

livestock feed formulations, for example, replacing fish meal and fish oil in aquaculture. However, exploiting the full potential of microalgae biomass in food production systems is still limited due to a low social acceptability and challenges in policy implementation. Using algal biomass as feedstock for biofuel production suffers from several challenges. The impact of biological and technological constraints on microalgal composition (e.g. lipid content as dry weight percentage) and doubling time raises the cost of raw materials, harvesting and processing. According to a recent paper⁵ by an Italian research team in algal physiology based in Università Politecnica delle Marche (Ancona) and led by

Dr Alessandra Norici, the most productive species or cultivation plant would still require roughly half the area of Italy (corresponding to the country's entire stock of arable land) to fulfil 9% of the energy demanded in 2030 by the transport sector—the estimated goal for biofuel quota according to the Sustainable Development Scenario⁶ (International Energy Agency, 2020).

Microalgae production in Italy is mainly at laboratory scale

Italy has 21 producers (20 of them cultivating also or only *Spirulina*) with a total of 70 employees (Calderon and Lopez, 2022). Most activities concerning the microalgae sector are at

university research level and on a laboratory or pilot scale. They often investigate the integration of a side-stream microalgae process for the treatment of domestic/pig farm/agro-industrial wastewaters. Among the challenges facing the development of a microalgae industry in Italy, is the lack of appropriate regulations and incentives to support the development of this sector. In 2018 the Italian Association for the Study and Applications of Microalgae (AISAM, <https://www.aisam-microalghe.it/>) was established. It currently includes over 100 individuals, 20 companies and 2 institutions as its members. It is a non-profit association that aims to promote scientific research and youth training and to support Italian

companies in the sector, encouraging exchange and cooperation in the production, processing, and use of microalgal biomass. AISAM activities include conferences, workshops and webinars focused on fundamental and industrial issues. It is also concerned with regulatory and ethical issues, and it cooperates with national and international bodies (such as the Italian ministry of agriculture) to propose guidelines for the industrial exploitation of microalgae.

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⁵ Gerotto C, Norici A and Giordano M (2020) Toward Enhanced Fixation of CO₂ in Aquatic Biomass: Focus on Microalgae. *Front. Energy Res.* 8:213. doi: 10.3389/fenrg.2020.00213

⁶ International Energy Agency (2020). Transport Biofuels - Analyses. Available online at: <https://www.iea.org/reports/transport-biofuels> (accessed June 24, 2020). Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001.

AquaNet, a new organisation in the Danish aquaculture sector, **holds its first conference**

Shaping the future of Danish aquaculture

On 13 April 2023, the new Danish aquaculture organisation, AquaNet, held its first symposium, “Towards a green transition in Danish aquaculture: Opportunities, challenges and new directions” at the University of Copenhagen. More than 100 participants from Danish and foreign research organisations, companies, interest organizations, and public agencies discussed the future of Danish aquaculture as the food sector in general contemplates a green transition.

The background for the establishment of the network and the symposium was the increased global focus on the need to produce high quality protein more sustainably to feed a growing world population. As we face a global climate crisis and a world population that has exceeded

8 billion people, it is more important than ever to discuss how to support and ensure sustainable, efficient, and safe ways to produce food in the future. Aquaculture is the fastest growing sector for animal-based food production for human consumption in the world, and is a significant source of

high-quality protein, essential fatty acids, vitamins, and minerals.

Danish aquaculture production has been stable for years

On a global scale, farmed fish production has increased by 56%

from 78 million tonnes in 2010 to 122 million tonnes in 2020. Production is mainly in Asia (92%). European aquaculture only contributes 2.7% to the global total, and only one third of that is produced in the EU. In Denmark, production has remained relatively constant over the past 30



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The AquaNet conference brought together stakeholders from research, NGOs, and the industry to discuss the future of Danish aquaculture.

years at 45,000-50,000 tonnes per year even though Danish production systems are among the most environmentally efficient and official governmental goals for several years have been to create growth in the sector.

In addition to being an important source of healthful and protein-rich food, aquaculture has also a lower climate and environmental footprint than most land-based animal production, such as pig and cattle. Fish are also more efficient at converting feed into protein than warm-blooded animals, which contributes to a more climate friendly production. CO₂ emissions from beef-based protein production is, for example, on average 20 times *higher* than the emissions from the production of fish protein from rainbow trout. Carbon emissions and environmental impact are particularly low for seaweed and shellfish production. Consequently, there is a potential positive environmental and climate effect from a large-scale transformation of land-based to aquaculture-based production of protein for food.

Due to increasing demand for aquaculture products in the EU,

a very large part of the supply is covered by imports from Asia where production often takes place in a non-sustainable way. It has therefore become a stated goal of the EU to reduce dependence on foreign aquaculture products and to increase production within the EU with a particular focus on sustainability. Thus, there is increasing recognition of the aquaculture sector's potential as a supplier of sustainable and nutritious food. The Danish and European aquaculture sector can potentially play an important role in this development.

