

# creatingvalue

Project year 2023



25 examples of  
useful research



# 42 highlights from research on closed systems

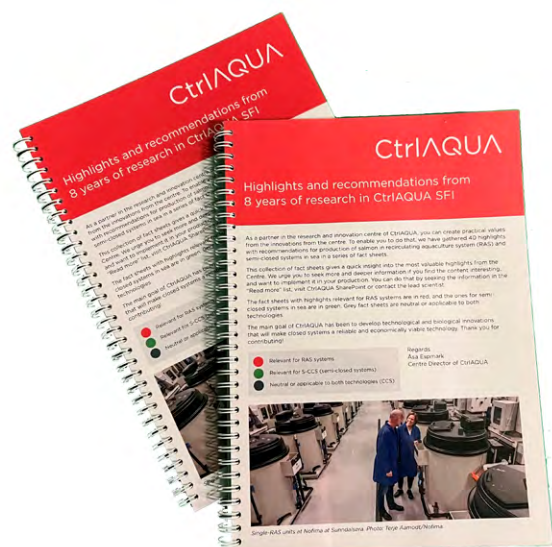


Photo: Terje Aamodt, Nofima

From 2015 to 2023 Nofima hosted the Centre for Research-Based Innovation (SFI) in Closed-Containment Aquaculture - CtrlAQUA.

The main goal was to develop technological and biological innovations that will make closed systems reliable and economically viable technologies.

Together with our partners in industry and research, we have created a lot of knowledge. We have gathered 42 highlights with recommendations for production of salmon in recirculating aquaculture system (RAS) and semi-closed systems in sea in a series of fact sheets.



View the 42 factsheets:



# 25 examples of useful research

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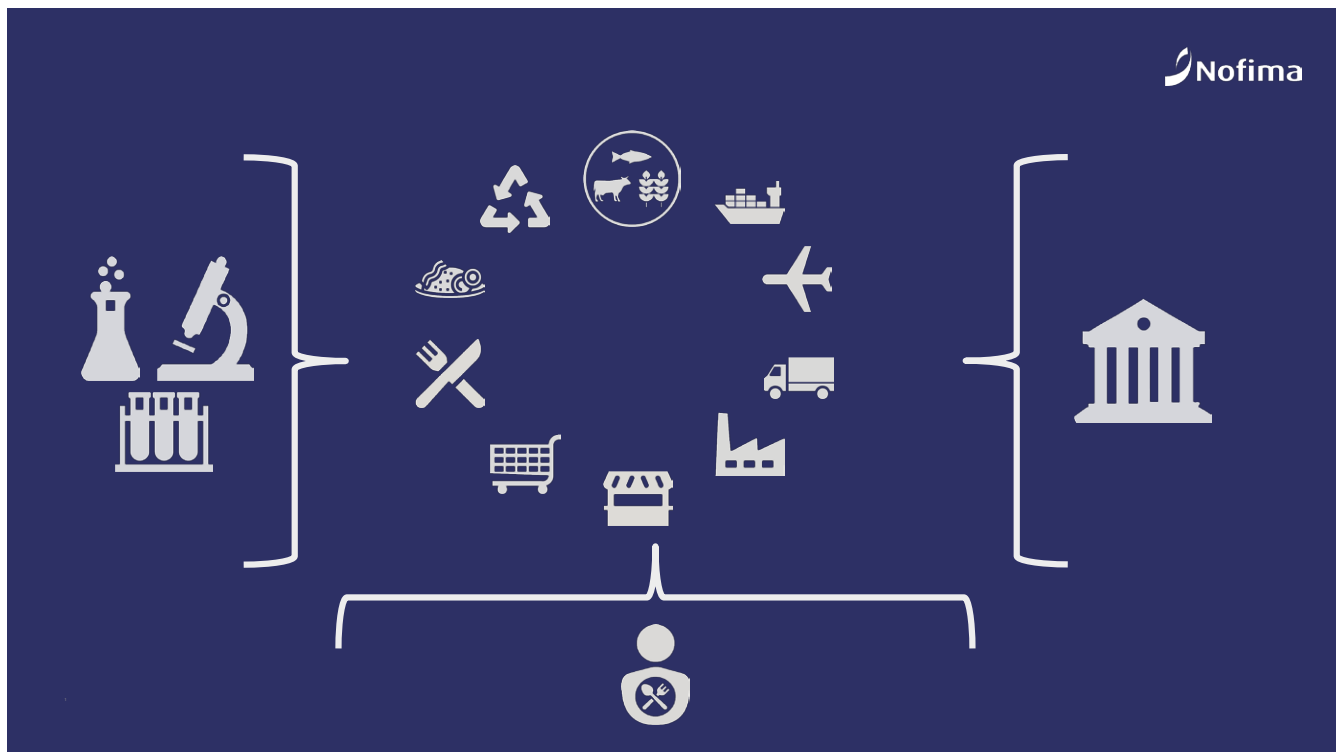
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# Think of the food system as a circle



It has been a long time since we realised the Earth was not flat but round like a circle. Food systems are the same, but the following can't be said enough times: we need to think of food systems as a circle, and research and act accordingly.

After six months as CEO of Nofima, I am more convinced than ever that we must strengthen the circular mindset in food systems. We must take into account all the input factors when working towards Nofima's vision; sustainable food for everyone. This is a big task that demands a lot of effort.

Land-based food systems account for one-third of anthropogenic greenhouse gas emissions. The potential for reducing greenhouse gas emissions is therefore huge. Primary production is part of the circle, and this is followed by transport, processing, marketing, sales, distribution, preparation, consumption, and reuse. Things have then come full circle. Nofima's research contributes concrete solutions throughout the entire circle.

UN's "Sustainable Food Systems Summit" in 2021 confirmed that all 17 Sustainability Development Goals depend on the development of sustainable food systems. In order to succeed globally, the local and national food systems must have a concrete strategy for sustainable development. The message is "Think globally, act locally".

Norway is conducting strategy work for the Norwegian sustainable food system. I am pleased that the Ministry of Agriculture and Food is coordinating this important national dialogue where seven ministries are involved. The first meeting with the various actors has already taken place. I participated myself, and Nofima will follow up this work with knowledge and expertise on sustainable solutions in the food systems of the future.

A sustainable food system delivers food security and nutrition to everyone in such a way that the economic, social and environmental foundations are maintained for future generations. Nofima develops concrete solutions with insight into the holistic food system.





Food is cross-sectoral. The health authorities recommend that we eat a balanced diet with ingredients from the blue and green sectors. Lean and fatty fish, fruit, vegetables and meat. There are also many examples showing that the problems and rest raw materials in one food sector can be resources in another. When we think of a food system as a circle criss-crossing between sectors, rest raw materials can become a valuable resource as food and feed ingredients. Nofima contributes to the development of such useful solutions in all food sectors.

The world needs healthy and safe food. And enough food. Today, 25 % of produced food is thrown away. Can a Norwegian food research institute do something about this? Yes, we believe so. Minimising food waste is necessary for a well-functioning food system. At Nofima, we conduct research to increase the shelf life and quality of food, develop optimal packaging solutions, make better use of rest raw materials, and to understand and influence consumer attitudes and behaviour related to food waste.

