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SEAFOOD

DENMARK IS A LEADING HUB FOR SUSTAINABLE PRODUCTION AND INNOVATION WITHIN FISHERIES AND AQUACULTURE

INSIDE THIS WHITE PAPER:

- **Responsible fisheries in harmony with the wild stocks**
- **A model of circularity within land-based aquaculture**
- **The technology at the heart of quality and food safety**

FOOD NATION
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Seafood

Denmark is a leading hub for sustainable production and innovation within fisheries and aquaculture

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EXECUTIVE SUMMARY

The fishing industry draw on a strong Danish tradition of high quality food production and strict requirements from the industry. The suppliers excel within efficiency, food safety and hygiene

Surrounded by ocean, Denmark has an age-old tradition for being a nation of fishers. From small beginnings, the Danish fishing industry has grown into a thriving platform for fisheries, aquaculture and processing – not to mention the seafood trade in partnership with Greenland and the Faroe Islands as a united Kingdom of Denmark.

This is the backdrop to Denmark's ranking as the largest seafood exporter in the EU and a leading supplier of technology and knowhow for fisheries, aquaculture and the processing sector. The fishing industry draw on a strong Danish tradition of high quality food production and strict requirements from the industry. The suppliers excel within efficiency, food safety and hygiene.

The need to protect the environment – both at sea and on land – is a major driver of innovation. As a result, our wild caught fisheries have reduced their carbon footprint by more than 60% since 1990 and are now heading towards the goal of full carbon neutrality by 2050.

Within aquaculture, the emergence of water recirculation technology has resolved problematic nutrient emissions and enabled the transition towards sustainable land-based fish production – a development of critical importance for the global food supply.

For the seafood processing industry, the era of automation is improving working conditions on the factory floor while securing freshness, quality and maximum value derived from the fish. Fish trimmings and other side streams are no longer regarded as waste but as important raw materials for high-value ingredients for food, feed and health products for human consumption.

Most of these developments are the outcome of cross-sector collaboration between industry, academia and authorities. Such partnerships continue to drive the research and innovation that is preparing fisheries and aquaculture for the future.

This white paper gives an insight into the evolution of Danish seafood technology and knowhow, the challenges they solve and the opportunities they create for the international seafood community.

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Supporting the SDGs
How does Denmark contribute?

Fisheries and aquaculture can make a significant contribution to a sustainable food supply chain for the world. The UN's sustainable development goals (SDGs) are a guiding light for Danish food production in establishing best practices and identifying innovation targets in collaboration with academia and authorities.

An efficient and sustainable food sector will directly or indirectly contribute to all 17 goals. However, in relation to fisheries and aquaculture, there are some goals where the Danish food cluster can make a specific impact. These include **Goal 2** *End hunger, achieve food security and improved nutrition, and promote sustainable agriculture,* **Goal 12** *Ensure sustainable consumption and production patterns,* **Goal 13** *Take urgent action to combat climate change and its impacts and* **Goal 14** *Conserve and sustainably use the oceans, seas and marine resources for sustainable development.*

Achieving the ambitious goals of the 2030 agenda requires global support and partnerships. In Denmark, extensive cross-sector collaboration accelerates the progress of national and international initiatives and directly contributes to **Goal 17** *Strengthen the means of implementation and revitalize the global partnership for sustainable development.*

SUSTAINABLE DEVELOPMENT GOALS

FOREWORD


Photo: Steen Brogaard

Danish technology has shaped and adapted the seafood industry over generations. Today, it is an innovative force, bringing fishermen, producers and processors closer to their sustainable performance goals.

The Danish seafood industry has a global reputation for driving fish and shellfish production in a sustainable direction. An important element in the Danish seafood trade and processing is the close partnership with Greenland and the Faroe Islands.

From offshore fisheries to land-based aquaculture and the seafood processing industry, Danish technology and knowhow continue to lower CO2 emissions and increase efficiency, without compromising food quality and safety.

Today, the growing demand for seafood places more responsibility on industry shoulders at a time when climate change and biodiversity loss are high on the agenda. Concerns are increasing about overfishing of wild stocks and the need to protect the marine environment.

In Denmark, such challenges tend to inspire the next generation of solutions. Over the years, we have seen our fishing fleet become one of the most technologically advanced with solutions that minimize its carbon footprint and unwanted bycatch. Close dialogue with the Danish authorities supports fishermen in complying with EU fishing quotas while continuing to run a profitable business.

Within aquaculture, Denmark's first aquatic environment plan in the 1980s was a turning point. Including strict regulations to limit nutrient leakage, the plan kick-started an innovative journey that has become a true export adventure for our technology providers – the development of advanced water recirculation systems. This technology has transformed Danish aquaculture and brought land-based fish farms to some of the driest locations in the world.

We have seen a similar level of innovation in our seafood processing industry where innovative efforts focus on high-speed automation and value optimisation. A positive outcome of this is Denmark's long-standing status as the biggest producer of high-quality fishmeal in the EU, using the latest tools to maximise the extraction of protein.

In all these developments, our culture of collaboration is a common denominator – a characteristic way of working that is apparent throughout the Danish agri-food cluster. Knowledge sharing, open innovation and mutual trust enable multi-faceted innovation that takes all needs and perspectives into account. A stronghold we share with our export markets.

Jacob Jensen
Minister for Food, Agriculture and Fisheries

CHAPTER 1

FROM SMALL FISHING NATION TO SUSTAINABLE SEAFOOD LEADER

INNOVATION AND RESOURCE-FULNESS IN THE FACE OF CONSTANT CHANGE

Photo: Unsplash

Denmark has a global reputation for responsible fisheries, aquaculture and seafood processing. Cross-sector collaboration prepares the industry for tomorrow's challenges.


Photo: Mette Johnsen

With almost 8,600 kilometres of coastline and covering the seas around Greenland and the Faroe Islands, the Kingdom of Denmark was always destined to be a nation of fishermen. Today, our country's age-old fishing heritage has grown into a thriving modern industry, known for wild catch fishing, aquaculture and fish processing and as a global hub for the seafood trade.

Through this evolution, Denmark has become a major importer of seafood from 90 countries around the world for consumption, processing or re-exportation – strengthening our ranking as the largest seafood exporter in the EU, with exports to more than 115 countries.

In an industry where change is a constant companion, the ability to adapt swiftly and efficiently to every challenge is a necessity. Fluctuating wild fish stocks, fishing quotas, environmental regulations and many other factors have an unrelenting impact. The Danish culture for cross-sector collaboration is an important advantage when developing innovative solutions.

Sustainability at sea

Along our coast, the Danish fisheries industry operates as an efficient, cooperative community, providing specialised employment at many levels – from the crews of the fishing vessels to the providers of maritime equipment and technology. Working with national authorities and researchers as well as international partners, the goal is to ensure the highest standards of sustainability and traceability in line with the fishing quotas laid down by the EU. Such collaboration also helps to prepare the industry for future demands. This includes developing our fishing fleet, today the most digitalised in the world.

Leading in aquaculture

Denmark's aquaculture sector has existed since the late 1800s, becoming a world-leading player from an early stage. In the 1970s, recognition of the environmental impact led to the enforcement of strict national regulations. Since then, the sector has undergone a major transformation, starting with the development of the Danish model fish farm and the move towards more land-based facilities. Following continuous technological innovation, Denmark now has a global reputation for sustainable fish production based on recirculation aquaculture systems (RAS) and other technologies with a minimal environmental footprint.

Specialised processing

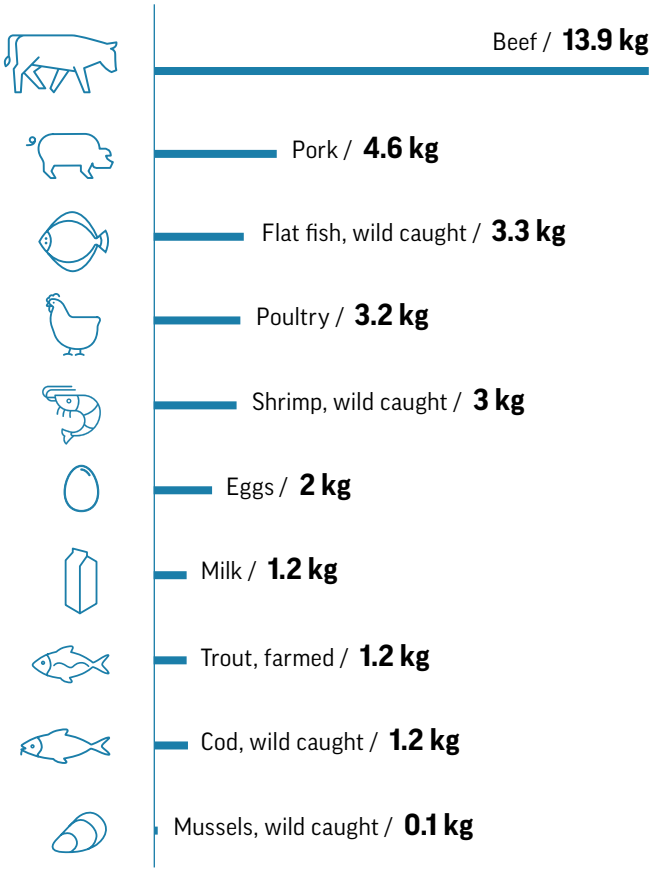
Seafood from the Kingdom of Denmark is served in restaurants all over the world – delivered as fresh, smoked, frozen, marinated or canned by specialised processing and trading companies.

