERLO T.[1, 2, 6], MULDER M.T.[1]

[1] Department of Internal Medicine, Section Pharmacology and Vascular Medicine, Erasmus University Medical Center, 3015 CN Rotterdam, The Netherlands.
[2] Department of Neuroscience, Biomedical Research Institute, Faculty of Medicine and Life Sciences, Hasselt University, B-3590 Hasselt, Belgium.
[3] Key Laboratory of Marine Drugs, Chinese Ministry of Education, School of Medicine and Pharmacy, Ocean University of China, Qingdao 266003, China.
[4] Department of Food and Drug, University of Parma, 43124 Parma, Italy.
[5] Department of Microbiology and Systems Biology, The Netherlands Organization for Applied Scientific Research (TNO), 2333 BE Leiden, The Netherlands.
[6] Department Psychiatry and Neuropsychology, Division Translational Neuroscience, Mental Health and Neuroscience Institute, Maastricht University, 6200 MD Maastricht, The Netherlands.
[7] Institute of Clinical Chemistry and Clinical Pharmacology, University Hospital Bonn, D-53127 Bonn, Germany.
[8] Department of Immunology, Erasmus University Medical Center, 3000 CA Rotterdam, The Netherlands.
[9] Department of Ophthalmology, Erasmus University Medical Center, 3015 GD Rotterdam, The Netherlands.
[10] Department of Neuroscience, Erasmus University Medical Center, 3015 CN Rotterdam, The Netherlands.
[11] Department of Pediatrics, Section of Molecular Metabolism and Nutrition, University of Groningen, University Medical Center Groningen, 9713 GZ Groningen, The Netherlands.
[12] European Research Institute for the Biology of Ageing (ERIBA), University of Groningen, University Medical Center Groningen, 9713 AV Groningen, The Netherlands.
E-mail: m.t.mulder@erasmusmc.nl

Abstract

We previously demonstrated that diet supplementation with seaweed *Sargassum fusiforme* (*S. fusiforme*), its lipid extract or pure 24(S)-saringosterol could prevent cognitive decline and neuropathology in a mouse model of Alzheimer's Disease (AD) [1-2]. Moreover, the *S. fusiforme* lipid extract could prevent cardiovascular disease (CVD). We tested a lipid extract of European seaweed *Himanthalia elongata* (*H. elongata*). Diet supplementation with *H. elongata* extract prevented cognitive deterioration in APPswePS1ΔE9 mice [3]. The cerebral amyloid-β plaque load remained unaffected. However, IHC analysis revealed that the extract lowered glial markers in the brains of APPswePS1ΔE9 mice. While cerebellar cholesterol concentrations remained unaffected, both extracts increased desmosterol, an endogenous LXR agonist with anti-inflammatory properties. The *H. elongata* extract increased cholesterol efflux and decreased the production of pro-inflammatory cytokines in LPS-stimulated THP-1-derived macrophages. Additionally, our findings suggest a reduction of AD-associated phosphorylated tau and promotion of early oligodendrocyte differentiation by *H. elongata*. RNA sequencing on the hippocampus of one-week-treated APPswePS1ΔE9 mice revealed effects of *H. elongata* on, amongst others, acetylcholine and synaptogenesis signaling pathways. In conclusion, an extract of *H. elongata*

shows potential to reduce AD-related pathology in APPswePS1ΔE9 mice. Increasing desmosterol concentrations may contribute to these effects by dampening neuroinflammation.

References

[1] Bogie J, Hoeks C, Schepers M, Tiane A, Cuypers A, Leijten F, Chintapakorn Y, Suttiyut T, Pornpakakul S, Struik D, Kerksiek A, Liu HB, Hellings N, Martinez-Martinez P, Jonker JW, Dewachter I, Sijbrands E, Walter J, Hendriks J, Groen A, Staels B, Lütjohann D, Vanmierlo T, Mulder M. Dietary Sargassum fusiforme improves memory and reduces amyloid plaque load in an Alzheimer's disease mouse model. *Sci Rep*. 2019, 9, 4908.
[2] Martens N, Schepers M, Zhan N, Leijten F, Voortman G, Tiane A, Rombaut B, Poisquet J, Sande NV, Kerksiek A, Kuipers F, Jonker JW, Liu H, Lütjohann D, Vanmierlo T, Mulder MT. 24(S)-Saringosterol Prevents Cognitive Decline in a Mouse Model for Alzheimer's Disease. *Mar Drugs*. 2021,19, 190
[3] Martens N, Zhan N, Yam SC, Leijten FPJ, Palumbo M, Caspers M, Tiane A, Friedrichs S, Li Y, van Vark-van der Zee L, Voortman G, Zimetti F, Jaarsma D, Verschuren L, Jonker JW, Kuipers F, Lütjohann D, Vanmierlo T, Mulder MT. Supplementation of Seaweed Extracts to the Diet Reduces Symptoms of Alzheimer's Disease in the APPswePS1deltaE9 Mouse Model. *Nutrients.* 2024, 16, 1614

Acknowledgments

This research was funded by the Dutch Research Council (NWO-TTW; #16437), the Alzheimer Nederland and Alzheimer Forschung Initiative (#AFI-18024CB, #AFI-22034CB, #WE.03-2018-06 AN and #WE.03-2022-06, and #WE.15-2021-08), the Ministry of University and Research (MUR), National Recovery and Resilience Plan (NRRP), project MNESYS (PE0000006), a multiscale integrated approach to the study of the nervous system in health and disease (DN. 1553 11.10.2022).

Short Biography of the speaker

Dr Mulder is Associate Professor and head of the Laboratory of Vascular Medicine at the Department of Internal Medicine. Her laboratory focusses on obtaining insight into the role of lipid and sterol metabolism in the onset and progression of cardiometabolic and neurodegenerative diseases.
Because numerous age-related diseases are associated with altered lipid fluxes, we aim at modulation of lipid/lipoprotein metabolism to prevent or slow down disease progression. Our research focusses, among others, on liver X receptor-activation, using marine-derived compounds for preventing the progression of Alzheimer’s disease in a long standing collaboration with the University Hasselt, University Clinics Bonn, UMC Groningen.

SeaWheat
COST Action CA20106

אוניברסיטת חיפה
University of Haifa
جامعة حيفا

SEAWEED-DERIVED BIOACTIVES: HARNESSING OCEAN-DERIVED COMPOUNDS FOR SUSTAINABLE CROP IMPROVEMENT

MCKENNA S.[1], DA SILVA PEREIRA H.[1], GUERINEL Y.[1], FORT A.[1]

[1] Department of Bioveterinary and microbial Sciences, TUS: Midlands, Athlone, Ireland.
E-mail: antoine.fort@tus.ie

Abstract

The rising demand for sustainable agricultural practices requires solutions that stimulate crop productivity without compromising our ecosystems. One of those solutions lie in the use of seaweed-derived bioactives, which have emerged as potent biostimulants capable of enhancing plant growth, stress tolerance and soil health.

Seaweeds synthesize a broad spectrum of bioactive molecules including polysaccharides (e.g., alginates, carrageenans, *Ulva*ns), polyphenols, betaines, and plant hormone analogues such as cytokinins, auxins, and abscisic acid. These compounds, when applied to crops have been shown to improve various agronomical traits such as germination rates, root and shoot development, and increased resistance to (a)biotic stresses. Among the possible mechanistic action of seaweed bioactives, gene expression associated with stress defence pathways, as well as improvements in nutrient uptake efficiency, have been documented following treatment with some seaweed extracts, indicating a possible priming of plant physiological responses. Lastly, the application of seaweed-derived bioactives can also impact the soil microbiome, which can lead to a modulation of agronomical performance as well as soil health in general.

While seaweed-derived crop bioactivities have been studied with some depth, another potential source of crop-acting bioactives could originate from the seaweed-associated microbiome (SAM). Indeed, the SAM has been shown to produce a plethora of compounds that could impact crop productivity. Those include phytohormones, antimicrobial compounds or defence elicitors that could be used to prime the crop's pathogen response pathways, triggering a response similar to seaweed biostimulants themselves. Despite this potential, actual uses of SAM-bioactives on crops have not been thoroughly investigated. In order to bridge that gap, our research focuses on the isolation and characterisation of the epi- and endophytic microbes associated with seaweed species present in Ireland. High-throughput screens for bioactivities on crops have been designed to quickly identify extracts, pools and fractions containing crop-acting bioactives, to be followed by compound characterisation and elucidation of their mode of action.

By systematically isolating and screening microbial communities from diverse Irish seaweed species, we aim to expand the current biostimulant toolbox beyond seaweed-derived molecules to include microbially-sourced bioactives. This dual approach not only enhances our understanding of the seaweed holobiont systems but also lays the groundwork for developing novel biostimulants formulations. Ultimately, integrating seaweed and SAM-derived bioactives into crop management strategies holds significant promise for advancing sustainable and resilient agricultural practices.