With a joint research strategy for the entire institute, we work with all parts of the food systems to utilise the company's expertise and infrastructure in the best possible way. The solutions will still be local, in a limited part of the circular system, and developed with good insight into the food system they are part of. We can then innovate so that the food systems of the future will collectively be more sustainable.

Sustainable food for everyone is our vision, and we strive to fulfil it every day.

**Bente E. Torstensen**  
Managing Director



# Good, green, healthy and Norwegian

New nutritious and tasty plant-based products made from Norwegian ingredients will soon be available on dinner tables and in hotel buffets.



Photo: Jon-Are Berg-Jacobsen, Nofima

Grethe Iren Borge, Astrid Nilsson and Tom Johannessen in some of the halls at Nofima, where testing and development of the plant-based concepts takes place.



*Rapeseed oil has a high content of healthy unsaturated fats and a lot of omega-3 fatty acids*



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**Funded by:** FJM – Forskingsmidlene for jordbruk og matindustri

**Partners:** Jæder Ådne Espeland AS (project owner), Igeløsa Life Science AB and 12 industry actors.



In the NORSKVegetar project, Nofima experts have worked with project owner Jæder and 12 other partners to develop plant-based products. The result is two promising concepts where taste, health and origin of produce are key.

“The raw ingredients are healthy, and their combination gives good flavour and the correct nutritional composition. The necessary functional properties are also in place, such as stable unsaturated fats. Several research challenges have involved combining functionality and nutritional goals,” says Senior Scientist Grethe Iren Borge. She is responsible for the project’s research.

“Fat is important for product quality. The ambition for healthy products led us to rapeseed oil. Rapeseed oil has a high content of healthy unsaturated fats and a lot of omega-3 fatty acids,” says Senior Scientist Astrid Nilsson.

The challenge of only using rapeseed oil as an ingredient in plant-based products is that it is liquid at room temperature and therefore seeps out of the product easily.

“We have managed to solve this challenge. In collaboration with Alimenta, our Food Technologist Tom Johannessen has developed a method to stabilise the rapeseed oil so it can be used in the products. This is an important step towards healthier plant-based products,” says Astrid Nilsson.

### Grains play a key role

Norwegian barley and oats are included in the concepts. Both are good sources of protein and are rich in dietary fibre and, together with vegetables, ensure that the products are rich in fibre. The grains also provide good texture and suitable chewing resistance.

One product concept is a grain and vegetable dough with high fibre content and typical Norwegian vegetables such as carrot, onion, beetroot and potato. The other is a plant-based dough. This dough has a similar protein content to minced meat and is based on protein from fava beans, grains and vegetables.

Photo: Nofima



Vegetables can be further processed into ingredients or into own products.

### Easier to reach 5 a day

“Our plant-based products should not compromise, neither on taste nor nutritional content. The colour and texture must also be in line with consumers’ preferences,” says Rakel Wester, Marketing and Sustainability Manager at Jæder, and project manager for NORSKVegetar.

Different types of vegetables are included in the products and are selected based on several criteria. They should be growable in Norway, they should complement each other both nutritionally and taste-wise, and they should emphasise desired flavours and colours, such as beetroot that contributes red colour and umami flavour.

“Different vegetables provide different nutrients and healthy phytochemicals. That’s why we included a wide range. The products can contribute to increased vegetable intake in the population. A variety of produce is also good for intestinal health,” says Grethe Iren Borge.

### Building a platform of knowledge

“Many types of vegetable have been tested, both fresh and frozen. We have also taken a closer look at surplus tomatoes with varying degrees of ripeness. Vegetables that are processed into purées and emulsions can give positive characteristics to the product both in terms of texture and bioavailability. This applies to beta-carotene, for example,” says Borge.

This is an example of research knowledge that has not been used in the first products. Nevertheless, the knowledge will be useful. This new knowledge is gathered in a platform of knowledge and can be used in future development work.

Another part of the platform of knowledge is nutritional content.

“We have done a number of nutritional calculations and looked at total fat and the ratio of unsaturated and saturated fat, and protein, fibre and salt content,” says Ida Synnøve Grini, Senior Nutrition Adviser.



Ida Synnøve Grini has made nutrition calculations for the various product concepts.

Photo: Jan-Are Berg-Jacobsen, Nofima

# Fully possible to avoid runoff

It is possible to eliminate the problem of runoff water from lorries transporting fresh fish. Temperature control makes all the difference.

“The critical factor is to sufficiently chill fish to a core temperature lower than 1°C before they are packed in crates filled with ice”, says Nofima scientist Bjørn Tore Rotabakk.

Most of the fresh fish transported by lorry in Norway are transported in EPS crates chilled with ice. Insufficient cooling of fresh fish before packing causes a significant amount of ice to melt during transport. The meltwater then drains off the lorries through drainage holes and onto Norwegian roads. This leads to traffic hazards and fouling.

“If the temperature in the fish is 3 degrees, almost 650 liters of runoff is produced, and if the lorry temperature is also set to 3 degrees, 740 litres are produced during the first 48 hours of transport,” says Rotabakk.

He has led efforts to find a preferred temperature regime from packing to delivery of fresh fish in order to reduce the amount of runoff during transport.

## Model for calculating runoff

It has resulted in a model that will help industry actors to calculate the volume of runoff that is produced based on the temperature of the packaged fish.

“There are major differences in fish temperature control between the various industry actors. The main runoff challenge probably lies with the producers, where the fish are generally not sufficiently cooled,” says Rotabakk.

The researcher believes that rapid and effective cooling should be in the interests of the producers, distributors and consumers alike, as it provides better quality and extended shelf life of the fish.

“If you are unable to sufficiently cool the fish, for example during transport in the summertime, you can either compensate by postponing the shipment, or by using watertight crates,” says Bjørn Tore Rotabakk.



*Rapid and effective cooling should be in the interests of the producers, distributors and consumers alike, as it provides better quality and extended shelf life of the fish*

## Several methods can solve the problem

Several attempts have been made to stop the runoff problem, but no one has succeeded in eliminating it so far. The researchers summarise in the report ‘Reduction of meltwater runoff from fish transport’:

- Watertight crates seem to be an alternative that can be implemented quickly if the fish are sufficiently chilled. Watertight crates must either be designed to collect the meltwater runoff without the water coming in contact with the fish, or an absorbent layer must be used. Both solutions will be more expensive compared to the current solution, where the meltwater runs through drainage holes in the crates.
- Another option is to fit collection tanks underneath the lorries to collect the runoff meltwater. There are certain capacity issues with this option, as the tanks currently available only hold around 250 litres. It will also take time before tanks can be installed on all lorries transporting fish in Norway.
- Another option is alternative refrigerants that do not produce runoff, such as CO<sub>2</sub> snow and gel-ice. CO<sub>2</sub> snow is costly and can involve HSE concerns. Gel-ice is also more expensive than ice and creates waste problems for the customer.