Local fishermen and aquaculture facilities supply around a third of the raw materials used for their production and wholesale trade, with imports from other nations contributing to a wide range of speciality products.

Thanks to rapid freezing technology and global container freight, it is possible to reach many distant markets. Equipment and solutions suppliers from Denmark within fish processing draw on a strong Danish tradition of high quality food production and strict requirements from the industry. The suppliers excel within efficiency, food safety and hygiene.

A no-waste philosophy ensures that close to 100% of fish trimmings and other by-products are upcycled to create more sustainable value – as ingredients for the food and feed industry or as feedstock for biogas and other biofuels.

CO2 kg emission per 1 kg product including all steps in the value chain



Source: DCA Danish Centre for Food and Agriculture, 2016

Photo: Billund Aqauculture

CHAPTER 2

RESPONSIBLE FISHERIES IN HARMONY WITH THE WILD STOCKS

THE COORDINATED EFFORT TO PROTECT QUALITY AND THE OCEAN

Photo: Danish Fishers PO

Danish technology is behind a new age of speed and efficiency in the fisheries industry – with a sustainable mindset in front.

Danish fisheries have made tangible progress towards improving the sustainability of their operations. Close collaboration with the Marine Stewardship Council means Denmark is today a frontrunner for sustainable certification – with more than half of the wild catch bearing the blue MSC label.

Since 1990, the industry has reduced its carbon emissions by more than 60% and taken action to minimise impact on the territorial seabed. According to the National Institute of Aquatic Resources, 68% of the seabed is fully exempt from trawl fishery.

Ocean-fresh quality

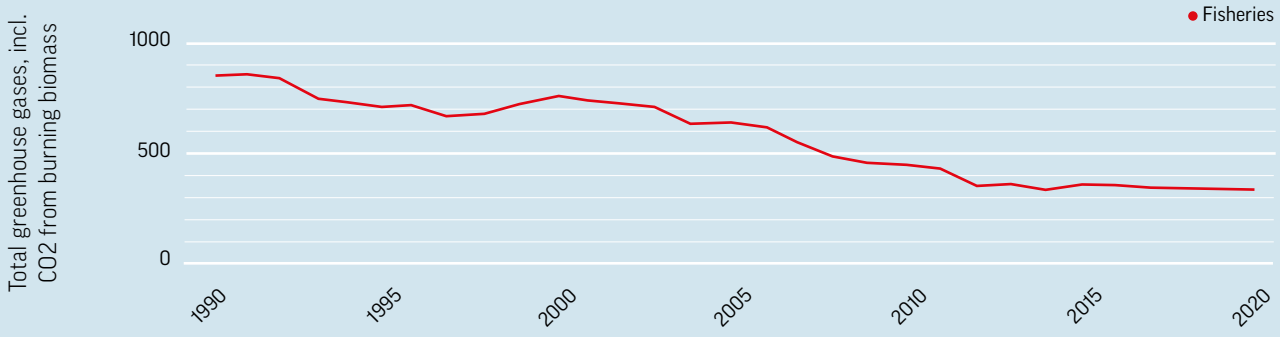
On a daily basis, the priority is to preserve the freshness and quality of the catch from the moment it is hauled from the ocean. Onboard cooling systems make a critical difference in this respect, with some vessels also having automated systems to pack fish and shellfish before arrival on land.

Speed and efficiency are key at every stage. This is why our fish processing plants are located close to or at the ports. Some of the largest plants have specialised technology to transfer the catch directly from the vessel and separate the by-catch on the spot. After travelling via high-speed sorting lines and transport partners, a fish brought on land during night or in the morning in Denmark can arrive on a dinner table in France the very same day.

Wild stock conservation

For all stakeholders in the fisheries industry, the conservation of wild fish stocks is both a mutual interest and a sustainability obligation. To prevent the discard and waste of undersized fish or unwanted species, the EU enforced a regulation in 2019 that requires

Greenhouse gas accounting (in CO2 equivalents) by emission type, industry and time



The greenhouse accounts are calculated for the Danish economy. It differs from reports to the UN (UNFCCC), e.g. by including emissions from international transportation. In the past year there are no figures for fluorinated gases, and the figure from the previous year is used for the total.

Source: Statistics Denmark, 2021

all catches to be landed and counted against the fishers' quotas. The Danish authorities monitor compliance with the quotas to prevent overfishing.

Danish fishers are playing their part by using specially designed nets that minimise unwanted bycatch and fitting CCTV cameras that can help sort the fish while still in the water. As some bycatch is inevitable, there is a strong focus on optimum utilisation. Fishers are also developing catch documentation schemes to facilitate compliance with quotas and support traceability and research.

Saving energy and eco-systems

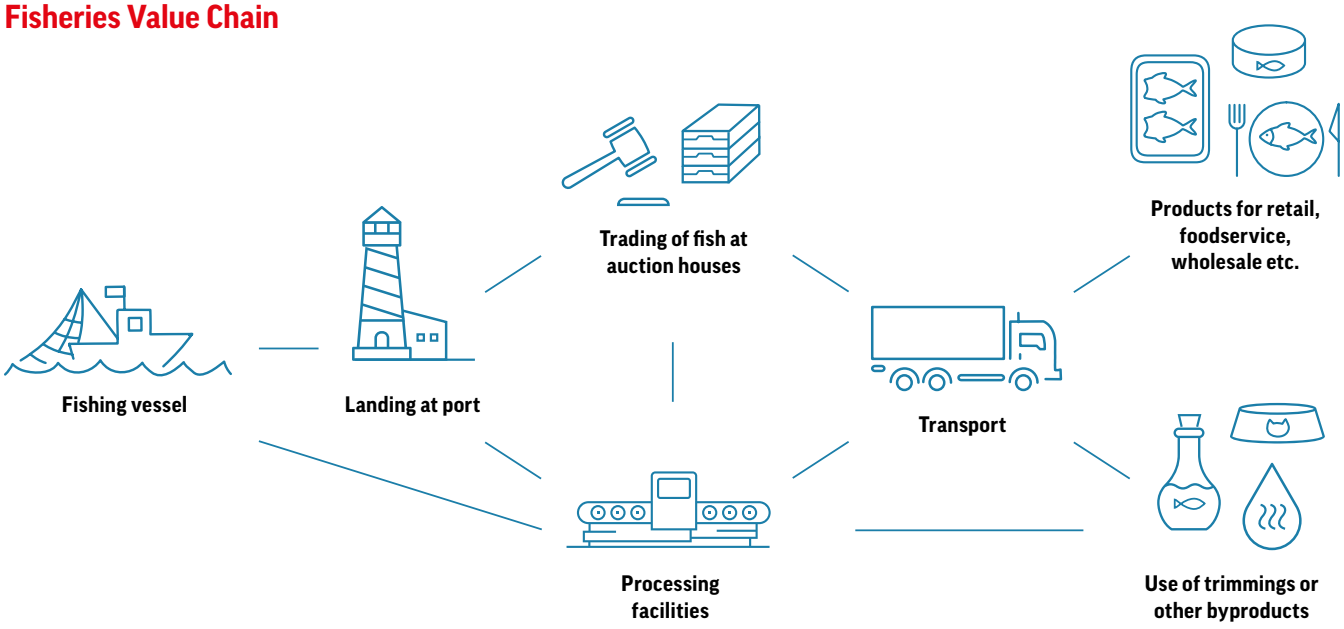
The Danish fisheries industry is constantly working to reduce energy consumption and the risk of negative impacts on the seabed. Initiatives include the implementation of electronic power management programmes, energy-optimised engines and specially designed propellers with a lower rotation speed. On vessels with electric winches, the excess energy from wiring is stored in large batteries.