A powerhouse in RAS development and production

Denmark leads in the development of land-based recirculated aquaculture systems (RAS) and is the biggest producer of rainbow trout from RAS in the EU. Moreover, there is a high degree of experience and expertise regarding the development of new types of feed, disease prevention without antibiotics, organic production, utilisation of aquaculture side streams, and production at lower-trophic levels (seaweed, shellfish). Danish researchers also study how to

optimise regulation of the sector to ensure the largest possible societal contribution with the lowest possible climate and environmental effects. The sector thus has a good starting point for expanding production and contributing with knowledge and solutions which can secure sustainably produced food of high quality, thereby reducing dependence on imports of aquaculture products from non-EU countries. Thus, promoting sustainable aquaculture in Denmark will increase exports and economic growth, create new jobs in rural areas and contribute to increasing employment in ancillary industries (e.g. side stream processing, feed and equipment manufacturing).

Despite the economic and climatic potential of expanding production in Denmark, there are several limiting factors. These relate to other environmental issues associated with the industry such as the discharge of nutrients, organic matter, and drug residues. An expansion of production must be sustainable and in accordance with environmental requirements. This includes reduced discharge of nutrients and reduced use of antibiotics. Danish (and European) aquaculture must become an even more blue/green

industry with a further reduced climate and environmental footprint which supports the EU's "Farm-to-Fork" strategy.

Further research and development is crucial for Danish aquaculture's green transition

This can be achieved with targeted research and development efforts to promote new technologies, production and regulatory methods, and new farmed species that can reduce the environmental impacts from the industry, reduce disease outbreaks and optimise resource and energy consumption, as well as to develop alternative healthful food products. Research that focuses on new blue/green technologies will contribute to exploiting the climate and economic potential that lies in a blue/green transition and will place Denmark in a favourable position regarding the expected expansion of European aquaculture.

To address these important issues, to promote collaboration between stakeholders supporting green transition initiatives in the sector, a group of scientists from the University of Copenhagen established



Denmark harbours deep reserves of knowledge within aquaculture feeds, disease prevention without antibiotics, exploitation of waste from fish farms, and organic farming among other aquaculture-relevant areas. This provides a solid base for the expansion of sustainable farmed fish production.



Danish aquaculture technology such as these water filters contribute to reducing the environmental impact of farmed fish production in different parts of the world.

the Danish aquaculture network, AquaNet. It is led by Professor Mathias Middelboe, Department of Biology in collaboration with Assistant professor Moonika Marana and Professor Kurt Buchmann, Department of Veterinary and Animal Sciences; Associate professor Rasmus Nielsen and Associate professor Max Nielsen, Department of Food and Resource Economics; and Assistant professor Violetta Aru, Department of Food Science with support from the Green Solutions Centre at the University of Copenhagen.

A new forum to accelerate sustainability in the sector

AquaNet is an eclectic mixture of scientists, stakeholders, private companies, and NGOs with a shared interest in developing and supporting the sustainable transition of the aquaculture sector in Denmark. This includes:

1. describing long-term goals for the green transition of Danish food production by focusing on aquatic production

2. identifying and resolving societal, environmental, and technical challenges associated with sustainable growth in the aquaculture sector
3. promoting collaboration between stakeholders in Danish aquaculture sector and supporting green transition initiatives
4. identifying specific research projects that can target national and international funding calls and move the field forward, and
5. putting aquaculture on the agenda as a strategic solution in the green transition of national (and global) food production.

To initiate this process and to discuss these issues, the AquaNet symposium programme included a number of sessions with presentations from experts in the different topics:

- Session 1: Challenges and limitations in Danish aquaculture production
- Session 2: Aquaculture technology - Increasing production

and reducing environmental impact

Session 3: Economic aspects and perspectives: What is required to develop a more climate friendly and economically viable aquaculture industry with a better reputation?

Session 4: Food biotechnology - optimization of aquaculture products

Session 5: Animal welfare: Is an increased aquaculture production compatible with high animal welfare?

Session 6: Disease prevention - sustainable alternatives to antibiotics

Session 7: Funding landscape - opportunities for aquaculture funding in DK and EU

The contributions from the speakers were combined with round table discussions with a panel of experts with different backgrounds and interests to promote interaction and discussion among all participants in the symposium.

Overall, there was general agreement at the symposium that an expansion of sustainable aquaculture is critical for the future blue/green food production. The outcome of the symposium was the identification of a number of key topics and challenges that must be addressed in the coming years to promote an expansion of the industry and the development of more sustainable food production. A report from the network discussions and conclusions on the topics, technology advances, resources, regulatory challenges etc, which were identified at the symposium is in preparation and will soon be published at the AquaNet web page: <https://www1.bio.ku.dk/english/research/mbs/projects/cross-disciplinary-network-for-a-green-transition-in-the-aquaculture-sector/>

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