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**Partners:** SINTEF Narvik and NTNU





Photo: Christian Petrich, Sintef

*Runoff from lorries carrying fresh fish is a traffic hazard. Nofima, Sintef and NTNU have launched a website that can help solve the problem.*

### Main findings

- The most important measure to reduce runoff from lorries transporting fish is to sufficiently chill the fish to below 1°C before loading.
- Measures such as watertight crates and collection systems are feasible, but no systems currently exist that present a quick solution to the problem.
- A combination of improved chilling practices and watertight crates or collection systems could be a good option
- A model has been created where one can calculate the volume of runoff produced based on the temperature of the fish as it enters the crate and the ambient temperature of the crate.





*Bente Ruyter and her colleagues at Nofima have been researching a new oil for fish feed.*

# Research on new oil source

When fish eat plant oil containing marine omega-3, they get more omega-3 in their flesh, better pigmentation and fewer dark spots.

A new oil has been approved and can be used in fish feed.

Currently, the world cannot make enough ingredients containing marine omega-3 fatty acids. Demand is greater than supply.

Bente Ruyter has conducted research for many years to find out how farmed salmon can get a higher content of omega-3 in the fillet. One option is oil from modified canola.

## Canola oil

"The Norwegian Food Safety Authority has approved a genetically modified canola oil that can be used in salmon feed. The plant produces marine omega-3 fatty acids. Many years of research together with the industry has brought us to this point," says Ruyter, Senior Scientist at Nofima.

Canola is a variant of common rapeseed. The canola that provides the oil researched by Nofima has been genetically modified and developed by the Australian research organisation CSIRO in collaboration with the company Nuseed. As a result, it contains more of the omega-3 fatty

acids that salmon need to stay healthy, and that humans benefit from.

"This oil has been extracted," says Bente Ruyter. It means that it is extracted from the canola seeds and does not carry any of the plant's genetic material that has been modified.

"Research has been carried out over many years to see if this oil can be used in fish feed," she says. The scientists have found that it is suitable and the Norwegian Food Safety Authority has also approved it.


## EPA and DHA

It is all about the omega-3 fatty acids called EPA and DHA. In nature, marine microalgae produce these fatty acids. Crustaceans then eat these microalgae, and the fish eat the crustaceans. Therefore, EPA and DHA end up in the fish.

It has been difficult to get high enough level of these fatty acids in farmed salmon. Therefore, microalgae genes have been inserted into canola so that it can also make the same fatty acids. When the oil is used in fish feed, the





 *Currently, the world cannot make enough ingredients containing marine omega-3 fatty acids. Demand is greater than supply*

scientists have found that the fish perform better, get more omega-3, fewer dark spots and better red colour in the fillet.

#### **Not enough wild fish**

"Global production of fish oil is stable: catching more wild fish is not sustainable. Therefore, fish oil is becoming less and less available for the aquaculture industry every year as the industry grows", says Ruyter.

In 2000, 30 % of salmon feed consisted of fish oil. In 2020, this was down to 10 %.

"Our research shows that it is not healthy for salmon to have such low levels of omega-3 in the feed. They become less robust and their flesh has poorer colour. The industry has therefore started to increase the level of omega-3 fatty acids in the feed again," she says.

#### **Need new sources of omega-3**

"The production of genetically modified canola has great potential for growth, and will probably become an important new source of omega-3 in the fish feed," says Ruyter.

It makes the fish healthier than if they were only fed standard plant oil. Salmon also need a certain level of omega-3 in their feed in order for their muscles to get the delicate pink colour. Nofima's research also shows that the omega-3-rich canola oil reduced the prevalence and severity of dark melanin spots in salmon fillets.

Nofima has previously shown that [the fatty acid DHA has this effect](#).

In order to document the properties of the oil in salmon, scientists have had to carry out trials in fresh water, in closed tanks and finally in net-pens at sea. All the while, they have had to ensure that nothing is discharged into the surrounding nature. As a result, they carried out trials in all phases of the fish's life.

"It is now approved for use. Whether the industry uses it is another matter. But I think it will force its way in," says Bente Ruyter.



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# Sustainability as an innovation driver

Having more environmentally friendly and healthier food is an important sustainability strategy for Norwegian food companies.



Photo: Jon-Are Berg-Jacobsen, Nofima

Antje Gønera and Laura Carraresi have studied major Norwegian food companies' relationship to sustainability-oriented innovation.

"We interviewed nine major food companies and reviewed their sustainability reports. We then mapped how sustainability work affected their innovations," says senior scientist Antje Gønera.

All nine companies have created positions dedicated to sustainability. The initiative is strategically important and an investment in the future. Investments in sustainability do not yield short-term gains. The concept of sustainable food is complex and controversial. There are many definitions, but the UN Sustainable Development Goals are an important starting point.

## Better public health, packaging and resource utilisation

Several of the companies point out that they have always worked on innovation in areas related to the UN goals. Public health is one example, where many have reduced salt, sugar and saturated fat content, and increased dietary fibre. Another example is packaging; solutions based on recyclable and/or recycled materials, and the use of new types of raw materials, such as cellulose and algae.

Companies prevent food waste by using new/updated technology. Examples are sensor and hydrolysis technology for better utilisation of raw materials, or sequencing technology that identifies harmful bacteria.

## Building expertise

Consumer wishes and demands are an important driver of sustainability innovation. At the same time, companies are working in areas that consumers don't notice as much, such as solar panel systems and biogas, or alternative modes of transport. The requirements for suppliers are increasing at the same rate.

"We have developed a model that shows the effects for three levels of sustainability innovation; operational optimisation, organisational change and system development. We also see that collaboration with new actors and participation in research projects increase innovation capacity and improve skills and ability to implement," says Laura Carraresi.



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# Identifying nephrocalcinosis in field

Nofima scientists have further developed diagnostics making it possible to identify the extent of nephrocalcinosis in live fish.

Nephrocalcinosis is a rapidly developing kidney disease in salmonids, the extent or causes of which are not fully known.

The annual fish health report from the Norwegian Veterinary Institute grades nephrocalcinosis as the hatchery-phase disease or welfare problem that most fish health experts say is increasing. They report high mortality rates and reduced welfare.

"More nephrocalcinosis is emerging in new modes of operation. When we are not always able to reproduce the disease in trials, it shows that the causes are complex," says veterinarian Kirsti Hjelde.

## Applicable in the field

The kidneys purify blood and are one of the largest blood-forming and immunological organs in fish. When smolt are transferred to sea with defective kidneys, they tend to struggle more.

X-ray analysis of nephrocalcinosis is used commonly on mammals. The scientists are now using a new X-ray method right next to the tanks of fish. Nofima has adapted an existing diagnostic tool for practical use:

The method has been published by Christine Klykken from Aqua Kompetanse and NTNU in her PhD. Hjelde has further developed diagnostics to be more practically applicable in the field.

Hjelde believes that the diagnostic tool is important in finding out how much nephrocalcinosis there is.

However, it is also important that everyone working on diagnosing the disease speaks the same language.

"I know many who have their own diagnostics. We all need to coordinate so we can compare occurrence and start finding causes and measures."

## Extra relevant in RAS

The disorder is well known in intensive farming of rainbow trout, but it is now increasing in salmon and occurs in many RAS facilities.

"When we deprive farmed salmon of all choices, we must ensure we provide them with good conditions," says Hjelde.