A particular innovation worth naming is the Dyneema rope. A much lighter alternative to the heavy steel wires traditionally used for seabed fishery, this Danish design brings a significant energy saving to lowering and lifting tasks in the ocean. Another is the introduction of advanced trawl doors that make little or no contact with the seabed, preventing disruption of sensitive eco-systems.

Day-to-day efficiency

As Danish fisheries methods and technology continue to advance, many of the developments are the outcome of an outstanding openness to collaboration. Apart from the advantages from a sustainability perspective, working in this way brings practical benefits that support everyday efficiency. One well-known example within the fisheries community is that many of Denmark's ports serve as one-stop shops. So a vessel only needs to dock in one place to find specialists that can cover all service and repair needs.

Fisheries Value Chain



CASE / Thyborøn Trawldoors

CONTROLLABLE TRAWL DOORS PROTECT THE SEABED

Photo: Thyborøn Trawldoors

Bottom trawling accounts for almost a quarter of global wild fish landings. Using traditional methods, that can have negativ impact on the seabed – a problem one Danish company has been determined to resolve.

Thyborøn Trawldoors has long experience in tailoring trawl doors to the needs of pelagic, semi-pelagic and bottom fishing all over the world. One of their solutions – the Thyboron type 32 Bluestream remote-control trawl door – could be the future for fishers who struggle with bottom contact when trawling.

The doors are fitted with an electronic device which is connected to the bridge either by hydrophones on the bottom of the vessel or by a wi-fi solution. Precision position control enables fishers to continue fishing as normal. The only change is that the trawl doors are positioned so there is little or no contact with the seabed.

Using the specially designed trawl doors, it can support fishers opportunity of obtaining and maintaining Marine Stewardship Council certification.

Small adjustment prevents disruption of sensitive ecosystems and reduces fuel consumption at the same time

CASE / Danish Pelagic Producers Organisation

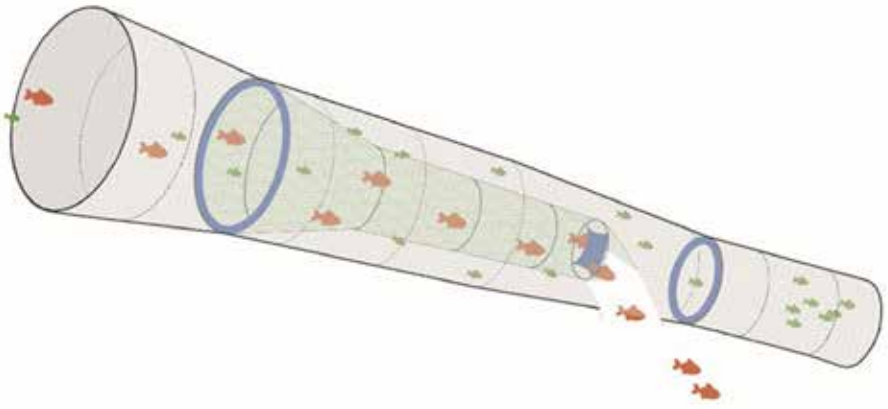
INNOVATION MINIMISES PELAGIC BYCATCH

Unintentional bycatches can be critical for fish stocks and marine wildlife, and in fisheries also for business, where it reduces the value of the catch.

In the fishery for Norway pout an innovative project led by the Danish Pelagic Producers Organisation (DPPO) has resulted in the development of a new safe and selective gear that not only minimises the risk of accidental bycatches of other fish and marine wildlife, but also provides for a much safer working conditions on deck, lower CO2 emissions and not least secures higher catches of the Norway pout fishers are targeting.

Known as the Excluder, the advanced trawl insert comprises an outer net and an inner selection tube, with an escape panel that allows fish and other unintentional catches to swim out of the trawl unharmed.

> Excluder minimizes risk of accidental bycatches, reduces fishing effort, impact on marine environment and CO2 emissions



Tests are now underway in other pelagic and demersal fisheries, and several scientific projects have been initiated to further develop the technology and tailor to the challenges faced in those fisheries. These include minimizing the risk of accidental bycatches of marine mammals.

The Excluder is the outcome of a collaboration between DPPO, scientists at the Technical University of Denmark, trawl makers at Egersund Tor-MoTrawl and the crew of fishing vessel Themis S144. Denmark's Green Development and Demonstration Programme funded the project.

Photo: Danish Pelagic Producers Organisation

CHAPTER 3

A MODEL OF CIRCULARITY WITHIN LAND-BASED AQUACULTURE

RESOURCE-EFFICIENT TECHNOLOGY FOR SUSTAINABLE FISH FARMS

Photo: Billund Aquaculture

Since the first model fish farm, Danish recirculation systems have led the world in optimising aquaculture productivity with minimal environmental impact.

Denmark's modern aquaculture sector is founded on respect for the environment. Back in the 1970s, the Danish authorities kickstarted a major transformation by imposing the first anti-pollution regulations. Recognising that the legislation posed a massive challenge, the authorities simultaneously introduced collaborative programmes to facilitate the development of new methodologies for farming fish without harmful emissions.

Denmark has been a world leader for efficient and sustainable aquaculture technology ever since. Today, more than half of the world's fish consumption is based on farmed fish. A large proportion are produced with the aid of Danish knowledge and technology.

The recirculation model

Over the years, the combined efforts of fish farmers, technology suppliers and universities have produced model fish farms based on the concept of water recirculation. By cleaning the water and feeding most of it back into land-based ponds and tanks, these facilities can produce large volumes of fish in up to 15-100 times less water compared to traditional farms. Modern land based facilities with recirculation of water in Denmark are primarily proficient suppliers of 'portion-size' fish for consumers and smolt for grow-out in sea-cage fish farms.

Water recirculation methods are continuously refined and improved, creating a stream of opportunities for land-based aquaculture to optimise water and energy consumption. Efficient pumps and other equipment have reduced energy consumption in salmon production, for example, to 2.5 kWh per kilo. As a result, it is now possible to establish facilities almost anywhere, eliminating dependence on rivers and streams.

Closed system innovation

Recirculation aquaculture systems (RAS) are a particular Danish strength in this regard. Here, automated monitoring technology manages water quality and feeding programmes tailored to the needs of individual species – safeguarding their health and natural behaviour and optimising productivity.

RAS technology ensures that potential issues, such as heavy metals, viruses and bacteria, are filtered out of the water. In addition to mechanical filters, the cleaning system makes use of biofilters, where bacteria consume digested nutrients and other particles that come from the fish. Ozone and ultraviolet light treatment disinfect and purify the water before it is returned to the fish tanks, contributing to a high level of biosecurity that minimises disease and the need for antibiotics.

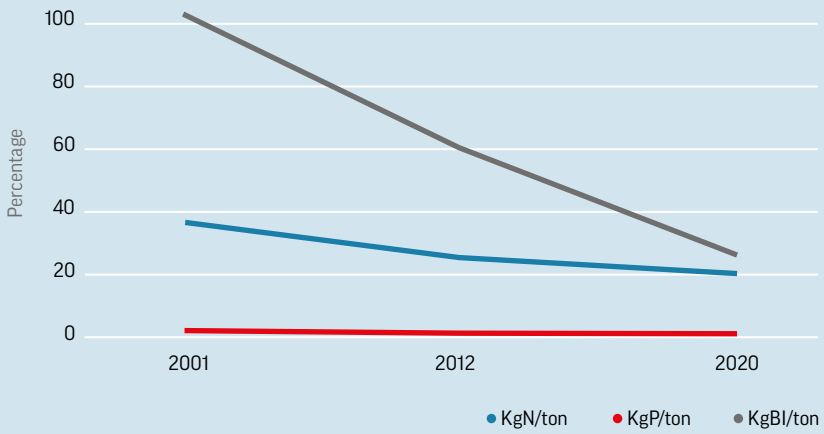
Sustainable credentials

Danish companies today export RAS equipment and entire facilities to more than 130 countries, where they enable land-based production close to consumers – reducing the climate footprint of fish transport.

The utilisation of nutrients extracted from the water further contributes to the biocircularity of the technology. One innovative possibility under development involves incorporating units for land-based seaweed production in water recirculation systems.

From a marketing perspective, Danish aquaculture technology paves the way to traceable fish farming that meets the requirements of the Aquaculture Stewardship Council (ASC). Consumers who buy fish with an ASC label can, therefore, be sure the farms that produced them have been independently assessed as environmentally and socially responsible. In Denmark, between 60% and 100% of farmed fish have currently achieved ASC approval, depending on the species. Continuous improvement ef-forts are ongoing.