References

[1] Family Name, A. et al. Coffee melanoidins: structures, mechanisms of formation and potential health impacts. *Food Funct.* 2012, *3*, 903.

Acknowledgments

The authors would like to acknowledge funding from Research Ireland (AMicrobioM project, grant #22/FFP-P/11555)

Short Biography of the speaker

Antoine Fort graduated with a MSc in Plant Biotechnology from Bordeaux University, France, in 2010 and later on obtained his PhD in NUI Galway on the theme of crop improvement through genetic engineering in 2013. This was followed by several post-doctoral positions, where Antoine worked on a variety of organisms ranging from crops, seaweeds, invertebrates and microbes. Antoine's expertise and research work is multidisciplinary in nature and ranges from "omics" (genomes, transcriptomes, proteomes & metabolomes) to cas9 genome editing and molecular ecology. After his work on seaweeds physiology in the University of Galway as postdoctoral researcher, he joined the Technological University of the Shannon as a lecturer in 2021. His current research interests are focused on the discovery of novel bioactives from the seaweed microbiome, funded through a Research Ireland Frontiers for the Future project

ULVA CAROTENOIDS: STUDIES ON THEIR BIOACCESSIBILITY AND GREEN EXTRACTION WITH EMERGING BIOSOLVENTS

MENCHACA-MARTÍNEZ DE[1], STINCO CM[1], BENÍTEZ-GONZÁLEZ AM[1], MORÓN-ORTIZ A[1], MAPELLI-BRAHM P[1], ROMERO A[2], MELÉNDEZ-MARTÍNEZ AJ[1]

[1] Food Colour and Quality Laboratory, Facultad de Farmacia, Universidad de Sevilla, 41012, Sevilla, Spain.
[2] Chemical Engineering Department, Faculty of Chemistry, Universidad de Sevilla, 41012 Sevilla, Spain.
E-mail: ajmelendez@us.es

Abstract

Ulva (sea lettuce) is a genus of green seaweeds long known as a source of compounds of interest to the agri-food industry and others (pharma, cosmetics, biomaterials). They are sources of carotenoids, including the ones present in the human macula lutea, above all lutein. These are versatile compounds of great interest as components of diverse products intended for human consumption, such as functional foods, nutricosmetics or supplements. Studies on the potential bioavailability (bioaccessibility) and extraction of carotenoids from algae in general and *Ulva* in particular are very timely considering the global challenge of producing healthier and more sustainable foods and associated policies and concepts, such as the Green Deal, the Blue Economy or the Circular Economy [1–3]. In this work, the main outcomes of recent studies of our group on these topics are presented.

In one of these studies, ultrasound pre-treatment conditions were optimized in order to enhance the macular carotenoids bioaccessible content (CBC, an estimation of potential bioavailability) of *Ulva lactuca*. Sea lettuce (kindly donated by Porto-Muíños S.L., Spain) was desalted, freeze-dried, ground and sieved. To optimize the sonication conditions, response surface methodology (RSM) was applied and a central composite design (CCD) was performed. The ratio sample: distilled water was 1g/ 40 mL. The parameters tested were amplitude (20–50%) and time (1–5 min). After the treatments, the solids were recovered and subjected to a consensus in vitro gastrointestinal digestion [4]. The micellar fractions were analyzed by RRLC-DAD [5]. The results indicated that the sonication conditions tested can significantly influence ($p < 0.05$) the macular CBC from the seaweed. The optimal conditions for maximising bioaccessibility were the use of an amplitude of 45% for 1 minute, which led to a 1.3-fold increase relative to the untreated control.

In another study, the efficacy of two green technologies, microwave-assisted extraction (MAE) and ultrasound-assisted extraction (UAE) in the extraction of *Ulva* carotenoids was evaluated. For this purpose, traditional food-grade solvents (acetone, ethanol, ethyl acetate, and hexane) were compared with emerging biosolvents such as 2-methyltetrahydrofuran (MeTHF) and ethyl lactate. Dehydrated *U. lactuca* was ground for 5 minutes at a frequency of 30 Hz at a sample:solvent ratio of 1:20. The conditions for UAE were 30% amplitude, 20 kHz frequency and 2 minutes of treatment. Those for MAE were 300 W of power for 5 minutes. The levels of carotenoids in the extracts were analyzed by RRLC-DAD [5]. The data revealed that the efficiency of UAE varied as a function of the carotenoids and the physicochemical properties of the solvents. In general, this intensification technology led to significantly ($P < 0.05$) higher contents of individual carotenoids with all evaluated solvents. Significant increases in the levels of total carotenoids were observed compared to the control and the UAE treatment regardless of the extraction solvent.

Hexane and MeTHF were the most effective solvents for total carotenoid extraction, with no significant differences between them. MeTHF appears as a sustainable, environmentally friendly

alternative compared to other conventional solvents used for carotenoid extraction, notably hexane, which is very toxic and petroleum-derived [6].

References

[1] Hofmann LC et al. The green seaweed *Ulva*: tomorrow's "wheat of the sea" in foods, feeds, nutrition, and biomaterials. *Crit Rev Food Sci Nutr* 2024; 1–36.
[2] Mapelli-Brahm P et al. Microalgae, Seaweeds and Aquatic Bacteria, Archaea, and Yeasts: Sources of Carotenoids with Potential Antioxidant and Anti-Inflammatory Health-Promoting Actions in the Sustainability Era. *Mar Drugs* 2023;21:340.
[3] Meléndez-Martínez AJ et al. Carotenoids: Considerations for their Use in Functional Foods, Nutraceuticals, Nutricosmetics, Supplements, Botanicals and Novel Foods in the Context of Sustainability, Circular Economy and Climate Change. *Annu Rev Food Sci Technol* 2021;12:433–460.
[4] Brodkorb A et al. INFOGEST static in vitro simulation of gastrointestinal food digestion. *Nat Protoc* 2019;14:991–1014.
[5] Stinco CM et al. Simultaneous determination of dietary isoprenoids (carotenoids, chlorophylls and tocopherols) in human faeces by Rapid Resolution Liquid Chromatography. *J Chromatogr A* 2019;1583:63–72.
[6]Morón-Ortiz A et al. Sustainable Green Extraction of Carotenoid Pigments: Innovative Technologies and Bio-Based Solvents. *Antioxidants* 2024;13: 239.

Acknowledgments

This study was financially supported by grants PID2022-140995OB-C22 (SUSHEALTHCARICH) funded by MICIU/AEI/ 10.13039/501100011033 and ERDF/EU. In addition, PMB was supported by a posdoc fellowship from Consejería de Transformación Económica, Industria, Conocimiento y Universidades de la Junta de Andalucía (PAIDI 2020). AMO was supported by a grant associated to grant PID2019-110438RB-C21 (NEWCARFOODS). DEMM, AJMM, PMB and AMO are members of the Spanish Carotenoid Network (CaRed), grant RED2022-134577-T, funded by MCIN/AEI/10.13039/501100011033. This article is based upon work from COST Action SEAWHEAT (CA20106, https://seawheatcost.haifa.ac.il/), supported by COST (European Cooperation in Science and Technology).

Short Biography of the speaker

Prof. Meléndez-Martínez is a Stanford University's World's 2% Scientist since 2020. His main research interest deals with the sustainable production of health-promoting foods, with a strong focus on carotenoids in the context of agro-food, health and cosmetics. He coordinated two large international networks, one Iberoamerican (CYTED-IBERCAROT) and another European (COST Action EUROCAROTEN). Some awards and recognitions: 1) Extraordinary Prize of Doctorate; 2) International Carotenoid Society (ICS) George Britton Award for Young Researcher; 3) Fellow of the ICS; 4) Manuel Losada Award to Excellence in Agro-food Research; 5) Iberoamerican Academy of Pharmacy Award; 6) Stanford University's World's 2% Scientist; 7) Induction into the scientific honour society Sigma Xi (USA).

COMPARATIVE ANALYSIS OF GROWTH, BIOCHEMICAL COMPOSITION, QUALITY, AND BIOREMEDIATION POTENTIAL OF *ULVA* SP. AND *GRACILARIA* SP. CULTIVATED IN PHOTOBIOREACTORS WITH DIFFERENT CULTURE MEDIA

MOCCIA D.[1 *], PASQUINI V.[1], MILIA M.[1], BIANCACCI C.[2], LEDDA C.[3], ANGIONI A.[1], ADDIS P.[1], PUSCEDDU A.[1]

[1] University of Cagliari, Department of Life and Environmental Science, Cagliari, Italy, 09100
[2] Cawthron Institute, Aquaculture Department, 139 Glen Rd, Glenduan, Nelson 7071, New Zealand
[3] Livegreen Società Agricola S.r.l., Vico Episcopio 12, 09170 Oristano, Italy

E-mail: Davide Moccia, mocciadavide@unica.it

Abstract

The cultivation of marine macroalgae is increasingly recognized as a sustainable solution to address global challenges in food security, climate change mitigation, and the development of a circular bioeconomy. Beyond serving as sources of alternative protein and bioactive compounds, macroalgae provide essential ecosystem services such as nutrient recovery and carbon sequestration. This study assessed and compared the growth, biochemical composition, and nutrient uptake of *Ulva sp.* and *Gracilaria sp.* cultivated in cylindrical indoor photobioreactors with four culture media: untreated lagoon water (WL), lagoon water enriched with anaerobic digestate (WD), lagoon water enriched with effluent from sea urchin aquaculture (WU), and lagoon water enriched with synthetic F/2 medium (WF/2).