Photo: Terje Aamodt, Nofima

*Scientist Kirsti Hjelde hopes the entire aquaculture industry can diagnose nephrocalcinosis in the same way so that the cause can be found.*



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# The auction obligation works

Halfway through the evaluation period, the auction obligation for frozen cod and saithe looks to have worked as intended.

“The percentage of frozen, whole, gutted cod and saithe offered in the Norwegian Fishermen’s Sales Organisation and Surofi’s auctions increased in 2022”, says Senior Scientist Geir Sogn-Grundvåg.

From 2013 to 2017, the proportion of frozen whitefish sold at auction through Surofi decreased from 58 % to 40 %. At the Norwegian Fishermen’s Sales Organisation, the auction share for frozen cod fell from 52 % in 2009 to 31 % in 2017.

## Fewer raw materials for onshore industry

When a significant percentage of fish is not sold at auctions, it may also become less available as raw material for the Norwegian processing industry.

“To increase the percentage of raw materials offered at auction which will then be available to the onshore industry in Norway, the possibility of self-acquisition of catches was removed from 1 October 2021. A partial auction obligation was also introduced in 2022 for whole frozen cod and saithe”, says the scientist.

A minimum of 50 % of the frozen whole cod and saithe from each vessel must be offered at auction during the year.

## 2023 Evaluation

The submitted interim report shows that the main purpose of the evaluation is to investigate whether the partial auction obligation leads to the most open competition possible for the raw material, and to ensure that the fish processing industry in Norway has sufficient access to raw materials.

“Now that more fish is being offered at auction, it seems the obligation has worked,” says Geir Sogn-Grundvåg.

At the request of the industry, FHF has extended the project by one year so that all of 2023 will also be included in the final evaluation.


 *When a significant percentage of fish is not sold at auctions, it may also become less available as raw material for the Norwegian processing industry*

Illustration photo: Ole Åsheim, Nofima



In order for the fishing industry to get more raw material, a partial auction obligation for frozen cod and saithe was introduced in 2022. It seems to be working.



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*These breeding cod are sixth-generation farmed cod and they spawn fewer times than their ancestors.*

# Fewer spawnings than before

Previously, farmed cod in the breeding programme could spawn three times before reaching harvest weight. After being selected for growth, they spawn once.

On behalf of the Ministry of Trade, Industry and Fisheries, Nofima runs the national breeding programme for cod, and supplies fertilised eggs to cod farmers.

For six generations, the breeding goal has mainly been growth. Breeding for growth has reduced the number of cod spawnings during the 20 months at sea before slaughter weight from three down to one.

Spawning is undesirable in fish farming. For the farmer, spawning means reduced growth. For the environment, there may be a risk of spreading fertilised eggs in the sea cross with wild fish in the following generation.

## Breeding for growth results in fewer spawnings

Many cod still reach sexual maturity prematurely if light cycles are not manipulated. In the industry however, development is controlled with light.

Sexual maturation reduces the availability of resources that can be utilised for rapid growth. Energy is relocated from muscles and liver to gonads. Sexual maturation results in the cod spawning.

## Can be postponed

While it is a prerequisite that cod spawn in a breeding programme, spawning is an undesirable trait in commercial farming. Therefore, Nofima wants to put an end to early sexual maturation.

Recently, Nofima breeding scientist Anne Kettunen led a major trial. She tested the extent of early sexual maturation on more than a hundred full-sibling families in net-pens in Nordland. The study showed that 84 % of females and 91 % of males reached sexual maturity at two years of age when they were not managed with light. Calculations show that there is considerable genetic variation in early sexual maturation in cod. 33 % of the trait depends on genes, the rest on the environment.

"This means that it is possible to breed for lower frequency of early sexual maturation, and thus further reduce the risk of spawning in net-pens.

In Nofima's breeding work, we are looking for several solutions, where breeding is one of them. Of course, production management at the fish farms is also part of the solution," says Kettunen.



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# Norvegia should always taste the same

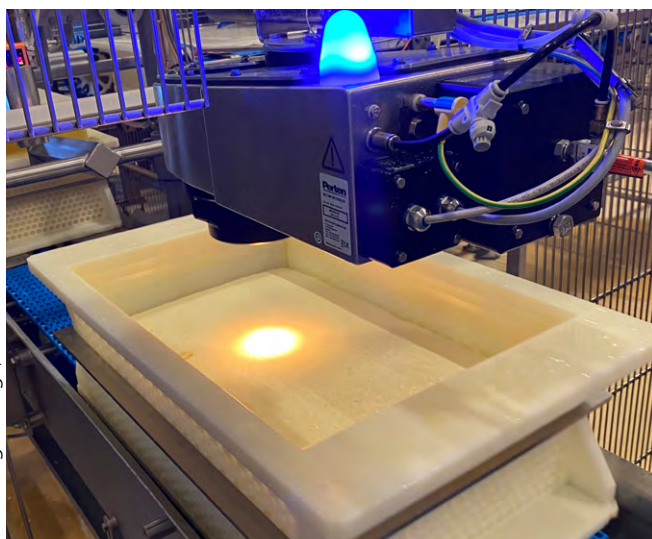
Tine's Jæren dairy produces Norway's best-selling cheese – Norvegia. They can now control the process so that the cheese always tastes the same.

Photo: Jon-Are Berg-Jacobsen, Nofima



Senior scientist Ingrid Måge collects data that contributes to Norvegia cheese always tasting the same.

Photo: Ingrid Måge, Nofima



The NIR sensor measures the content of a block of cheese, using light.

An NIR sensor has been installed at the dairy's production line. Using light rays, it measures the fat and dry matter contents of the passing cheese.

– “It is a challenge to produce cheese with consistent quality. Milk varies according to cow breed, season, weather and feed. The process conditions also affect things,” says Kjetil Holstad, Head of Research and Development at Tine Meieriet Jæren.

## Dry matter is important

Norvegia plays an important role in regulating the milk market. When milk production is high, more is made – and the cheese is stored longer.

– “Norvegia becomes softer during storage when protein is broken down, so more dry matter is needed for longer storage. We also know that our customers dislike cheese that is too firm and dry,” says Holstad.

## Measuring every cheese

A comprehensive dataset is needed to unravel the links between raw materials, process conditions and cheese quality. Expertise and investment in data processing and analysis are also needed. TINE has therefore collaborated with Intelec and Nofima for several years.

Previously, only one in every 350 cheeses was sampled. The NIR sensor measures every cheese directly on the production line and collects enormous amounts of data.

– “Data must be collected over a long period of time to record all variations. We also need to test the effect of different process conditions by making controlled changes in temperatures and time spent in the different production stages,” says Nofima Senior Scientist Ingrid Måge.

Nofima provides the measurement methods and data analysis that give a better understanding of process relationships.

Intelec specialises in time series analysis. They focus on finding information and patterns from sensors that stream continuous data, such as temperatures and pH values.



*It is a challenge to produce cheese with consistent quality*



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**Funded by:** The Foundation for Research Levy on Agricultural Products (FFL), SFI DigiFoods, the Research Council of Norway and partners

**Partners:** Tine Meieriet Jæren, Intelec



# Huge breeding potential in microalgae

Scientists have now shown that microalgae can grow faster and form more omega-3 if bred. This makes them even more interesting as a feed ingredient.