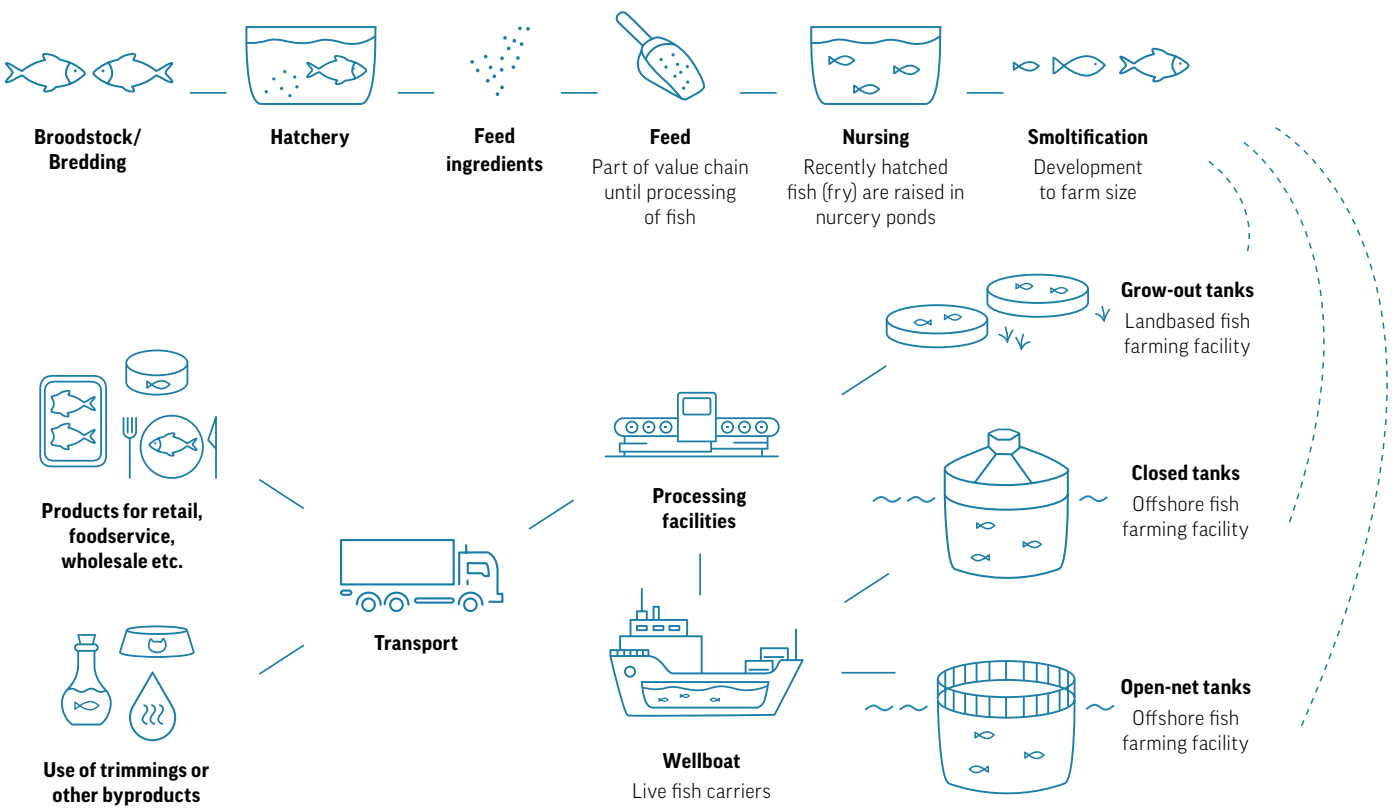
Nitrogen, Phosphorus and Organic Material (BI5) emissions from freshwater fish farming



Nitrogen emissions have decreased by **46.10%** between 2001 and 2020, and by **15.5%** between 2012 and 2020. Phosphorus emissions have decreased by **38.90%** between 2001 and 2020, and by **11.60%** between 2012 and 2020. BI5 emissions have decreased by **74.90%** between 2001 and 2020, and by **58.30%** between 2012 and 2020.

Source: Calculated on the basis of the Danish Environmental Protection Agency's annual Reports (2001, 2012 and 2020), where 2020 is the latest available

Aquaculture Value Chain



CASE / Billund Aquaculture

INTENSIVE AQUACULTURE WITH THE SMALLEST ENVIRONMENTAL FOOTPRINT

In 2017 Billund Aquaculture won the tender to design and construct one of the world's largest, most intensive RAS for salmon smolt production in Tasmania. With Australia's tight environmental laws, Billund Aquaculture was under pressure to push process optimisation to an unprecedented level. Not only was the Whale Point facility to have a capacity of 750 tons biomass, but the designs also had to provide maximum flexibility so production could easily be adapted to demand.

To deliver all that with minimum environmental impact, the design engineers came up with a unique combination of cutting-edge technologies. One innovation was to pair a full-flow ozone treatment system with an intensive wastewater treatment system. At the same time, the water purification setup had to be dimensioned to serve the largest smolt production tanks that Billund Aquaculture had ever produced, and the longest pipeline for fish transportation stretching over 1.2 km.

Completed in 2019, the RAS facility has more than lived up to expectation. The owner – Huon Aquaculture – is now producing the largest smolts in the Southern Hemisphere with the lowest consumption of water across all projects globally.

> For Billund Aquaculture this large and challenging project was a technology gamechanger. The knowledge and experience gained underway continues to benefit new projects

Photo: Billund Aquaculture

CASE / AquaPri

SUSTAINABLE ZANDER FARMING MOVES ON LAND

Photo: AquaPri

Consumers all over the world are getting a taste for the delicious and versatile zander or pike perch. In Denmark, the fish farming company AquaPri has invested in a successful solution – sustainable zander production in a land-based RAS system.

Having farmed zander since 2005, AquaPri is experienced in controlling the production chain from egg to dispatch of the fully grown fish.

The RAS system uses the latest technologies to produce 700 tons of the fish a year. Full control and traceability ensure food safety is of the highest standard

One of the only companies in the world to have developed a method to make zander spawn four times a year, AquaPri is able to deliver high-quality fresh fish all year round. This makes it possible for customers to plan campaigns and other marketing activities ahead. The fish are typically ready for dispatch just six hours after they are taken out of the basin.

The zander has an incredibly delicate meat structure and is highly appreciated all over Europe. The tasty, white fish meat is firm in texture and tender when cooked. In addition, it has a high natural content of protein.

Farmed zander is on the World Wildlife Fund's green list for sustainable seafood. Due to the rearing environment, the RAS facility ensures the fish are free of parasites and do not need to be frozen. This is what makes zander from AquaPri suitable as fresh sushi and sashimi.

CASE / OxyGuard International

CLOUD-BASED MANAGEMENT KEEPS AQUACULTURE ON TRACK

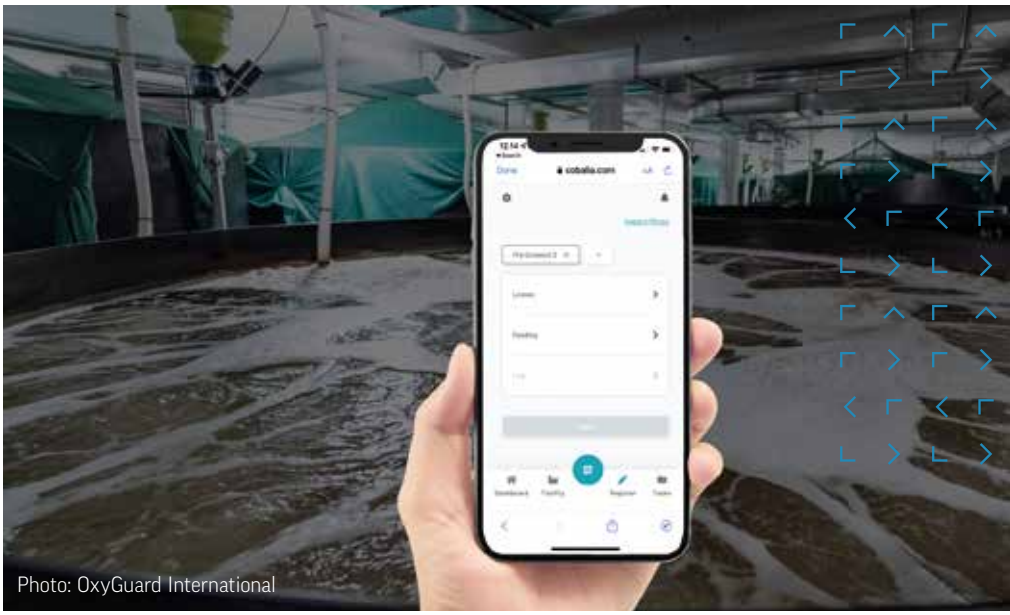


Photo: OxyGuard International

Even tiny changes in oxygen levels can have negative impact in aquaculture. Fish can lose their lives in a matter of seconds, causing massive waste of resources and severe economic consequences for the fish farmer.