Our results revealed that *Gracilaria* achieved its highest specific growth rate (SGR) in WU (9.45 ± 0.40% day^{-1}), outperforming *Ulva* in nutrient-poor conditions (WL and WU), while *Ulva* showed more consistent performance across treatments, with the highest growth rate in WF/2 (8.10 ± 0.75% day^{-1}). The biochemical profiles of the two species differed markedly: *Gracilaria* exhibited significantly higher levels of protein (up to 17.97 ± 2.77% DW in WF/2), carbohydrates (70.37 ± 7.63% DW in WL), and lipids (notably in WU). By contrast, *Ulva* consistently exhibited significantly higher concentrations of pigments—including chlorophyll-a, chlorophyll-b, and polyphenols—as well as higher fiber content across all treatments. In terms of bioremediation, *Ulva* consistently demonstrated greater nutrient uptake efficiency (NUE) and nutrient uptake rates (NUR), for total phosphorus in all treatments, while *Gracilaria* showed greater nitrate uptake in the WL and WD treatments.

This study shows how different nutrient sources affect biochemical composition, growth, and biomass quality, and underscores the complementary potential of the two species: *Ulva* excels in rapid nutrient removal and pigment-rich biomass production, while *Gracilaria* offers higher yields of protein and carbohydrates. Their combined use in multispecies cultivation systems could enhance year-round biomass production, diversify product applications, and improve the ecological resilience of macroalgae cultivation systems. The results provide a valuable foundation for optimizing high-value macroalgae cultivation strategies under controlled indoor conditions.

Acknowledgments

This research was financially supported by the project Marine Macroalgae for eco-TECHnological applications and marine REStoration [M2TECHRES], funded by the Italian Ministry of Research under the PON "Research and Innovation" 2014-2020 Program (D.M. 1062 del 10.08.2021; CUP F25F21002260003).

Short Biography of the speaker

Over the past three years, my research has focused on the study of macroalgae, with particular emphasis on how their biochemical profiles vary in response to different environmental conditions, including marine heatwaves and eutrophication. I have explored how these stressors influence the composition and of valuable metabolites such as phytopigments, proteins, carbohydrates and lipids. In parallel, I have investigated the application of algal photobioreactors as a sustainable strategy for mitigating excess nutrient loads in aquatic systems, while simultaneously producing biomass suitable for the extraction of high-value biochemical compounds.
Additionally, my work has involved the extraction, quantification, and characterization of bioactive compounds from several native macroalgal species, such as *Ulva sp*., as well as from invasive or alien species including *Asparagopsis taxiformis* and *Caulerpa spp*. My research aims to support the development of integrated bioremediation and biorefinery approaches that promote both environmental sustainability and the valorization of algal biomass in biotechnology**.**

NUTRIENT REMEDIATION AND BIOMASS PRODUCTION OF *ULVA* SPP. IN AN IMTA SYSTEM WITH SEA URCHIN *PARACENTROTUS LIVIDUS*

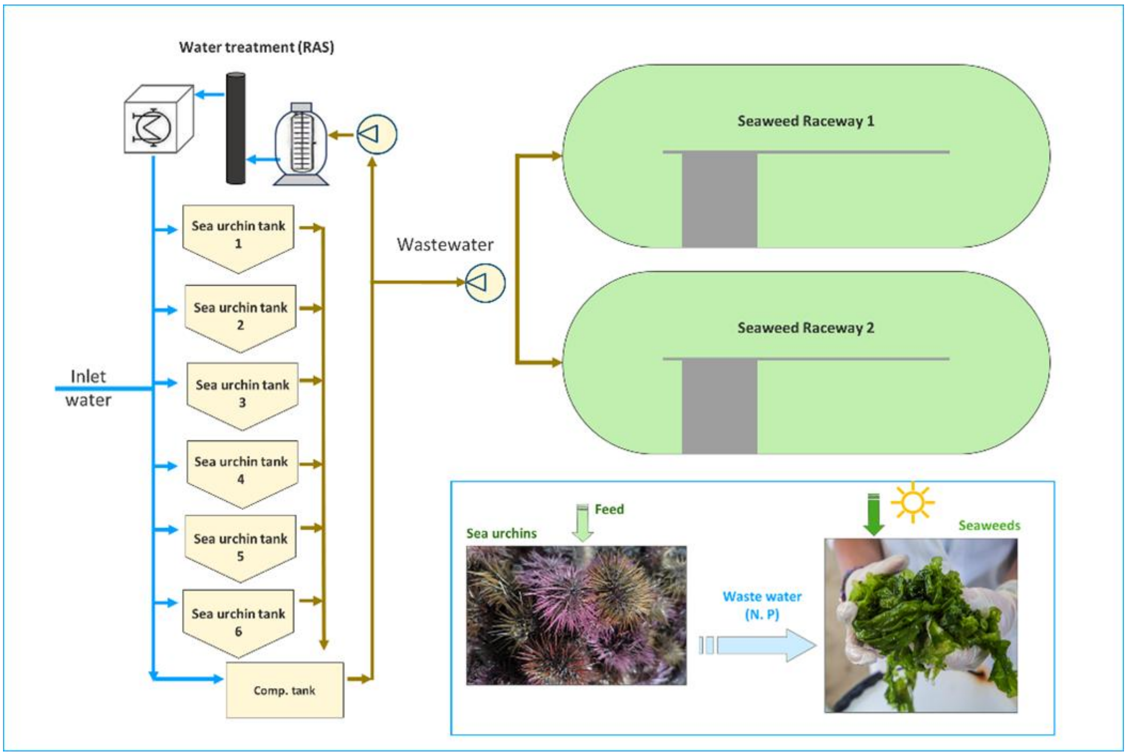
PASQUINI V. [1*], MOCCIA D. [1], MAXIA M. [2], ADDIS P[1].,

[1]Department of Life and Environmental Science, University of Cagliari
[2] Agris, Agricultural Research Agency of Sardinia, Loc. Bonassai S.S. 291 Sassari-Fertilia—Km. 18,600,07100 Sassari
E-mail: viviana.pasquini@unica.it

Abstract

Integrated Multi-Trophic Aquaculture (IMTA) is a kind of co-culture where different species belonging to different trophic levels, such as fish, seaweeds, and shellfish are produced together. IMTA seeks to biodiversify fed aquaculture (e.g. finfish or shrimps) with extractive aquaculture, recapturing the inorganic (e.g. seaweeds) and organic (e.g. suspension- and deposit-feeders) nutrients from fed aquaculture for their growth (Chopin et al., 2012). The combination of fed/extractive aquaculture aims to engineer food production systems providing both biomitigative services to the ecosystem and improved economic farm output through the co-cultivation of complementary species (Chopin et al., 2012). IMTA systems offer a sustainable approach to aquaculture by co-cultivating species from different trophic levels, allowing nutrient recycling and economic benefit from the diversification of the productions. In this study, we evaluated the performance of *Ulva* sp. With foliose morphology as an extractive species in an IMTA system with the sea urchin *Paracentrotus lividus* as the fed level. The experimental setup involved culturing *P. lividus* under controlled conditions (20°C) in V shaped Tank and fed with defrosted wild sea lettuce collected from the Santa Gilla Lagoon (Sardinia, Italy). *Ulva* sp. was concurrently cultivated in 2700L raceway provided with paddle wheel and artificial light (24h) to absorb the inorganic nutrients released through urchin excretion. Every week the water from the sea urchin tank is transferred to the raceway where Ulva growth. The nutrient absorption by *Ulva* sp. was estimated each week for one month.
Water quality parameters (ammonium, nitrate, nitrite and phosphate) were monitored weekly, alongside with *Ulva* sp. biomass growth and nutrient uptake efficiency. Results demonstrated that Ulva exhibited significant growth rates (20%) and effectively reduced inorganic nutrient concentrations (90 to 99% of nitrate), indicating efficient biofiltration capacity. These findings support the integration of Ulva in IMTA systems as a viable strategy for nutrient bioremediation and increased sustainability in echinoderm aquaculture.

Graphical Abstract



References

Chopin, T. et al. Open-water integrated multi-trophic aquaculture: environmental biomitigation and economic diversification of fed aquaculture by extractive aquaculture. *Rev Aquac* 2012, 4, 209–220

Acknowledgments

This work has been developed within the framework of the project e.INS www.einsardinia.eu (Next Generation EU- PNRR - M4 C2 I1.5 CUP F53C22000430001.