Photo: Jon-Are Berg Jacobsen, Nofima

*It has now been shown that selective breeding can significantly increase the omega-3 content of microalgae. Marie Lillehammer is behind the research.*

The most promising new feed ingredients for farmed fish are found at the very bottom of the food chain. This includes microalgae.

## Pioneer: Breeding potential

In order to grow, algae require light, temperature and nutrients. However, growth is also affected by the genes of the algae. Therefore, scientists tested whether it is possible to breed microalgae as one does with farmed fish: When crossing individuals or genera that produce high yields, the next generation produces higher yields than the previous one, and so on.

"We wanted to know whether breeding can contribute to faster growth and increased omega-3 content. The initial trials we carried out yielded very promising results," says Nofima Senior Scientist Marie Lillehammer.

They are probably the first to calculate genetic variation in microalgae.

Many microalgae reproduce vegetatively. Therefore, the scientists chose the species *Seminavis robusta* – a well-

studied alga that has sexual reproduction. Eight lines of the species were crossed with each other in one generation and tested in the breeding trial.

## 25 percent increase in one generation

Although the species is not very relevant as a feed resource, the trial showed that 18 % of omega-3 production in the algae is determined by the genes (heritability). Breeding gives an 8.8 % increase of omega-3 in one generation.

Growth percentages were even higher. With a 50 % heritability, the microalgae grows 25 % faster per generation; in theory, a ninefold increase per year, given ten generations in one year.

"It may be that inbreeding and physiological limitations would halt growth over generations, or growth would have side effects. However, the trial shows that breeding should be explored further if microalgae is to become an important feed ingredient for European aquaculture," says Lillehammer.

The research has been part of the EU project NewTechAqua.



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Photo: Lars Åke Andersen, Nofima

*Grete Lorentzen with the crabs that are growing well and have made it through the first, critical moult with great results.*

# Vast potential for crabs in the north

Research on crabs reveals vast potential for developing the snow and red king crab industry in the north.

Several previous, present, and future Nofima research projects involve developing what is becoming a lucrative part of the Norwegian seafood industry.

"The strategic 'SIS Helt Konge' project provides many answers but just as many new questions. There are no quick fixes in the development of a new industry. There is a lot we don't know yet, but the potential is vast," says Senior Scientist Grete Lorentzen.

Snow and red king crabs are also key species in the research project 'Fishery at 78° – Small-scale fishery for local value creation on Svalbard'.

"The project aims to prepare Longyearbyen, as the world's northernmost town, to become a culinary destination offering locally caught and processed red king and snow crab. In more detail, we aim to improve the

utilization of the local marine resources towards novel food products according to ideas from restaurant chefs on Svalbard and feedback from a survey among locals and visitors", says Lorentzen.

## Crab is King

The 'Helt Konge' project is about feeding juvenile red king crabs in groups towards commercial sizes.

The key for success includes right food, environment, and good conditions.

"The crab has turned out to be a good candidate for aquaculture. We know a lot about what it takes for crabs to thrive in captivity: eating, growing, and being nice to each other. And we are now in the process of finding the correct feed as well," says crab scientist Sten Siikavuopio



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**Funded by:** The Research Council of Norway and Nofima

**Partners:** The Matis research institute, and a number of industry actors in Svalbard





Sten Siikavuopio confirms that the snow crabs have grown considerably since the Institute of Marine Research first discovered them near Svalbard in 2017.



Photos: Nofima

Crab scientist Sten Siikavuopio (right) and chef Rogier Jansen at Basecamp Explorer with proof that snow crab are present at Isfjord Radio.

"If we succeed, we will potentially facilitate for a new industry in Western Finnmark," says Grete Lorentzen, head of the two crab projects.

Norwegian authorities do not want the red king crab to spread beyond the quota-regulated area in Eastern Finnmark. Therefore, a free fishing zone west of Honningsvåg has been established to minimize its presence. All red king crabs, irrespective of size and sex, are to be captured in the free fishery zone.

"The crabs caught west of Honningsvåg are generally too small for the market, as weights of minimum 1 to 2 kilograms are preferred," says Grete Lorentzen.

### Successful moulting

Therefore, in the spring of 2022, the study started feeding small crabs with an initial weight of 250 g aiming for a minimum weight of 1.6 kg after 2 years of feeding.

"Before we get that far, the crabs have to go through two critical moultings where they get rid of the old exoskeleton and obtain a larger skeleton. This is how they grow, and the crabs are very vulnerable in this phase," explains Siikavuopio.

After successful moults, the scientists are optimistic.

"It has exceeded all expectations. The moulting shows that the crabs are growing well, and the mortality rate is less than 10 %. These are excellent numbers," says Siikavuopio.

### Trial fishing yielded results

In the ongoing 'Fishery at 78°' project, trial fishing for snow crab has been carried out to ascertain whether it can be considered a local species, which can help build Svalbard's culinary profile.

"The aim of the fishing trials is to find out whether snow crab is established in the fjords of Svalbard. We also want to identify whether the quantity is so large that it can be caught to use it for local value creation. Local, exclusive, Arctic food for residents and visitors", says Siikavuopio.

The very first discoveries of very small snow crabs northwest of Svalbard were made by the Institute of Marine Research back in 2017. In May, Siikavuopio and his colleague Gustav Martinsen declared that there is snow crab off the coast of Svalbard and that it has grown larger – but not yet reached commercial sizes.

"Other activities in the project have been testing crab among residents and restaurants in Svalbard, analyzing regulations facilitating for a future fishery, and a survey where we map tourists' and residents' expectations of utilising locally caught crab," says Grete Lorentzen.

# Food fit for a king

Lumpfish seem to be a suitable food for red king crabs after they have finished eating lice in fish farms.

“The idea behind the ‘Kongemat’ research project was to make something sustainable out of lumpfish,” says project manager Birthe Vang.

Cleaner fish in fish farms stop eating salmon lice when they reach sexual maturity. Today, the aquaculture industry often has to pay to get rid of the remnants of cleaner fish. It is not a good solution from either an economic or animal welfare perspective.

However, lumpfish have proved suitable as bait in crab fishing, so the question the researchers asked themselves was: Can lumpfish be used to feed small red king crabs?

## Increased appetite and feed intake

There are several ongoing projects at Nofima that focus on feeding small crabs until they reach marketable sizes of around 1.3 kilos. A suitable feed has already been developed by Nofima.

With this as a starting point, Birthe Vang and her colleagues got to work.

“We wanted to test whether whole or processed lumpfish that have been used as cleaner fish can increase appetite and feed intake in small red king crabs leading to increased meat content and value”.

## Hungry for lumpfish

24 red king crabs were part of a 12-week trial:

- 6 received crab feed developed by Nofima
- 6 received crab feed covered by a lumpfish protein concentrate
- 6 received half crab feed and half lumpfish
- 6 received lumpfish only

The results show that the crabs fed crab feed with lumpfish concentrate ate significantly more than the group that received regular feed.

Of all the seafood that Norway exports, red king crab achieves the highest price per kilo.

“If we succeed with this feed, it will contribute to the development of the circular bioeconomy and increased utilisation of raw materials. It will also help to increase value creation in the seafood industry and facilitate local jobs,” says Birthe Vang.