The Danish company OxyGuard International has more than 35 years of experience in providing high-quality equipment for fish farmers in more than 120 countries. Their solutions cover everything from land-based aquaculture to fish transportation and offshore installations.

Over several years, OxyGuard has worked with fish farmers to co-develop a revolutionary, cloud-based management system called Cobália. It is designed for operations of all sizes, from the small pond farmer using a handheld oxygen meter connected to a smart phone to the biggest farms where large volumes of data are gathered from numerous sensors.

Cobália gathers all data and presents it to the user in a way that enables a swift reaction when things start to go wrong – whether there is a problem with oxygen saturation, pH, water level or something else.

In this way, farmers can avoid expensive and wasteful scenarios, such as a reduction in feed efficiency, high energy consumption or even fish mortality.

> OxyGuard expects the data-driven management tool to reduce feed use by five to ten%, enable traceability and provide farmers with detailed documentation of production performance

CHAPTER 4

THE TECHNOLOGY AT THE HEART OF QUALITY AND FOOD SAFETY

RAISING INTERNATIONAL STANDARDS BY ADVANCED AUTOMATION

Photo: Food Nation

For safe, high-quality seafood production, a fast and efficient process is the bottom line. Danish technology sets international standards.

Danish technology suppliers to the fish and shellfish processing industry have grown up in a tradition for high-quality food production with a sharp focus on food safety and hygiene. Due to the perishability of seafood raw materials, safe and gentle handling is critical. This is where advanced automation makes a difference.

The ability of our processing equipment suppliers to develop new technology in close collaboration with food producers is an important advantage when developing efficient, high-capacity lines that meet the highest standards of quality, food safety and traceability. For the food producers, fine-tuned processes are also key to achieving their environmental targets while helping them stay competitive.

Consistent high standards at home lay the foundation for trusted exports of fish and fish products. In Denmark, the standards developed by the food industry are both internationally recognised and a source of inspiration for EU regulations such as the Hazard Analysis and Critical Control Point (HACCP) system for managing food safety risks. Via the Danish 'own controls' system, all food manufacturers must document the safety and hygiene of their production. Regular checks by the Danish Veterinary and Food Administration ensure their compliance with legislation. Most Danish producers subscribe to private food safety schemes on stricter terms than EU hygiene standards.

Intelligent automation

Today, smart automated solutions from Denmark hold a prominent position on the global market. Their innovative technology optimises every processing step, from slaughtering, weighing and grading through gutting, deboning and filleting to packaging, freezing and palletising. Cutting-edge robots are one example of the latest digital advances, designed to secure seafood quality during the canning process.

Danish turnkey solutions meet all needs from beginning to end of the production line – making seafood products ready for dispatch, quickly, safely and with minimal reliance on manual labour. Solutions are also available for efficient by-product handling. In regards to aquaculture high-quality fish feed manufacturers and turnkey suppliers secure high-quality production including sub-suppliers to both land-based RAS facilities and offshore facilities as well as supply vessels and wellboat production.

Onboard quality assurance

Securing high quality and food safety starts as soon as fish and shellfish are caught in the ocean. This is why Danish processing equipment is also fitted on large fishing vessels internationally, including machinery for gutting, cutting, slicing and vacuum-packing individual portions.

In addition, the Danish pelagic processing industry uses specially designed weighing systems and camera monitoring when the fish is landed to the factories. All data is made available for independent third-party control, which ensures each catch has been properly weighed, sorted and registered in line with legal requirements.

Natural preservation aids

Health concerns have led to a growing demand to reduce the use of salt in fish preservation. The response from Danish processing plants is to replace salt with natural bio-preservation technology. In this way, they can meet dietary requirements without compromising food safety.

CASE / Royal Greenland and DTU

COOPERATION DEVELOPS A PREDICTIVE MODEL TO KEEP SEAFOOD SAFE

Bacteria control in lightly preserved and ready-to-eat seafood is no longer a global challenge following a long collaboration between the seafood company Royal Greenland and the Technical University of Denmark (DTU). Together, they have produced and tested a refined mathematical model for predicting the growth of Listeria monocytogenes and guaranteeing food safety right through shelf life.

Researchers at DTU began developing the model in the early 2000s by taking measurements from smoked salmon and Greenland halibut samples. This included investigating the effect of 12 environmental factors on listeria growth, such as storage temperature, pH, salt, organic acids and smoke content.

Royal Greenland has subsequently tested the model continuously, implementing the findings in daily operations in the smokehouse and other production units that produce prawns in brine and other ready-to-eat seafood.

Software based on the model now makes new product development faster and easier, eliminating the need for lengthy trials. When environmental data is tapped into the software program, the impact on food safety parameters is evaluated in an instant.

In addition to predicting bacteria growth, the research has shown that, when harmless organic acids are added to lower the pH of a product, listeria is unable to grow.

In addition to predicting bacteria growth, the research has shown that, when harmless organic acids are added to lower the pH of a product, listeria is unable to grow

Photo: Royal Greenland

Today the software growth models are available as open source tools and are also verified for use in the global meat and dairy industries.

The project received funding from the Danish Ministry of Food, Agriculture and Fisheries and the Green Development and Demonstration Programme.

CASE / Norbech

AUTOMATED SHRIMP PEELING IN AN ALL-IN-ONE MACHINE

Reliance on expensive manual peeling used to be unavoidable in the shrimp and prawn business, as certain species were unsuitable for the available machines. That meant sea-cooked Pandalus Borealis shrimp, for example, were transported to countries with low labour costs – a journey that added to their carbon footprint and compromised freshness.

Today, the Danish company Norbech has solved this challenge with their peeling machine – the SeaPeeler Flex.

The SeaPeeler Flex gathers the entire peeling process in one flexible and compact machine that saves space on the factory floor and and reduces the labour costs. Easy to install on existing lines, the system can handle most types and sizes of shrimp and prawn.

Photo: Norbech

> The SeaPeeler Flex increases peeling capacity for sea-cooked Pandalus Borealis by at least 300%, protecting freshness at the same time

Compared to other machine peelers, the SeaPeeler Flex technology provides opportunities to increase capacity or save up to 70% on water consumption, depending on the product type.

Norbech has based the machine on a 360° rotating roller design. As each roller is only active when peeling shells, maintenance is low – saving time and costs. Another time-saving feature of the gentle and efficient roller action is that it removes accumulated shells as it peels.

The technology adapts easily to the varying needs of individual markets, resulting in shrimp and prawn business that always meets the markets expectations of high-quality products with an appealing fresh colour and flavour.

CASE / DSI Dantech

ULTRA-FAST FREEZING PRESERVES SEAFOOD QUALITY


Photo: DSI Dantech

Effective and rapid freezing of bulk and block seafood products is a must in the fishing industry. As global demand for seafood grows, there is a need to change traditional, non-contact freezing methods as they fall short on quality, energy efficiency and speed.

The Danish company DSI Dantech aims to meet the needed change by transforming the industry and creating cutting-edge products that benefit the environment and the customer's budget.

The world's first one-stop supplier of mechanical, cryogenic and plate freezing technology, DSI Dantech delivers customised freezing solutions to processing plants and fishing vessels. Each solution is designed to freeze large quantities of fish and shellfish rapidly and consistently.

Applicable to bulk and packaged seafood in cartons and trays, plate freezing can be tailored to optimise the utilisation rate and minimise waste – improving profits in the process.

> Plate freezing has revolutionised the process with its short freezing cycle, which cuts freezing time from 18 to 36 hours to as little as two to four hours

Rapid freezing also prevents shrinkage and reduces enzyme activity, which can lead to biochemical and microbial changes with an impact on seafood quality. So, when the products are prepared for consumption, their appearance, aroma, taste and nutritional content are all intact.

DSI Dantech's range of high-tech products includes vertical plate freezers, horizontal freezers and customised automation solutions for high safety and hygiene and reduced handling.