Short Biography of the speaker

My research focuses on the study of commercially important marine invertebrates, such as sea cucumbers and sea urchins. For years, I have been working on developing aquaculture protocols for these species, designing innovative solutions in pilot-scale facilities.
Currently, I am a researcher within the eINS project where I am involved in the development of a pilot integrated multi-trophic aquaculture (IMTA) system. This approach aims to move beyond monocultures, diversifying production and repurposing waste products in line with circular economy principles. At the same time, I am studing the use of algal photobioreactors to reduce excess nutrient loads and utilize the produced biomass for the extraction of bioactive compounds or the formulation of plant-based feeds for aquaculture, particularly for emerging species.

Funded by the European Union

INNOVATIONS IN LAND-BASED SEAWEED AQUACULTURE

PEREIRA R.[1], SOUSA P.[2], VAZ P.[2], FREITAS D.[2]

[1] A4F Algae for Future, Centre for Innovation in Macroalgae, Lisbon, Portugal
[2] Green Aqua Vagos Lda, Vagos, Portugal
E-mail: rui.pereira@a4f.pt

Abstract

Innovations in seaweed aquaculture and particularly in land-based systems, are rapidly transforming the industry, offering new solutions for food security, environmental sustainability, and industrial applications. Recent research highlights advances in cultivation technologies, integrated systems, and the development of value-added products, positioning seaweed as a key player in the global bioeconomy and climate change mitigation efforts. Some examples of technological advancements include: industry 4.0 and automation, Infrastructure innovations, integrated multi-trophic aquaculture. The combination of these is can also be a reality in the near future and not only enhance productivity and economic viability but also deliver substantial environmental benefits, positioning seaweed as a cornerstone of sustainable aquaculture and the global bioeconomy.

Acknowledgments

The author acknowledges project INNOQUA (proj. ref.101084383) and its partners for supporting this participation.

Short Biography of the speaker

Presently the Director of the Centre for Innovation in Macroalgae at A4F – Algae for Future, a Portuguese company with more than 15 years of experience in the field of algae biotechnology. Trained as a Biologist, completed his PhD in 2004, working on the life-cycle of North Atlantic Porphyra and, after a typical research career, moved to the business world in 2012. Co-founded ALGAplus, where he stayed until 2020. As researcher, including also the years within the business field, accumulates the experience of participation in >20 national and international projects, published several book chapters and >40 scientific papers in peer reviewed journals. Current professional roles also include serving as member of the Portuguese committee for standardization of algae and algae products (CT211 and CENTC454); member of the industrial committee of the European Algae Biomass Association (EABA); leading WG02 – *Ulva* in aquaculture - of the Cost Action SeaWheat; leading WP2 of the European project INNOAQUA; serving as board member of the Kelp Ark (non-profit) organization.

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
Funded by the European Union

STUDYING BACTERIAL INTERACTIOS IN *ULVA* WITH APLICATION IN INTEGRATED MULTITROPHIC AQUACULTURE: A COLLABORATIVE RESEARCH WITHIN *SEAWHEAT* COST ACTION

PINTADO J.[1], QUI-MINET Z.[1], BRUNI L.[1], DEL OLMO G.[1], WICHARD T.[5], ENGELEN A.[3], AIRES T.[3], SULPICE R.[6], ROSIGNOLI S.[6], BIBI F.[6], GARCIA-CARDESÍN E.[2], PÉREZ-GONZÁLEZ A.[2], LASTRES M.[4], CREMADES J.[2]

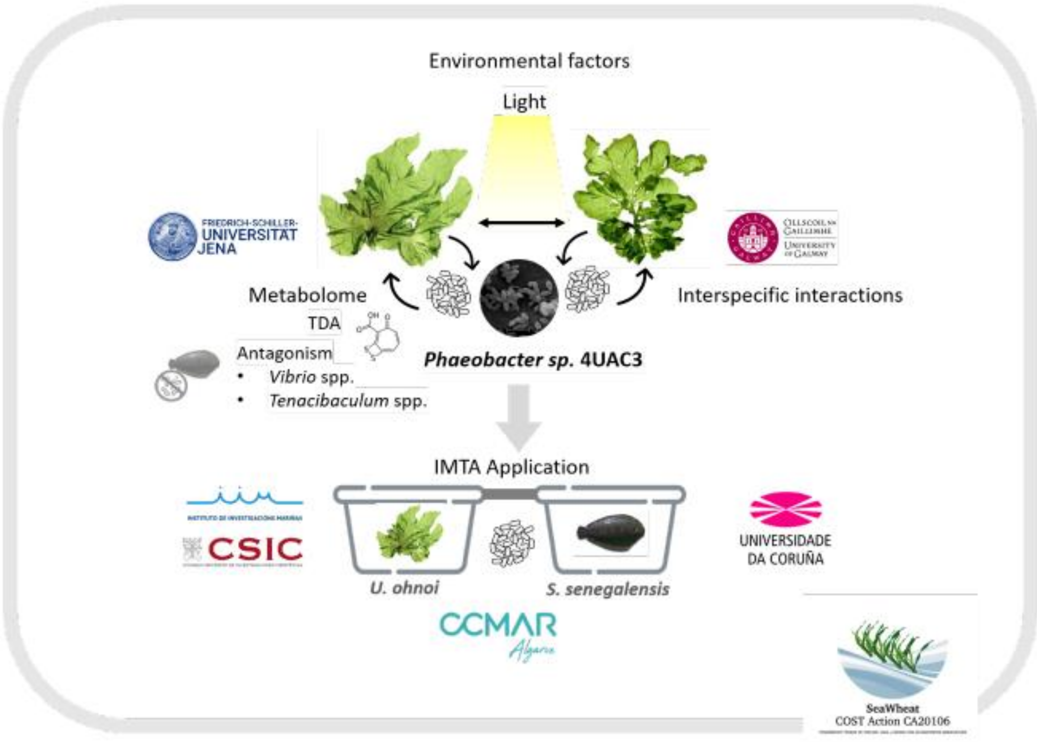
[1] Integrated Marine Ecology (InMare) group, Institute of Marine Research (IIM-CSIC), Vigo, Galicia, Spain
[2] Coastal Biology Research Group (BioCost). Interdisciplinary Center for Chemistry and Biology (CICA), Universidade da Coruña, Galicia, Spain.
[3] CCMar, Universidade do Algarve, Faro, 8005-139, Portugal
[4] Instituto Galego de Formación en Acuicultura (IGAFA), Xunta de Galicia, A Illa de Arousa, Galicia, Spain.
[5] Institute for Inorganic and Analytical Chemistry, Friedrich Schiller University Jena, Jena, Germany
[6] School of Biological and Chemical Sciences, University of Galway, Galway, Ireland
E-mail: pintado@iim.csic.es

Abstract

The laminar thallus of *Ulva* provides an important niche for biofilm-forming bacteria, such as those of the genus *Phaeobacter*, which can antagonise fish pathogens such as *Vibrio* spp.and *Tenacibaculum* spp., through the production of tropodithyetic acid (TDA). *Phaeobacter* bacteria have been shown to be effective as a probiotic in aquaculture, reducing the mortality of fish larvae experimentally infected with Vibrio. Therefore, at IIM-CSIC the co-cultivation of *Ulva ohnoi* with *Phaeobacter* sp. 4UAC3, a strain isolated from *Ulva australis*, has been propossed as a strategy to tackle fish pathogens such as *Vibrio* spp. in IMTA-RAS. However, high light intensity impacts *Phaeobacter*'s persistence on *Ulva*, which did not occur in non-living surfaces. *Phaeobacter* sp. 4UAC3 colonization on *U. ohnoi* decreased in the light but remained stable in the dark [1].
To elucidate the underpinning mechanisms of this behaviour, a collaboration within the SeaWheat COST Action was established with Thomas Wichard's group at the University of Jena, to investigate how the colonization of *Phaeobacter* sp. strain 4UAC3 on *U. ohnoi* surfaces affects the alga's microbiome and metabolome dynamics. The light regime significantly altered the microbial community structure, metabolite production, and physiological responses of both the bacterium and the alga. In darkness, *Phaeobacter* sp. strain 4UAC3, produced TDA and modulated the microbiome and the exo- and endo-metabolomes of *U. ohnoi* [2]. Based on these results, a two-phase light intensity approach to optimise antagonistic activity was developed for IMTA-RAS and scaled-up. The microbial communities are being analysed, in collaboration Aschwin Engellen's group at CCMAR, to understand the impact of *U. ohnoi* introduction and its microbial manipulation in the overall microbiome of IMTA-RAS at an industrial-scale.
Whether *Phaeobacter* sp. 4UAC3 could differentially affect the physiology of different *Ulva* species, and whether the observed behavior of the influence of light on the maintenance of *Phaeobacter* on the surface of *U. ohnoi* also occurred in other *Ulva* species, a collaborative research, in the frame of the SeaWheat COST Action was established with Ronan Sulpice's group at the University of Galway. The comparative phenotyping of different *Ulva* species (cultivated and wild) revealed interspecific interactions which favoured the maintenance of *Phaeobacter* 4UAC3 even under high light intensity. These results, indicated a possible interaction between the compounds produced by some *Ulva* species with the microbiomes of other species present

in the same environment. This opens a new approach to the study of bacterial interactions in *Ulva* spp., applying a populational perspective, not only applicable for IMTA-RAS but also to the understanding of mechanisms in green tides. Overall, this collaborative research, demonstrated the success of SeaWheat COST Action
CA20106 to bring together researchers from different areas of expertise to tackle both fundamental and applied research related to *Ulva* species.