Photo: Anne-May Johansen, Nofima

Scientist Anette Hustad and master's student Tora Conardi-Larsen weigh, measure and study wild-caught crabs that have been given three different feeds.



Photo: Birthe Vang, Nofima

Original feed developed by Nofima to the left. On the right, the same feed, with 'syrup' of lumpfish, which is meant to make it more appetising.



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**Funded by:** MABIT

**Partners:** Capefish (Storbukt fiskeindustri), Salmar





Elisabeth Ytteborg is researching how warmer oceans affect cod.

# Farmed cod is vulnerable to heat

Nofima is connecting climate projections and fish health. It provides practical knowledge that can benefit long-term operations.

"We look at the climate crisis under a microscope, because the details are important when implementing fish farming measures while temperatures are rising," says Elisabeth Ytteborg, Senior Scientist at Nofima.

In her projects, the UN's climate projections have been scaled down to site level. It shows that expected temperatures in 2030 can cause damage to fish skin.

## Example from a facility

The scientists chose a facility located at Dønna in Nordland county in Norway. This facility has good data on cod farming and the environment.

The scientists wanted to study the impact of temperature on fish health, and what happens if cod are infected with the *Fransicella* bacterium.

Cod prefer temperatures between 8 and 13 degrees. By 2030, the facility at Dønna may experience days above 17 degrees. They therefore studied the effect temperature had on cod skin at 12 and 17 degrees.

The results showed that temperature has much more of an effect on barrier tissue functionality compared to infection with *Fransicella* bacteria.

At high temperatures, cod suffered damage between cells that bind the skin together. These skin bonds seem to affect the fish's ability to heal wounds, and damage to them can make the fish more susceptible to other stresses.

In other words, the cod's barrier system is weaker if it faces a challenge in addition to increased temperature.

## What can be done about it?

Ytteborg says there are currently several cod farms further south in Norway which can expect higher temperatures:

"The impact of high temperatures and how to deal with them will play a more important role in the future in line with climate change. How much the fish can tolerate will be important in finding good measures to safeguard fish health if the water becomes too hot," says Ytteborg.

Elisabeth Ytteborg believes climate change must be taken into account when planning fish farming in Norway.

"We are releasing a publication on diversification where we look at 36 different species and their temperature tolerance in relation to climate change. If Norway is going to have a longer-term diversification plan, one should definitely focus on temperature."



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# No-waste chicken products

Together with the industry, Nofima scientists are developing innovative protein powders using rest raw materials from poultry.

After removing fillets, thighs, and wings from poultry carcasses, valuable tissue remains on the carcass. This rest raw material has nutritious potential which is today not fully utilised. Our goal is to develop food ingredients from this raw material using enzymatic hydrolysis.

## Nothing is left to waste

After mixing raw material with water and enzymes, a hydrolysis process takes place which imitates the body's digestive process. Enzymes split larger protein molecules into smaller peptides and amino acids. After an hour, the process is stopped and the mixture is separated into three different fractions: fats, water-soluble proteins and a fraction rich in minerals.

"What is unique about this process is that all the raw material is converted into valuable products – nothing is left to waste. The current tests focus on extracting the protein fraction", says Nofima Senior Scientist Nils Kristian Afseth.

It is important that the final recovered product has consistent quality, however the composition of raw material is highly variable. Therefore raw material quality must be assessed, and processing conditions adjusted to optimize output and attain a consistent high final product quality. At Bioco, an NIR sensor measures the content of fats, proteins and bones in the rest raw material that goes into the process. NIR spectroscopy is a technique in which light is passed through materials to measure how much light is absorbed at different wavelengths.

"With NIR spectroscopy we can determine how much the raw material quality actually varies, and then assess how this variation affects the process and the final product", says Nofima's Katinka Dankel.

## Neutral taste

Variation in raw material composition, different hydrolysis enzymes, and processing conditions all affect nutritional composition and taste. Nofima's sensory panel has characterised the sensorial properties of several variants of the protein hydrolysates, with a goal to produce a protein hydrolysate with neutral taste.



Photo: Jon-Are Berg-Jacobsen, Nofima

"We need to understand the relationship between raw material composition, processing and product quality," says Nils K. Afseth.



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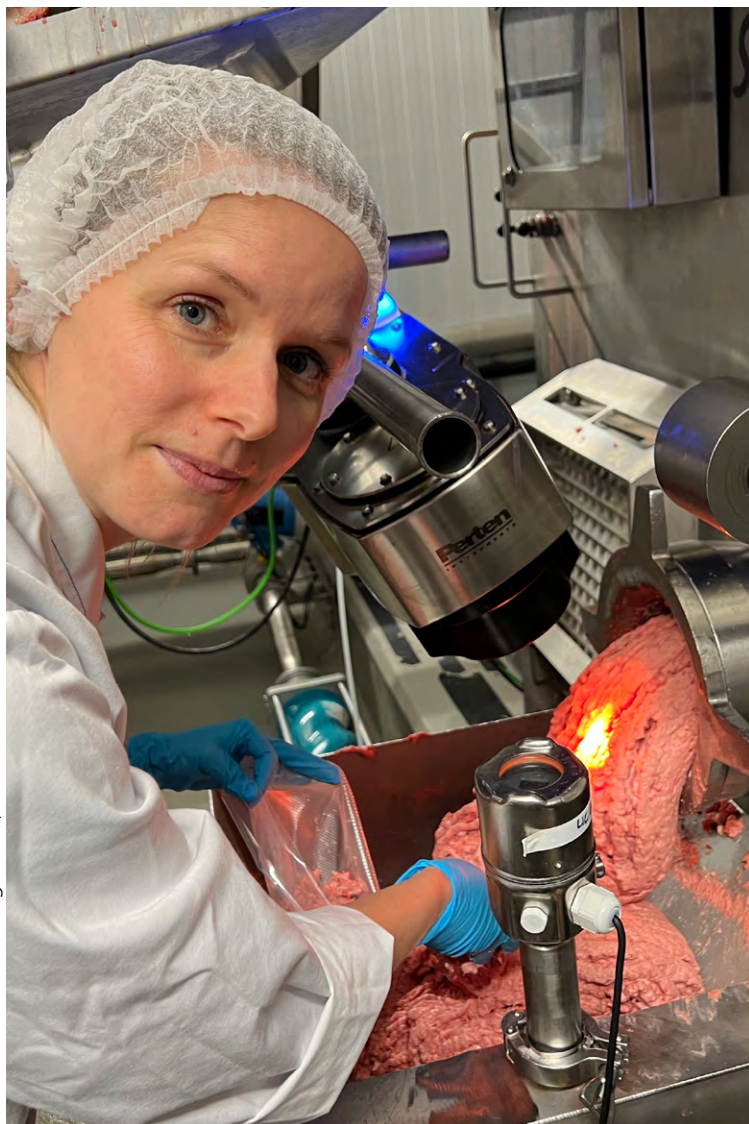
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 *What is unique about this process is that all the raw material is converted into valuable products – nothing is left to waste*



Katinka Dankel using the NIR sensor at Bioco. This measures the composition of the raw material going into the process.