CASE / Carsoe

EFFICIENT FISH GUTTING TECHNOLOGY FOR LAND OR SEA

Manual cleaning and gutting of fish is an exhausting, repetitive task for fishery workers. With an automated fish gutting machine from the Danish company Carsoe, fisheries can improve working conditions for their staff while improving efficiency and capacity.

Carsoe's KM Mark 7 fish gutting machine is made for installation on board fishing vessels or in land-based fish factories. By increasing capacity and automating cleaning, the KM Mark 7 machine substantially enhances the fish gutting process.

The machine is characterized by an ergonomic design with height adjustable legs and smaller depth resulting in operators being able to stand closer to the machine which creates better working positions.

Gutting length is easy to adjust while the KM Mark 7 is in operation – a feature that enables a continuous flow of fish through the thorough gutting and cleaning process, which also stands out for its low water consumption. On fishing vessels, it is valued for its space-saving design.

> With a capacity of up to 60 fish a minute depending on fish size it can do the work of three to five operators

Today the machine is trusted all over the world for gutting whitefish species to a high hygienic standard. Cod, saithe, hake, haddock, whiting, Alaska pollock, red cod, blue cod, southern hake, merluza, southern blue whiting and hoki are among them.

Photo: Carsoe

CASE / Innospexion

GAME-CHANGING TECHNOLOGY FOR FISHBONE DETECTION

For fish factories around the world, customer complaints about bones are one of the most common causes of recalls and returned shipments – with massive food waste as a result.

Still to this day, a significant number of consumers are reluctant to consume fish due to potential fish bones. Novel x-ray technology from the Danish company Innospexion is proving to be a highly effective solution.

The technology bridges a gap in bone detecting capabilities. Fishbones below 0.3 mm in thickness are not a problem because they are too small to notice. But, as fish processing lines were previously unable to detect bones below 0.7 mm, that left a significant margin for consumer dissatisfaction.

Innospexion's specialised x-ray imaging tool has now broken through this barrier – making it possible to detect fish bones right down to 0.1 mm at a speed of up to 300 frames a second.

Photo: Innospexion

> Accurate and reliable bone detection for guaranteeing boneless fish products

The system is designed for automatic bone detection in trimmed fillets from cod, haddock, red fish and other species. In addition, it can locate pin bones in salmon and small bone fragments in cut-offs used for fish blocks.

Each time a bone is detected, a computer control system sends a signal to a machine which then removes the bones from fish meat.

In this way, fish processors can ensure their products always deliver a high-quality eating experience and eliminate a wasteful problem.

Photo: Sæby Fiske-Industri

CHAPTER 5

GOING FOR MAXIMUM UTILISATION WHERE EVERY SEAFOOD COMPONENT COUNTS

FROM TOP TO BOTTOM OF THE VALUE CHAIN

Photo: Unsplash

Fish trimmings and other side streams are no longer regarded as waste but as important raw materials for high-value ingredients for food, feed and health products for human consumption.

Photo: Marine Ingredients Denmark

The Danish fishing industry has an ambition to create value from 100% of the seafood caught at sea or raised by aquaculture. Trimmings from fish fileting, bones, shells, skin and viscera – all have a value to explore and realise in ingredients for food, dietary supplements, petfood and feed.

Public-private collaborations in Denmark are constantly searching for new ways to make most efficient use of every component. In the pharmaceutical sector, the potential of bioactive marine compounds is consequently just starting to be revealed. At the lower levels of the value chain, seafood sidestreams are utilised as feedstock for biofuel production.

Apart from the exciting business opportunities they create, these efforts improve energy efficiency, reduce emissions and eliminate waste, enabling progress towards a circular bioeconomy.

Production of Marine Ingredients

Denmark is Europe's no. 1 producer of fishmeal and fish oil, producing more than 190,000 tonnes and 52,000 tonnes, respectively, a year and exporting to more than 40 countries worldwide. Along with sidestreams from fish production for the consumer market, the raw materials are primarily short-lived pelagic species, such as sprat, Norway pout, sand eel and herring,

Fishmeal producers receive most of their raw materials from the domestic and international fishery vessels that land in Denmark. Advanced processing facilities maximise the protein content of fishmeal, making it ideal for intensive livestock production, and secure the purity of fish oil, with its rich content of omega-3 fatty acids – known for their benefits to consumer health.

The consistently high quality of Danish fishmeal largely explains why so many export markets are keen to buy it. Co-production of fishmeal and fish oil is also key to Denmark's position as a leading exporter of feed and knowhow for aquaculture.

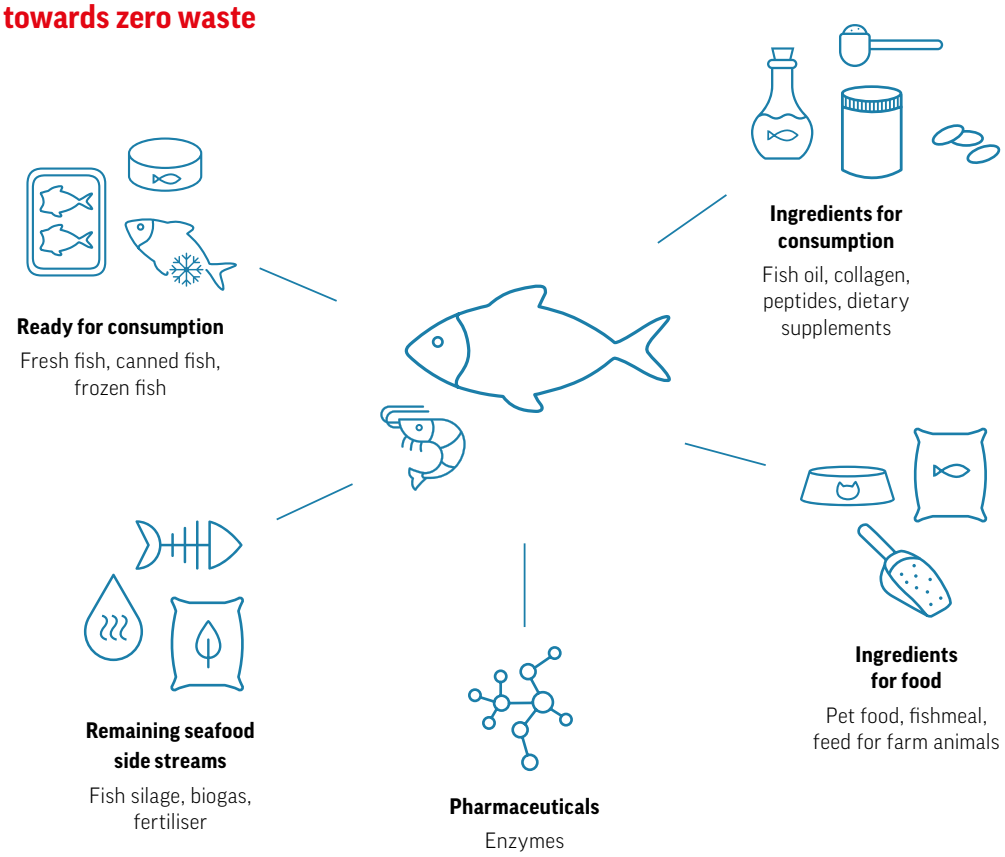
Other use of protein-rich fish trimmings
The fishmeal industry can look to Danish enzyme technology for solutions that optimise protein extraction while saving on energy consumption. The enzymes further enable the production of protein hydrolysates, natural flavours and flavour enhancers for the food industry.

In fish oil production, enzymatic processing is a gentler alternative to chemical extraction, improving the quality of the omega-3 fatty acids and enabling the creation of oils with differing ratios of docosahexaenoic acid (DHA) and eicosatetraenoic acid (EPA).

Nutraceutical potential
Danish research has inspired increasing investments in new value-added applications of marine ingredients in recent years. Fish-derived peptides and collagen are proving their potential in functional foods, nutraceuticals and pet food. Pioneering work at the University of Copenhagen has further discovered that fish oil intake during pregnancy can significantly reduce the risk of childhood asthma – a finding recognised by the Novo Nordisk Prize.

Renewable fuels and fertilisers
Once all other opportunities for value creation are exhausted, the remaining seafood side-streams serve as feedstock for biogas production and, after degassing, as a fertiliser. A recent initiative launched at one of the Denmark's primary fishery ports aims to convert protein-containing fishery wastewater into biogas. The biogas will be used to generate electricity and heat for the local community – the final link in a zero-waste value chain.