Graphical Abstract



References

[1] Del Olmo, G. et al. Optimizing *Ulva*-Phaeobacter co-culture: A two-phase light intensity approach for integrated multi-trophic aquaculture applications. J. Appl. Phycol. 2025, 37(2), 1227-1240.
[2] Qui-Minet, Z. et al. Light-regulated interactions between Phaeobacter sp. and *Ulva* ohnoi (Chlorophyta): Effects on microbiome dynamics, metabolome composition, and tropodithietic acid production. Environmental and Experimental Botany. 2025, 230, 106093.

Acknowledgments

The different aspects of the research were supported by the Spanish Agencia Estatal de Investigación. (*Ulva*Quo Project RTI2018–095062-B-C21 to J.P. and J.C), the Deutsche Forschungsgemeinschaft (SFB 1127 ChemBioSys, project number 239748522, to T.W.) and by the Xunta de Galicia with NextGenerationEU and the European Maritime Fisheries and Aquaculture Funds, within the Galicia Marine Science Programme, Complementary Science Plans for Marine Science of Ministerio de Ciencia e Innovación (Spain), included in the Recovery, Transformation and Resilience Plan (PRTR-C17.I1, to J.P. and J.C.). Z.Q.M was beneficiary of a grant from the Fundación Pablo García (BC 3/21,) L.B. was beneficiary of a Juan de la Cierva Formación grant by the Ministerio de Ciencia e Innovación (FJC2021-047947-I) and a STSM funded by SeaWheat COST Action CA20106. G.D.O. was beneficiary of a grant from the Axencia Galega de Innovación (IN606A-2021/038). J.P. was Visiting Researcher at the Plant System Biology Laboratory at the University of Galway, granted by the Spanish Ministry for Science, Innovation and Universities (grant reference PRX23/00535).

REMOVAL OF PESTICIDES BY *ULVA* AND ITS ASSOCIATED MICROBIOM

REDLICH S.[1], WICHARD T.[1]

[1] Institute for Inorganic and Analytical Chemistry, Friedrich Schiller University of Jena, Jena, Germany.
E-mail: Simon.Redlich@uni-jena.de

Abstract

The global level of environmental pollution has steadily increased over the past years and continues to rise annually. Pesticides impact our environment, wildlife, and human health, and we need innovative ways to remove them[1]. It was demonstrated that the macroalgae *Ulva compressa* and its associated microbiome can metabolize xenobiotics like BPs and steroid hormones[2,3].
High-throughput approaches were employed to investigate the potential of *U. compressa (cultivar U. mutabilis)*[4] for biological wastewater treatment with high temporal resolution. To ensure a high number of replicates for robust dose-response analyses, a semi-automated method for Pulse-Amplitude-Modulation (PAM) fluorometry was developed. This method enabled the assessment of the tolerance of *U. compressa* to selected xenobiotic compounds. Specifically, the impact of increasing concentrations on the maximum quantum yield of photosystem II, the electron transport rate, and oxygen production was evaluated.
Furthermore, removal experiments of selected pesticides by *Ulva compressa* and its associated microbiome were conducted. Therefore, targeted and untargeted mass spectrometry was performed to determine the removal rate, investigate the removal mechanism, and detect potential break-down products of the pesticides. We demonstrated that *U. compressa* and its associated microbiome could withstand high concentrations of a wide range of selected pesticides, up to mg/L level or higher. However, *Ulva* is less resistant against typical electron-transport inhibitors (e.g., hexazinone) but shows strong signs of a full recovery after periods with less exposure (Fig. 1A).
Furthermore, *U. compressa* can metabolize very efficiently specific hormones (e.g., hexestrol) entirely within four days into bromide derivatives (Fig. 1B). These findings highlight *U. compressa* and its microbiome as a resilient and promising system for sustainable, biologically driven wastewater treatment.

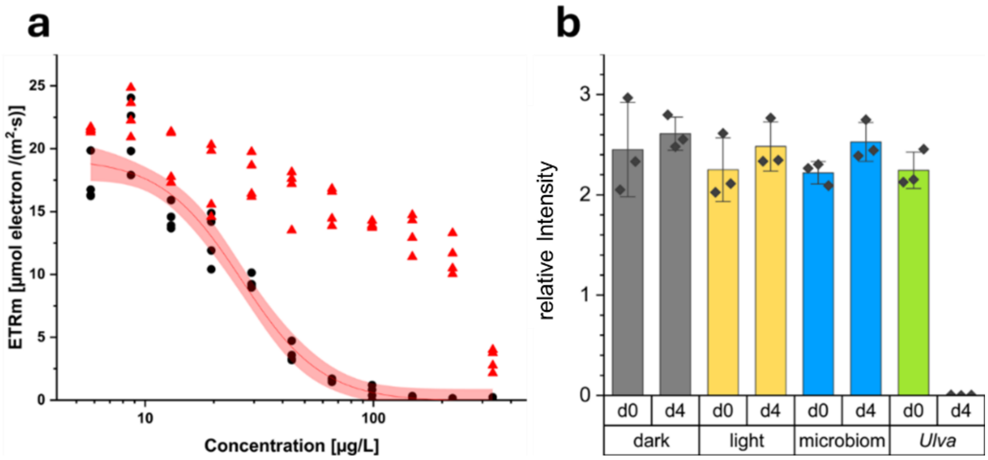


Figure 1. (a) Dose-response curve of hexazion intoxication (black circle) surveyed after 4 days by ETRm in *U. compressa* (EC50 = 26.5 ± 1.9 µg/L). ETRm was measured again after 4 days upon a growth medium exchange to test the detoxification potential. (b) Removal of hexestrol

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
Funded by the European Union

from the growth medium by *U. compressa* was compared with abiotic controls in dark or light, and the microbiome in the absence of *Ulva*.

References

[1] Punia, A., Singh, R., & Chauhan, N. S. Impact of Xenobiotics Under Changing Climate Scenario. In: Singh, R., Singh P., Tripathi, S., Chandra, K. K., & Bhadouria R. (Eds.), *Xenobiotics in Urban Ecosystems: Sources, Distribution and Health Impacts*, Springer International Publishing, 2023, pp. 3-26.

[2] Hadegen, J., Amend, G., & Wichard, T. Lifecycle-dependent toxicity and removal of micropollutants in algal cultures of the green seaweed *Ulva* (Chlorophyta). *Journal of Applied Phycology*. 2023, 35, 2031.

[3] Hadegen, J., Knips, M. S. F., Däumer, J. K., Kretzer, S., & Wichard, T. Biodegradation of xenoestrogens by the green tide forming seaweed *Ulva*: A Model System for Bioremediation. *ACS ES&T Water.* 2025, 5, 1195.

[4] Wichard, T. From model organism to application: Bacteria-induced growth and development of the green seaweed *Ulva* and the potential of microbe leveraging in algal aquaculture. *Seminars in Cell & Developmental Biology.* 2023, 134, 69-78.

Acknowledgments

The project was supported as part of the "Clusters 4 Future" initiative of the German Federal Ministry of Education and Research (BMBF) within the Thuringian Water Innovation Cluster (ThWIC, project VANAPLA, 03ZU1214BB).

Short biography of the presenter

Simon Redlich is a PhD candidate in chemistry and a member of the Thuringian Water Innovation Cluster research group at the Friedrich Schiller University of Jena in Germany. He obtained a bachelor's degree in Biogeosciences and a master's degree in Chemistry – Energy – Environment. His research investigates the toxicological tolerance and xenobiotic removal capacity of *Ulva* and its associated microbiome.