Scientists are testing methods to neutralise unwanted taste without adding artificial flavour. They measure the peptide and amino acid composition of each powder and compare this to the panels assessments to identify particular peptides that give an unpleasant taste.

“We filter out the peptides that have bitter and unwanted taste. This has quite a good effect. In addition, even a tiny proportion of fat in the protein fraction can affect the taste. Removing more of the fat also gives good results,” says Mari Øvrum Gaarder.

### Three products instead of one

The raw material contains muscle proteins and connective tissue proteins. Nofima scientists have developed methods to extract three different products with different properties and uses.

- A muscle peptide product suitable for protein-enriching food or to develop food products that are rapidly absorbed into the body, such as sports nutrition or food for the elderly.
- A product containing large collagen peptides. These have a lower nutritional quality but can replace gelatine in food and pharmaceutical products.
- A product containing small collagen peptides that have potential for development of bioactive ingredients.

“We get more value out of each chicken and turkey by separating the protein part into several protein products,” says Nils Kristian Afseth.

**Funded by:** The Research Council of Norway and The Agricultural and Food Industry Research Funds (FFL/JA) Samarbeidspartnere: Nortura, Norilia and Bioco

**Partners:** Nortura, Norilia and Bioco

**Projects:** Precision, DigiFoods, HydroSens



Seafood consumption among young adults in Norway is far below the health authorities' recommendations. But sushi is popular with many.

# More seafood with good recipes?

A survey among almost 1000 young adult consumers in Norway suggests that better recipes can get more of them to eat more seafood.

Seafood consumption among young adults in Norway is far below the Norwegian Directorate of Health's recommendation of 2-3 meals per week. The authorities want to remedy this.

"Cooking skills are key. Good recipes and knowledge that give you confidence in the kitchen seem to be decisive factors in getting more people to eat fish and other seafood", says scientist Morten Heide.

## Taste and price of seafood are important

According to the survey, the main reason why some young adults never eat fish is that they prefer other foods.

"In addition, young adults are more insecure about preparing seafood than many other types of food," says Heide.

The youngest consumers had poorer cooking skills regarding fish and seafood consumption.

"The availability of good seafood recipes for young adults is therefore important", says Heide.

"It is also important to understand how recipes should

be designed – for example, whether they should be written or visual in order for them to be used, understood, and incorporated into the permanent repertoire of dishes young adults can make", says Research Director Pirjo Honkanen.

## Men find inspiration on YouTube

The scientists also found that men were more insecure than women about using written and visual recipes.

"The factors that make men more insecure and how to increase their confidence should therefore be studied more closely", says Heide.

Various websites are largely used as a source of inspiration when young adults prepare fish for dinner. By far the most important of these was Matprat.no, and the king of sites offering purely visual cooking inspiration was YouTube.

"More men use YouTube as a source of inspiration compared to women. It also seems that young men use visual sources of inspiration to a greater extent than women", says Morten Heide.



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**Funded by:** The Ministry of Trade, Industry and Fisheries

**Partners:** Syno International





# Understanding salmon skin

Scientists now understand more about salmon skin. The result is improved vaccination against ulcers that are spread from fish to fish.

Photo: Jon-Are Berg-Jacobsen © Nofima



*Moritella viscosa* is one of the types of bacteria that causes ulcers on the salmon. Here, Christian Karlsen grows two varieties of the bacteria in the lab.

"We have documented what everyone thought," says Senior Scientist Christian René Karlsen. He is talking about salmon that get ulcers on their skin caused by bacteria.

## Skin first

Nofima scientists have been concerned about salmon skin for a long time. "It is the organ that first receives a notice that the surrounding environment is changing. The skin feels all the environmental changes that affect the fish," says Karlsen.

Salmon can get ulcers in cold seawater. A bacterium called *Moritella viscosa* causes these winter ulcers.

It is possible to vaccinate against these winter ulcer bacteria, but the problem is that the bacterium has many different strains. The vaccine works much better if you develop it using the correct strain of bacteria.

## Improved vaccine

Not even the vaccine can keep all the fish healthy. Karlsen talks about high ulcer development even in fish that have

been vaccinated. In a recent trial where fish with ulcers were mixed with healthy fish, 15 % of the fish suffered deep ulcers and 25 % suffered superficial wounds.

"The vaccine isn't perfect. That is why we have moved on," he says.

In addition to looking at the effects of the different *Moritella viscosa* strains, the scientists have learned how the bacterium begins to harm the fish. "It sticks to the surface of the scales. It then multiplies and forms a colony," says Karlsen.

The scales are not the outermost part of the salmon. "The scales are covered in mucus. The bacterium manages to get in between this layer of mucus and the scales. They can then create large wounds that can even reach muscle tissue," he says.

When a fish is vaccinated, it has the first bacteria on its scales. In unvaccinated fish, the bacteria go deeper into the skin earlier. There are now several vaccines against different *Moritella viscosa* bacteria on the market.



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**Partners:** Pharmaq part of Zoetis



# Can smolt grow too quickly?

Perhaps it is best for the health of farmed salmon if they do not grow as quickly during the initial period. More knowledge is needed about this.