Use of fish towards zero waste



CASE / TripleNine and FF Skagen

UTILIZING UNUSED RESOURCES TO CREATE HIGH-QUALITY INGREDIENTS

Photo: Marine Ingredients Denmark

Today, Denmark is one of the global leaders in fish meal and fish oil products and the leading producer in Europe. The Danish fish meal and fish oil producers are committed to sustainable usage of natural resources based on biological advice.

By utilizing small, bony fish with no market for direct human consumption as well as by-products and trimmings from the filleting industry, Denmark has become a global leader in rich feed ingredients that are used in modern, nutritious feed around the world. Two of the largest Danish companies within this field are TripleNine and FF Skagen.

The primary raw materials for both companies are either small, short-lived fish with little or no potential for use in direct food production or upcycled trimmings from fish processing. Used in the production of fishmeal and fish oil, these valuable resources deliver essential nutrients to the fast-growing global aquaculture sector and the livestock sector.

The ingredients are rich in protein and nutrition and obey the highest safety and quality standards in the business. The valuable feed ingredients are used in feed and pet food industries all over the world.

The innovative ingredients from TripleNine and FF Skagen are an example of the Danish food approach where one man's waste can be another man's treasure. The usage of trimmings thereby contributes to a circular economy and ensures full resource utilization of fish from the sea.

> The final product is a rich ingredient that makes positive, sustainable impacts in aquaculture and livestock production

CASE / BioMar

MICROALGAE SUPPORT THE FUTURE OF SUSTAINABLE FISH FEED

Photo: BioMar

Marine ingredients are a valuable source of nutrition for farm-grown fish. But, if you ask one of the world leaders in high-performance feed for the aquaculture industry, the search for novel ingredients to advance innovation and sustainability is ongoing.

This is why Danish BioMar was first to introduce the microalgae product AlgaPrime™ DHA as a sustainable alternative to marine-derived omega-3 fatty acids for use in fish feed.

The goal is to reduce the so-called Fish in – Fish out ratio, which refers to the volume of live fish required to produce enough fishmeal or fish oil to grow a unit of farmed seafood. At the same time, BioMar wants to ensure that feed for aquaculture does not compete with food supply chains for human consumption.

As a natural source of omega fatty acids, microalgae are an obvious alternative. It is from these microalgae that fish and fish oil obtain their content of omega fatty acids. By formulating feed mixes with microalgae, it is possible to skip the 'middle fish'.

Using BioMar feed mixes with AlgaPrime™ DHA, fish farms can reduce their dependence on wild fish stocks, lowering the environmental impact of their production and helping to keep more nutrients in the value chain.

The transition to more sustainable fish feed is well underway, as the first commercially available feed mix with microalgae was launched in 2016. Today, microalgae is no longer a niche ingredient – but a commercially viable choice.

> The first commercial feeds containing microalgae hit the markets in 2016, and by 2021 BioMar had reached one million tonnes of salmon feeds containing microalgae

CASE / Biomega®

TRANSFORMING HIGH QUALITY SALMON OFF-CUTS INTO PREMIUM HUMAN NUTRITION

Innovative approaches are constantly working on increasing the intensity and effectiveness of utilization of the whole fish - from head to tail – and finding new ways to add more value and generate new products. For Biomega® Denmark, that means applying sustainable biotechnology in the production of value-added ingredients from food-grade salmon off-cuts.

Biomega® Denmark produces high quality ingredients for human and pet nutrition. In its modern biorefinery, they turn food-grade fresh raw materials into premium ingredients such as salmon oil, pure salmon peptides and collagen suitable for human nutrition.

The company uses a patented continuous enzymatic hydrolysis process to carefully separate the nutritional components. It is this gentle technology that produces Biomega® SalMe Peptides.

That makes them a high value natural protein source for dietary supplements and many other nutritional food concepts. The peptides are 100% water soluble and are absorbed by the body faster than intact native protein, which maximises nutrient delivery to muscle tissues.

Biomega® has a zero-waste approach to its production process. The remaining sidestreams are used to produce petfood.

> Neutral in taste and smell, the peptides, which are presented in a powder form, consist of more than 90% highly digestible salmon proteins

Photo: Biomega®, Nina Lerbrekk

CASE / Landia

SALMON WASTE POWERS BIOGAS PRODUCTION

Danish company Landia was the first-choice supplier when an integrated waste management facility (IWMF) on Scotland's Isle of Lewis needed a strong solution for handling salmon waste.

Creed IWMF had seen an opportunity in a logistical challenge – the remote location of aquaculture production sites all over the Scottish highlands and islands. Due to the difficulties in collecting and treating the fish waste, all of it went to landfill. Now they wanted to use it in an anaerobic digestion plant for biogas production.

Photo: Landia

But first they needed the right equipment – an ensiling tank for pre-treating the waste and a pasteuriser to meet local animal by-product regulations, which require the waste to be treated for at least one hour at 70°C. It all needed to fit into a very tight space.

With almost 90 years of experience in tailoring energy-efficient machinery, Landia had all the right credentials to supply an ensiling tank to blend the salmon waste into a smooth puree and a pasteuriser that met local regulations.

> The Landia solution is now processing seven tons of salmon trimmings per shift at the facility

The pasteurised fish waste – a seven cubic ton batch per shift - is now integrated with household food waste and garden waste for Creed's anaerobic digestion process, making a positive environmental and economic impact by not sending it to landfill or having it transported off the island. And it is contributing to the renewable power supply for the island community.

835.66 tonnes of salmon waste for the biogas plant was processed between 2017 and 2022.

CASE / JS Proputec

PUMP MANUFACTURER TURNS FISH WASTE INTO VALUE

A Danish manufacturer of lamella pumps uses tested technology to protect the environment and generate revenue by utilising waste from fish and shellfish processing.

For years, JS Proputec has designed, produced and delivered pump solutions worldwide to handle waste and by-products. With their proven separation efficiency, the pumps are ideal for separating oil from the solids in seafood waste.

The pumps are part of the system that handles and transports seafood products during processing.

As raw materials are kept in a closed pipe system, the pumps improve hygiene while reducing odours. This capability and their compact design also mean they can replace screw conveyors, progressive cavity pumps, pressure tanks and conveyor belts.

Additional advantages include lower energy and maintenance costs, higher capacity and fully automatic operation – reducing production costs and the risk of injuries.

Instead, the resulting value creation contributes to food security by providing a sustainable source of protein for animal feed. It can also help sustain the industry and support local economies where fishing is a main source of income.

Photo: JS Proputec

From an environmental perspective, the use of fish waste ensures potential pollutants, such as nitrogen and phosphorus, are not released into the ocean, where they can have a negative impact on marine life

From an environmental perspective, the use of fish waste ensures potential pollutants, such as nitrogen and phosphorus, are not released into the ocean, where they can have a negative impact on marine life.

CHAPTER 6

THE COLLABORATIVE ORIGINS OF DANISH FISHING INDUSTRY INNOVATION

CROSS-SECTOR PARTNERSHIPS WITH A VIEW TO GLOBAL CHALLENGES

Photo: Food Nation

Danish industry, academia and authorities have a tradition for sharing knowledge and driving solutions for sustainable and profitable fishing.

Collaboration is the seedbed for innovation in the Danish fishing industry. By coming together to share knowledge and perspectives, representatives from industry, universities and authorities continue to build new possibilities for sustainable growth.

One example of this fruitful way of working is the North Sea Science Park. For four decades, the park has provided a base for public and private actors to conduct research, provide advisory services and showcase the latest developments within fisheries and aquaculture. Facilities include laboratories, breeding halls and one of the world's largest tanks for testing fishing equipment. Thanks to a location right on the coast, real seawater conditions are in easy reach.

At DTU Aqua, part of the Technical University of Denmark, research and innovation is continuously underway in collaboration with Danish and international partners. Among its extensive facilities, DTU Aqua operates Denmark's largest vessel for marine biology, fishery and environmental research. Other fields of investigation cover aquaculture, shellfish and seaweed – generating a stream of new knowledge about aquatic resources and their sustainable utilisation.

Sustainability and compliance

As demand from consumers increases and new laws are enforced, the Danish authorities are indispensable to supporting fisheries and aquaculture. Primary focus areas include the joint efforts to optimise sustainability at sea and on land, limit adverse impact on the seabed and improve knowledge of the nutritional value of seafood products.