BIOCHEMICAL DIVERSITY AMONG *ULVA* SPECIES ACROSS EUROPE

SIMON C.[1,2], INABA M.[1], BIBI F.[1], SULPICE R.[1]

[1] Plant Systems Biology Lab, School of Biological & Chemical Sciences, Ryan Institute & Marei centre for Marine, University of Galway, Galway, Ireland
[2] Merinov, Center for Innovation in Aquaculture and Fisheries, Gaspé, Québec, Canada
E-mail: c.simon2@universityofgalway.ie

Abstract

Ulva is arguably one of the most abundant, widespread, and well-known seaweed genera in the world. However, its true species diversity and biochemical composition remain significantly underexplored, even in well-studied regions such as Europe. This study, conducted within the framework of the COST Action SeaWheat (E*ULVA*) project, investigates the metabolic diversity of green macroalgae *Ulva* spp. across a wide range of natural environmental conditions. A total of 495 samples from 15 different countries were collected from various habitats, including rocky and sandy shores, aquaculture systems, freshwater streams, lagoons, and channels, during different seasons (spring, summer and fall). Sampling sites featured in situ temperatures ranging from 13 to 30 °C and salinities from 0 to 52 ppt.

Key metabolic parameters, such as starch, *Ulva*n, chlorophyll a, chlorophyll b, carotenoids, total amino acids, and proteins, were quantified and analyzed in relation to environmental variables and species. Significant correlations between temperature/salinity and carbohydrate and pigment levels were identified. A focused analysis of sites sampled across multiple seasons further confirmed these trends, revealing site-specific and seasonal variability in the biochemical composition of *Ulva* species.

This work highlights the naturally variable biochemical profile of *Ulva* biomass and provides valuable information on species-environment associations, with future applications in biotechnology and environmental monitoring.

Acknowledgments

We would like to thank all the COST Action members who provided the samples and made this collaborative analysis possible. All those members will be co-authors in an ongoing publication.

Short Biography of the speaker

Clara Simon is a marine biologist who completed her PhD at the University of Galway (Ireland) in 2024 under the supervision of Dr. Ronan Sulpice. Her research focused on the green seaweed *Ulva* spp., studying the impact of environmental factors on its life cycle and physiology. Clara aims to understand how environmental changes affect *Ulva*'s metabolism and to explore the best ways of exploiting its valuable biomass. This research combines fundamental and applied science to understand how photosynthetic organisms like *Ulva* adapt to their environment offers valuable insights and potential uses in biotechnology.

INTENSIVE AQUACULTURE AT A TURNING POINT: FROM MONOCULTURE TO INTEGRATED SYSTEMS – A NECESSITY BUT OPPORTUNITY AS WELL

SORGELOOS P.[1]

[1] Department of Animal Sciences and Aquatic Ecology, Laboratory of Aquaculture & Artemia Reference Center, Ghent University, Belgium
E-mail: patrick.sorgeloos@ugent.be

Abstract

Aquaculture practices can be broadly classified into "food" and "business" aquaculture [1]. The former, practiced for centuries in China and other Asian countries, has always been based on polyculture principles, resulting in an ecologically sustainable approach with minimal environmental impact. This form of aquaculture primarily provides food for local consumption. In contrast, business aquaculture emerged in Japan in the 1960s and expanded to the Western world over the following decades. Driven by advancements in the understanding of the biology of high-value species (such as various fish and crustaceans), innovative techniques in broodstock maturation, hatcheries, and grow-out systems (in ponds or cages) led to the development of industrial-scale practices. Business aquaculture, particularly the use of monoculture systems for grow-out, initially had low environmental impacts. However, as market competition intensified in the 1980s, the industry began to adopt higher stocking densities and more formulated feeds, which resulted in greater environmental impacts and an increased incidence of diseases caused by bacteria, viruses, and parasites. In the past decade, sectors like Penaeid shrimp farming in Asia have faced major catastrophes, with significant socio-economic consequences. It remains a hypothesis, but many farms may be operating beyond the local environment's carrying capacity. There is a pressing need to shift the focus in aquaculture from disease treatment to prevention. The current reliance on disinfection methods, which indiscriminately kill both harmful and beneficial bacteria, highlights the need for new microbial management strategies. Shrimp and marine fish cultured in recirculating aquaculture systems (RAS), where biofilters enhance microbial competition, appear to be less susceptible to unpredictable losses. Similarly, integrated farming practices such as Integrated Multi-Trophic Aquaculture (IMTA) – which combines fish, seaweed, and shellfish farming in coastal areas – or zero-water exchange intensive shrimp farming, where effluent is recirculated through tilapia and seaweed ponds before returning to shrimp ponds, seem to provide similar benefits. While still under investigation, these integrated systems may offer indirect microbial management benefits, potentially leading to improved overall performance.

References

[1] Sorgeloos, P. 2013. Aquaculture: the blue biotechnology of the future. *World Aquaculture*. 2013, *44(3)*,18

Funded by the European Union

Short Biography of the speaker

Patrick Sorgeloos has a PhD in marine biology and set up the *Artemia* Reference Center at Ghent University in Belgium in 1978. He has been involved in brine shrimp *Artemia* projects and fish/shellfish hatchery developments all over the world. Until his retirement as emeritus professor in 2013 over 350 Master and 70 PhD alumni graduated at Ghent University in the field of aquaculture.

As Past-President of the World Aquaculture Society, and co-founder and board member of the European Aquaculture Technology & Innovation Platform, Patrick is a strong promoter of international networking in aquaculture and is still involved with many international aquaculture organizations. He was co-founder of the Ghent University spin-off company Artemia Systems that is now operating under the name of INVE Aquaculture. He received honorary awards in China, Egypt, Greece, India, Malaysia, Russia, Thailand, USA, and Vietnam.

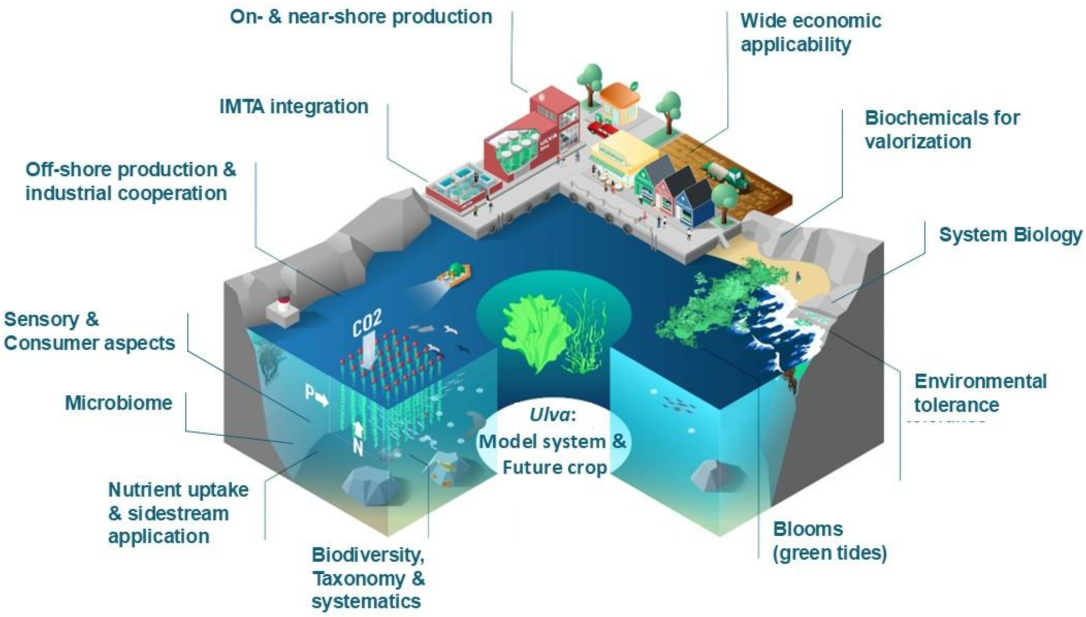
FROM GREEN WAVES TO GREEN FARMS – HOW BASIC RESEARCH ON SEA LETTUCES ENABLES A SUSTAINABLE BLUE ECONOMY

STEINHAGEN S.[1,2]

[1] Department of Marine Sciences, University of Gothenburg, Tjärnö Marine Laboratory
[2] Department of Natural History, University Museum of Bergen
E-mail: sophie.steinhagen@gu.se

Abstract

The green macroalga *Ulva* is emerging as a powerful model system for both fundamental and applied research, bridging key questions in system biology with urgent challenges in sustainable resource production. Characterized by extreme morphological plasticity and wide ecological distribution, *Ulva* offers unique opportunities to study genotype–environment interactions, adaptation, and ecotypic variation across contrasting marine habitats. Our research integrates aquaculture studies with high-resolution genomic analyses to dissect the drivers of phenotypic variability and to identify adaptive traits critical for growth and resilience. In particular, the Atlantic-Baltic Sea transect — with its strong environmental gradients — serves as a natural laboratory for understanding how *Ulva* responds to fluctuations in salinity, temperature, and nutrient availability. These insights not only inform our understanding of plasticity and local adaptation but also guide the selection of high-performing ecotypes for industrial yet sustainable cultivation. As a fast-growing organism rich in protein and essential nutrients, *Ulva* presents exceptional potential as a future crop—offering sustainable solutions for biomass production, bioremediation (including the valorization of food industry side-streams), and the development of bio-based materials. By positioning *Ulva* as both a model organism and a future crop, this research framework supports the co-development of basic biological insights and scalable aquaculture practices. Ultimately, our work lays the foundation for a resilient blue economy—where fundamental science and applied innovation jointly shape sustainable food and resource systems of the future.