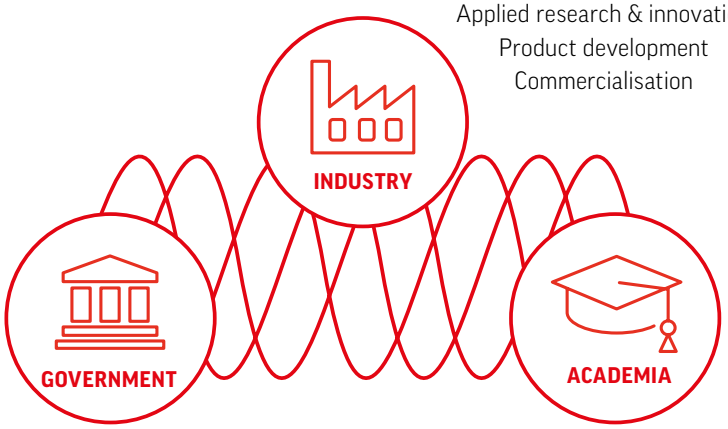
Another area of support concerns the trade of individual fishing quotas. The authorities take care of compliance with international regulations when quotas are transferred from one vessel to another. As in other fishing nations, the number of fishing vessels in the Kingdom of Denmark has fallen considerably since the turn of the century. However, those that remain have a bigger average size. An open and constructive dialogue between fishers and authorities ensures the Danish fleet can continue to operate a profitable business while maintaining wild stocks of each fish species.

Investments in the future

The tradition for collaboration plays a significant role in equipping Danish suppliers to meet a broad range of needs within international fishery, aquaculture and the seafood processing industry. New fishing equipment and technology is being developed to lower costs for fishermen and reduce environmental impact. At the same time, there is a great willingness in Denmark to nurture start-up enterprises with an innovative idea that can help solve some of today's global challenges. One Danish enterprise, for example, has developed a sustainable new protein source for aquaculture feed from methane-eating bacteria. Another young company has developed technology for producing nutrient-rich seaweed in the process water of land-based aquaculture – removing waste nutrients from the water. The innovative cycle goes on.

Triple Helix Model

Industry
Applied research & innovation
Product development
Commercialisation



Authorities
Legislative framework
Regulation

Universities/research & technology organisations
Basic & applied research
Education & training
Demonstration & testing
Government advice

CASE / DTU Aqua

SIMPLE INNOVATION IS THE KEY TO PRECISION FISHING

Fish quotas and regulations on bycatch give fishers many good reasons for wanting to know more about the fish they are catching in the trawl. By moving from a blind operation to precision fishing, they can improve their ability to catch only the desired species and size and reduce their environmental impact as well as CO2 emissions.

Research at the Technical University of Denmark's AQUA department (DTU Aqua) has developed new technology to help them on the way.

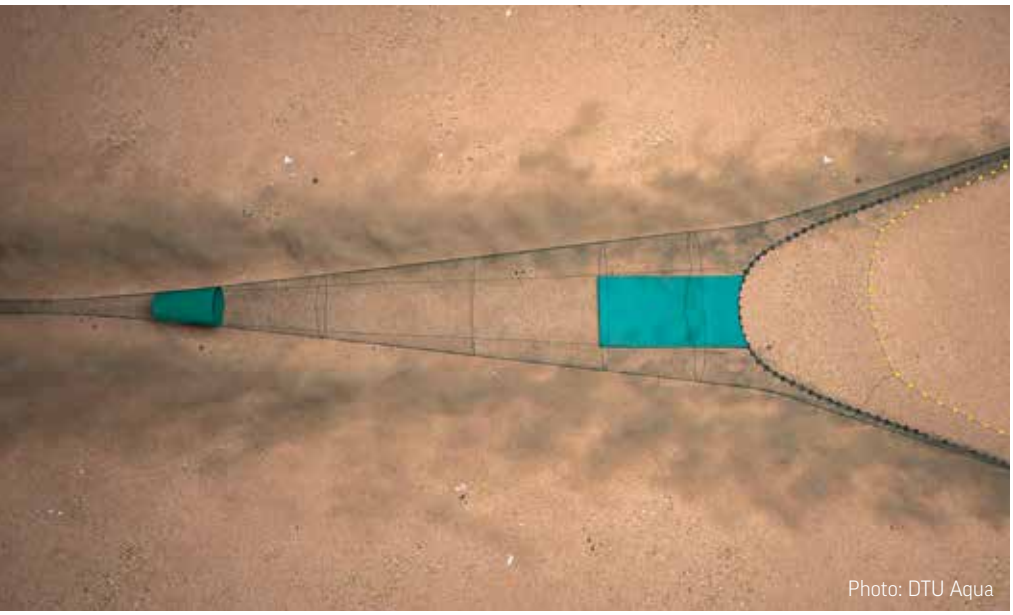


Photo: DTU Aqua

The first revolutionary step was the development of the first ever sediment dampening system, consisting of a sheet of tarpaulin mounted at the front of the trawl. This simple and effective system reduces the sediment swirled up by the trawl's movement to allow a clear camera view for monitoring, measuring and recording the catch.

Attracting great international interest, the sediment dampener has initiated further development of catch monitoring systems. In cooperation with the Danish company Atlas Maridan, DTU Aqua has designed a cable-based trawl camera system which shows the catch in real time.

Now, for the first time, it has become possible to follow the species entering the fishing gear and keep track of where they were caught.

> Based on this innovation, fishing with trawl no longer has to be a blind process. Fishers are kept informed about the commercial viability and sustainability of the fish in each fishing ground

CASE / DTU Aqua

AQUACULTURE TECHNOLOGY ALLOWS GROWTH WITHOUT COMPROMISE


Photo: DTU Aqua

Aquaculture has huge potential to feed the world's growing population. The challenge is to grow aquaculture production sustainably without conprimising on the environment.

A Danish collaborative project – Inno-Tek – has come up with two practical treatment technologies aimed at decoupling the growth of land-based fish farms from environmental impact caused by nitrogen, phosphorus and organic matter emissions.

The first solution is the use of flocculating bacteria to reduce nitrogen levels in end-of-pipe water, fast and efficiently. Using this technology, the nitrogen removal process can be reduced from 17 hours to four.

Secondly, the project developed a solution that draws on biodegradable flocculants and lignocellulose components to produce a much drier waste product. This makes waste streams easier and less expensive to transport and more suitable for reuse in energy production or as a fertiliser.

Together, the cleaning solutions allow the reactor used for nitrogen removal to be significantly reduced in size, while the dry matter content of waste is increased from five % to 50%.

The Inno-Tek project has received funding from the Danish marine and fisheries development program, which supports the EU goals of intelligent, sustainable and inclusive growth. The partners are DTU Aqua, Alumichem, Alpha Aqua, Dansk Akvakultur, Danforel and AquaCircle.

> The challenge is to grow aquaculture production sustainably without comprimising on the environment

ABOUT FOOD NATION

Photo: Food Nation

Interested in hearing more about Denmark's strengths as a centre for agrifood innovation? Contact Food Nation.

Food Nation is a non-profit partnership established by the Danish government and leading private organisations and companies. It is your gateway to information about the Danish food cluster and knowhow that can accelerate the growth of international businesses through better solutions, innovative products and trusting cooperation.

The Danish food cluster encompasses everything from primary production in agriculture and the fishing industry to the food products consumers buy in stores. Companies, universities, research institutes, local and national authorities and other private and public organisations belong to the extensive, collaborative network. Together, they work hand-in-hand with international partners to maintain and improve food quality and safety along the value chain.

Take an interactive tour

Food Nation's Visitor Centre in central Copenhagen and in Agro Food Park in Aarhus welcomes international delegations, providing them with an introduction to Danish capabilities within food and agriculture. An interactive installation at the centre gives visitors an up-to-date overview of the food value chain based on their individual interests. It is the ideal starting point before visiting Danish food producers and production facilities.

An inspiring preview is also available from the Food Nation digital universe. Here, inspirational publications, webinars, videos and talks provide insights into how Denmark can contribute to the green transition. Visit the digital platform at **foodnation.virtualhive.live**, register as a user and take a browse.

Food Nation is a great place to start learning about how Denmark support sustainable development through collaboration. Find out more about our services, the Danish food arena and arranging a visit to the Food Nation visitor centre at **foodnationdenmark.com**

INGREDIENT INDUSTRY

Producers of enzymes, cultures and other ingredients

PRIMARY PRODUCTION

Agriculture, fishing & horticulture

PROCESSING INDUSTRY

Producers of food, beverages & animal feed

The Danish food cluster

Denmark is home to countless large, medium and small companies, research institutes and other organisations that make the country a European hotspot for innovative food products, services and technology.

RESEARCH & INNOVATION

Research, education & counselling institutions

INNOVATIVE TECHNOLOGY

Producers of machines, technology & equipment

GASTRONOMY & THE CONSUMER

Retail, consumers, restaurant, authorities, tourism & other related industries

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