Graphical Abstract: *Ulva* as a model system and emerging aquaculture crop: Integrative research on *Ulva* exemplifies how basic research can drive innovation in the Blue Bioeconomy

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
Funded by the European Union

References

Steinhagen, S., Johansson, I., Specht, J., Enge, S., Larsson, K., Undeland, I., & Toth, G. B. (2025). Unlocking economic potential of the *Ulva* crop for low salinity environments: exploring the effect of salinity gradients on the performance and valuable compounds of Baltic Sea strains. *Botanica Marina*, *68*(1), 65-82.

Steinhagen, S., Hoffmann, S., Pavia, H., & Toth, G. B. (2023). Molecular identification of the ubiquitous green algae *Ulva* reveals high biodiversity, crypticity, and invasive species in the Atlantic-Baltic Sea region. *Algal Research*, *73*, 103132.

Steinhagen, S., Enge, S., Larsson, K., Olsson, J., Nylund, G. M., Albers, E., ... & Toth, G. B. (2021). Sustainable large-scale aquaculture of the northern hemisphere sea lettuce, *Ulva fenestrata*, in an off-shore seafarm. *Journal of Marine Science and Engineering*, *9*(6), 615.

Acknowledgments

We want to thank the FORMAS-funded projects ‘A manual for the use of sustainable marine resources’ (Grant no. 2022–00331).

Short Biography of the speaker

Sophie Steinhagen is associate professor at the University of Bergen (Norway) and docent at the University of Gothenburg (Sweden). She investigates seaweed biodiversity, phylogenetic relationships, and species-specific traits within seaweeds. Her current research explores the interplay between environmental factors and genomic set up of seaweeds, unravelling the secrets behind the content of high-value compounds and setting baselines for breeding programs in European seaweed crop strains to support a sustainable seaweed aquaculture.

EU SUPPORT TO ALGAE SECTOR DEVELOPMENTS

STULGIS M.[1]

[1] Policy officer on Blue bioeconomy, algae and aquaculture, DG Maritime Affairs and Fisheries, European Commission
E-mail: maris.stulgis@ec.europa.eu

Abstract

The presentation "EU Support to Algae Sector Developments" will provide an overview of the European Commission's strategic actions to unlock the full potential of algae as a key enabler of the green and blue transitions. Anchored in the **EU Algae Initiative**, this support spans policy development, funding, and stakeholder engagement, aiming to create a more robust, sustainable, and innovative algae ecosystem across Europe. Key efforts include the launch of **EU4Algae**, a multi-stakeholder platform facilitating collaboration, knowledge exchange, and market access; substantial funding allocations to **algae-related research and innovation projects** under Horizon Europe and other EU programmes; and the development of **evidence-based studies** to address regulatory and market barriers. Additionally, the Commission has taken proactive steps to raise **visibility and awareness** of the sector, notably through the organization of the **EU Algae Awareness Summit** and tailored **BlueInvest events** designed to attract private investment and accelerate algae entrepreneurship. Collectively, these initiatives reflect the EU's commitment to positioning algae as a high-impact, low-carbon solution for food, feed, materials, and ecosystem regeneration.

References

https://commission.europa.eu/about/departments-and-executive-agencies/maritime-affairs-and-fisheries_en
https://www.linkedin.com/in/maris-stulgis-7340738

Short Biography of the speaker

Maris Stulgis holds a university-level diploma in Water Bioresources and Aquaculture from Kaliningrad State Technical University. Prior to joining the European Commission, he spent 10 years in the Latvian national administration, focusing on environmental protection and fisheries control policy development and implementation. As a Policy Officer at DG MARE, he has worked on fisheries control policy - including the development of new control technologies and leading EU inspector teams in the Baltic and North Sea regions - as well as on fisheries data management, marine pollution, biodiversity, and environmental policy. Since 1 October 2020, he has been responsible for the Blue Bioeconomy, Algae, and Marine Aquaculture.

Funded by the European Union

USING MARINE FINFISH HATCHERY EFFLUENT TO GROW *ULVA SP.* IN A PILOT LAND-BASED IMTA SCHEME

TROIANOU E.[1], ABATZIDOU E.[1], TZOVENIS I.[1,2]

[1] Kefalonia Fisheries S.A., Livadi Lixouri, 28200 Kefalonia, Greece
[2] Microphykos, Athens 15238, Greece
E-mail: e.troianou@kefish.gr

Abstract

Ulva sp. seedlings, collected from a nearby natural macroalgae bed, were used to initiate a land-based pilot seaweed aquaculture system. The algae were cultivated in translucent HDPE tanks, each with a capacity of 1 m³. Water from the sedimentation tank—the final stage of the biological water treatment process of the marine finfish hatchery at Kefalonia Fisheries SA—was continuously flowing through the tanks, supplying inorganic nutrients (NH_4-N, NO_3-N, NO_2-N, PO_4-P, etc.) with a residence time of 20 minutes.
This hatchery effluent originated from the treatment of runoff water from broodstock, larvae, and fry tanks used for rearing sea bass (*Dicentrarchus labrax*) juveniles before their transfer to offshore sea cages.
Ulva sp., introduced at an initial loading of 1 kg per m³, grew well in the effluent, which had an average concentration of 0.87 mg/L total dissolved inorganic nitrogen and 0.62 mg/L inorganic phosphorus. Since January 2025, the integrated multi-trophic aquaculture (IMTA) system using *Ulva* sp. achieved an average daily growth rate of 10.870% (±7.802%), with lower rates observed in spring (4.827%, ±2.438%) and higher rates in early summer (18.927%, ±1.812%).
The success of this pilot *Ulva* sp. cultivation—effectively contributing to both additional treatment of the hatchery effluent and biomass production—supports the planned scale-up to treat the full volume of the farm’s discharge. Discussions are currently underway regarding the use of the produced biomass as raw material for agro-industrial applications, such as biostimulants and biofertilisers.

Short Biography of the speaker

Eva Troianou graduated from the Department of Biological Applications and Technologies at the University of Ioannina, Greece, and went on to complete a master's degree in Evolutionary Genetics at the University of Edinburgh. She has also worked with the Population Genetics Group at the Institute of Marine Research (IMR) in Bergen, Norway.

In 2018, she returned to her homeland, Kefalonia, where she currently works in the Research and Development Department of Kefalonia Fisheries. She is involved in national and European research programs, which focus on the cultivation of *Ulva* at an industrial pilot scale, among other topics related to macroalgae and sustainable aquaculture.

A QUICK VIEW OF THE *ULVA* INDUSTRY & THE SEAWHEAT SME PLATFORM

TZOVENIS I.[1]

[1] Microphykos, Aquaculture Systems & Services, Athens 15238, Greece
E-Mail: itzoveni@microphykos.com

Abstract

Europe, as a continent, lags behind other world regions in algae production. Specifically, regarding marine macroalgae (seaweeds), Europe contributes less than 1.4% to global production, with most of its supply being harvested from the wild. There are fewer than 200 companies involved in macroalgae production, and less than 20 of those either cultivate or collect *Ulva*. In contrast, over 500 companies, employing more than 2000 individuals, are engaged in the processing and product development of macroalgae, with over 40 companies incorporating *Ulva* into their product lines. The market for seaweed-based products, particularly in the cosmetics and meat alternatives industries, appears very promising despite the often negative connotation associated with the term "seaweed."
In the context of the COST action SeaWheat, we have developed a platform to facilitate interactive networking among all stakeholders involved in the research, production, and valorization value chain. Additionally, we have created a specific platform for exclusive communication between participating companies, known as the SeaWheat SME platform. Approximately 25 companies have expressed interest and joined this platform to gain access to firsthand information and foster idea exchange between experts and commercial entities.

References

[1] Araújo R, et al. Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy. *Front. Mar. Sci*. 2021,7.
[2] Vazquez Calderon, F. & Sanchez Lopez, J., An overview of the algae industry in Europe, Guillen Garcia, J. & Avraamides, M. editor(s), Publications Office of the EU, Luxembourg, 2022.

Acknowledgments

I am indept to Karīna Bāliņa (Latvia University) and Céline Rebours (Moreforsking) for their help in working with the SME platform

Short Biography of the speaker

Dr. Ioannis Tzovenis, with over 30 years of experience in algae biotechnology and aquaculture, founded MIKROFYKOS, a company that advises Spirulina producers and develops natural products from algae. A graduate of the National and Kapodistrian University of Athens and a Ph.D. holder from Ghent University, he taught for a decade at the Technological Educational Institute of Epirus in Greece. He is a member of several professional organizations, including EAS, EABA, ISAP, FELPS/HELPS, GEOTEE, and EBEA. Dr. Tzovenis has extensive experience in marine fish hatcheries, fish larvae nutrition, shellfish and algae technology, and integrated multitrophic aquaculture. He has delivered over 100 scientific presentations, has over 40 publications, and has participated in more than 40 EU or nationally funded projects.

UNRAVELLING DIVERSITY AND DISTRIBUTION PATTERNS IN *ULVA* THROUGH A PAN-EUROPEAN COLLABORATIVE EFFORT

VAN DER LOOS L.M.[1,2], D'HONDT S.[1], E*ULVA* CONSORTIUM, LELIAERT F.[3], DE CLERCK O.[1]

[1] Phycology Research Group, Ghent University, Ghent, Belgium
[2] Naturalis Biodiversity Center, Leiden, the Netherlands
[3] Meise Botanic Garden, Meise, Belgium
E-mail: olivier.declerck@ugent.be

Abstract

Ulva is one of the most abundant, widespread, and well-known genera of seaweeds globally. However, identifying individual species within this genus based on morphology alone is extremely challenging due to their high phenotypic plasticity and overlapping traits. As a result, the true diversity of *Ulva* species remains largely unknown—even in extensively studied regions like Europe. To address this gap, the European *Ulva* Taxonomy Initiative (E*ULVA*) is undertaking a comprehensive assessment of *Ulva* species diversity and their geographic distribution. In collaboration with 180 researchers, the E*ULVA* consortium has collected nearly 4,000 samples from diverse habitats across the Northeast Atlantic, the Mediterranean, and Macaronesia. This dataset spans 25 countries—from Morocco to Svalbard and from Iceland to Azerbaijan—and includes environments such as coastal zones, freshwater systems, and salt marshes. To efficiently analyze this large dataset, we developed a dual-barcoding approach using Oxford Nanopore Technologies. This method allows us to pool approximately 800 samples per sequencing run and target multiple full-length genetic markers (ITS, tufA, rbcL). By integrating these data with all relevant GenBank sequences from the region, we reassess species diversity and distribution, offering new insights into species concepts and biogeographic patterns. Our sequencing strategy has proven highly effective, achieving identification rates of 92–98% per 96-well plate. This represents a significant advancement in species discovery, enabling the detection of non-native and bloom-forming species, as well as the co-sequencing of small epiphytic and endophytic taxa such as *Ulvella* and *Acrochaete*.

Acknowledgments

This work makes use of resources and facilities provided by UGent as part of the Belgian contribution to EMBRC-ERIC (FWO I001621N).

Short Biography of the speaker

Olivier De Clerck is an expert on seaweed diversity, genetics and evolutionary biology. With his group at Ghent University he actively develops genomic resources, including genome editing techniques, for *Ulva.* He also studies the interaction of *Ulva* with microbiota (bacteria and viruses).

SEAWEED FEED AND FOOD SAFETY: EU POLICY AND OUTLOOK

VERSTRAETE F.[1]

[1] European Commission Directorate-General Health and Food Safety.
E-mail: Frans.Verstraete@ec.europa.eu

Abstract

The EU legislation on contaminants in food, Council Regulation (EEC) No 315/93 of 8 February 1993 provides that food containing a contaminant in an amount which is unacceptable from the public health viewpoint shall not be placed on the market (food can only be placed on the market when it is safe).
Furthermore, it is foreseen that contaminant levels shall be kept as low as can reasonably be achieved by following good practices at all stages of the production chain. In order to protect public health, maximum levels for specific contaminants shall be established where necessary. Also, the consultation of European Food Safety Authority (EFSA) for all provisions which may have an effect upon public health is mandatory.

Following requests of the European Commission, the Panel on Contaminants in the Food Chain (CONTAM) from the European Food Safety Authority (EFSA) has completed in recent years several scientific opinions on contaminants, including environmental contaminants, reviewing the possible risks for human health due to the presence of these substances in food, including seaweed. As follow-up to the outcome of the EFSA opinions, maximum levels are established in foods, including seaweed by Commission Regulation (EU) 2023/915 of 25 April 2023 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006.

The consumption of seaweed is increasing and the presence of contaminants in these foods might contribute significantly to human exposure to these contaminants. In order to be able to estimate that contribution, EFSA has issued in 2023 a report on “Dietary exposure to metals and iodine via consumption of seaweed and halophytes in the European population. Currently maximum levels for certain metals (such as lead, cadmium and arsenic) in seaweed for human consumption are under discussion.
Taking into account the possible animal and public health concern related to the presence of undesirable substances in feed, the undesirable substances are regulated at EU level in feed to ensure a high level of animal and human health and environmental protection.
Directive 2002/32/EC of 7 May 2002 of the European Parliament and of the Council on undesirable substances in animal feed is the framework for the European Union action on undesirable substances in feed.
Following requests of the European Commission, the Panel on Contaminants in the Food Chain (CONTAM) from the European Food Safety Authority (EFSA) has completed several scientific opinions on undesirable substances in feed, reviewing the possible risks for animal and human health due to the presence of these substances in feed and their presence in food of animal origin following the transfer from feed.
The use of seaweed as feed material is increasing also due to a favourable impact on the environment (such as lower methane emissions).
In the presentation recent developments and an outlook as regards EU policy on contaminants/undesirable substances in seaweed to ensure a high level of animal human health protection will be explained in detail. Also, more details will be provided how the outcome of EFSA opinions on contaminants/undesirable substances is followed up in EU regulation thereby referring to recent examples.

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
Funded by the European Union

Short Biography of the speaker

Frans Verstraete graduated in 1985 as agricultural engineer at the University of Ghent (Belgium). After his studies he held positions at the University of Ghent and thereafter at the Belgian Ministry of Agriculture and he was for a period technical adviser of the Belgian Minister of Agriculture. He is working for the European Commission since 1997. In the European Commission he is working at the Directorate General Health and Food Safety. He is responsible for the elaboration, development and management of the EU-legislation on certain contaminants in feed and food.

ADVANCES AND STRATEGIES FOR IDENTIFYING NOVEL MARINE BIOACTIVES WITH INSIGHTS FROM BACTERIA-ALGAE INTERACTIONS

WICHARD T.[1]

[1] Institute for Inorganic and Analytical Chemistry, Friedrich Schiller University Jena, Jena, Germany
E-mail: Thomas.Wichard@uni-jena.de

Abstract

The marine environment harbors many organisms that produce potentially novel bioactive compounds with promising applications in pharmaceuticals, biotechnology, and industry [1, 2]. Among these, macroalgae have gained attention due to their rich bouquet of chemical compounds and ecological significance. Recent advances highlight the critical role of bacteria-macroalgae interactions in modulating the production of metabolites in macroalgae [3].
In *Ulva*, for example, microbial symbionts influence algal development, defense mechanisms, and metabolic outputs, thereby shaping the profile of bioactive compounds. This presentation explores current strategies for identifying novel marine bioactives, specifically focusing on the *Ulva* holobiont and the associated microbial consortia.
Approaches such as co-cultivation experiments, metagenomic and metabolomic profiling, and systems biology tools have deepened our understanding of the molecular cross-talk between *algae* and their associated bacteria. The selection of species, cultivation techniques, experimental design, harvesting strategies, and improved analytical approaches all work together to enhance the identification of interesting compounds.
My presentation will highlight insights that reveal the potential for discovering unique natural products in macroalgae. In this context, understanding ecologically relevant microbe-host interactions may support the identification of novel compounds, as demonstrated by the discovery of (-)-thallusin in the *Ulva* holobiont [3]. Unlocking the biochemical potential of *Ulva*-bacteria systems may pave the way for innovative applications in environmental sustainability of aquacultures and novel approaches in agriculture.

References

[1] Karthikeyan A., Joseph A., Nair B. G. Promising bioactive compounds from the marine environment and their potential effects on various diseases. *Journal of Genetic Engineering and Biotechnology.* 2022, 14.
[2] Ozogul F., Trif M., Rusu A., editors. Seaweeds and seaweed-derived compounds: Meeting the growing need for healthy biologically active compounds. Springer, 2021.
[3] Wichard, T. From model organism to application: Bacteria-induced growth and development of the green seaweed *Ulva* and the potential of microbe leveraging in algal aquaculture. *Seminars in Cell & Developmental Biology.* 2023, 134, 69-78.

Acknowledgments

The Deutsche Forschungsgemeinschaft (DFG) funded the research through the SFB 1127 ChemBioSys (No. 239748522).

Short Biography of the speaker

Thomas Wichard is a research group leader and lecturer in analytical chemistry at the Institute for Inorganic and Analytical Chemistry of the Friedrich Schiller University Jena (Germany). After being awarded a PhD in biochemistry (Max Planck Institute for Chemical Ecology), he investigated the metal recruitment of nitrogen fixers at the Princeton Environmental Institute (USA). His team applies various analytical chemistry, chemical ecology, and molecular biology methodologies to understand the basis of eco-physiological processes in bacteria-macroalgae interactions (cross-kingdom interactions).

Funded by the European Union