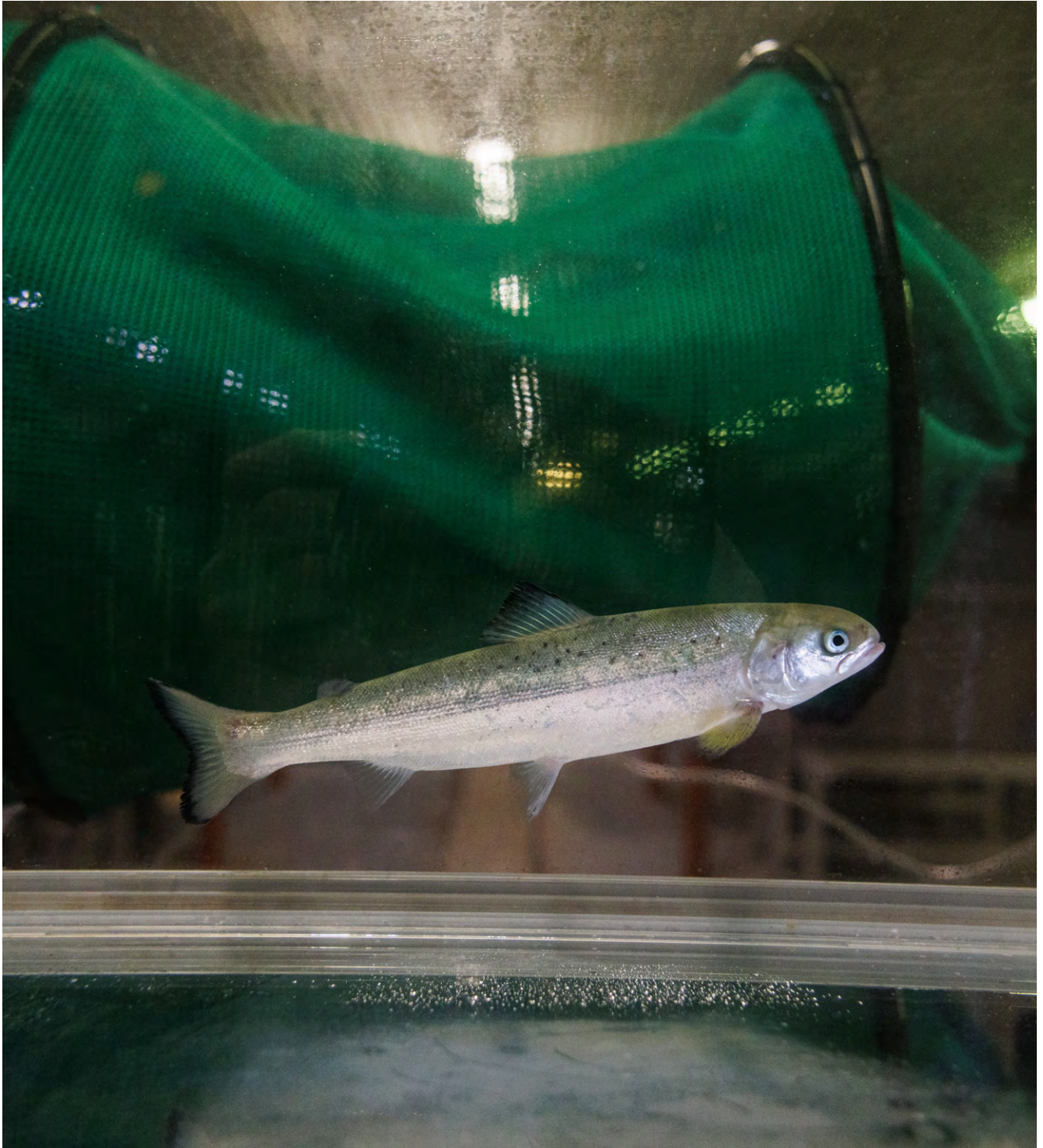


Photo: Terje Aamodt, Nofima

*When should juvenile salmon be transferred to the sea, and how big should they be? These are questions senior scientist Trine Ytrestøyl is gathering knowledge about.*





*The time of year when the big smolt are transferred varies. Roughly half are transferred in summer, while 27 % of the fish are transferred in January and February. Things indicate that it may not be ideal for them*

“There is no shared knowledge base,” as Trine Ytrestøyl puts it.

The senior scientist is working to collect knowledge about how salmon can grow well and survive until it is ready for slaughter after being transferred to salt water.

“Things are done differently at each facility,” she says.

She is now leading a project to find out more. It focuses on smolt – i.e., the juvenile fish that are ready to make the transition from freshwater to salt water. When should they be transferred to the sea, and how big should they be? In Norway, the answer differs from facility to facility and from region to region, according to the survey conducted by Ytrestøyl and her colleagues.

In Norway, the average weight of those transferred in the spring is 200 grams, and 180 grams in the autumn.

“The time of year when the big smolt are transferred varies. Roughly half are transferred in summer, while 27 % of the fish are transferred in January and February. Things indicate that it may not be ideal for them,” she says.

### Growing too quickly

Ytrestøyl compares this to the aquaculture industry in the Faroe Islands, which has more experience of transferring large smolt. The data indicate that the size of the smolt upon transfer does not have a significant impact on how well it survives or how much it grows at sea. The crucial factors seem to be whether the smolt lived in warmer freshwater as juveniles and thus grew more rapidly before being transferred to the sea.

“Fish that have grown rapidly during the land phase grew less and had poorer survival rates at sea,” she says.

A similar overview doesn’t exist in Norway. To obtain this data, researchers must collect it from each individual fish farming company. This can be difficult to obtain due to competition considerations. Relatively few fish farmers produce large smolt in Norway, so this data might be sensitive.

### Must be larger

A majority of fish farmers reported poorer performance at sea for the large smolt. They took longer getting started with feed intake and growth. However, Fish farmers want larger smolt.

“Roughly 20 % of fish farmers in Norway transfer salmon that are larger than 250 grams. More than one in three of those not currently doing this are considering whether to produce smolt of this size. Two out of three of those already doing it are considering whether to increase the percentage of big smolt,” says the scientist.

Salmon that spend more time in freshwater and less in the sea may have fewer problems with salmon lice. In other words, better growth, better fish welfare and lower mortality rates. This also enables fish farmers to utilise their licences better.

“On the other hand, large smolt can get other health problems. The fish farmers report on fish with more gill problems, greater size deviation, poorer appetite and higher mortality rates after being transferred to the sea,” says Trine Ytrestøyl.

Part of Ytrestøyl’s research project has been to identify where knowledge is lacking.

“Not much can be found in the literature on large smolt, and fish farmers are reportedly uncertain on what are the optimal conditions for a large smolt in RAS. They try out different things,” she says.

Since there are currently many different protocols in use it is difficult to pinpoint the factors affecting salmon performance after being transferred to the sea.

“In order to draw any conclusions about an optimal solution, we need more data from those fish farmers who are doing things differently. Thus it is crucial to collaborate with the industry,” says Ytrestøyl.

### More knowledge available

Fish farmers interested in finding out more about the scientists’ recommendations are encouraged to read the report, which can be found at [nofima.no](http://nofima.no).

Åkerblå and BDO offer an e-learning course in the project, which is available via [Akvademiet.no](http://Akvademiet.no).



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# The tiny regulators in our body

Food intake affects our health. Bacteria in the body play an important role as they help break down food into health-regulating compounds.

Most bacteria and other microorganisms are found in the colon, followed by the mouth. The composition and activity of these microbial communities are of great importance for the development of lifestyle diseases, but also for regulating human health. This is an extensive research field with many unanswered questions.

Nofima scientist Ida Rud and her colleagues are interested in how different foods affect bacteria in the body. For example, the importance of various food components, composition, processing and dietary changes. They have studied how changing to a more plant-based diet will affect intestinal microflora and health. A more plant-based diet will contain more dietary fibres and more plant proteins at the expense of animal proteins.

## Proteins and intestinal health

“Plant proteins are in general not digested as well as animal proteins. Undigested proteins will reach the colon and have the potential to cause unfavourable intestinal effects. In the GutFeedingNow project, we study how the combination of plant proteins and dietary fibres affects the gut micro-environment,” says project leader Ida Rud

The scientists study the digestibility of plant proteins as part of a wholemeal bread made from oats and wheat, which naturally contain both plant protein and dietary fibre. The scientists have also enriched the bread with extra proteins from oats and legumes, which are raw materials suitable for cultivation in Norway. The effects of the indigestible part of proteins are then studied in the colon to see how they affect the microflora.



Ida Rud is studying how dietary fibres in oat and wheat affects the intestinal microflora.



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### Different dietary fibres produce diverse intestinal microflora

Unlike proteins, dietary fibres are undigestible and move to the colon unchanged where they have major effects on the intestinal microflora. Oats are dominated by beta-glucan and wheat mostly contains arabinoxylan.

“Both of these dietary fibres increase the proportion of various beneficial bacteria, but not necessary the same type of bacteria. This can produce a more diverse intestinal microflora – and diversity is associated with good health,” says Ida Rud.

Various compounds are formed in the colon when dietary fibres and proteins are fermented. Dietary fibres form beneficial short-chain fatty acids, such as butyric acid. Protein can also form unfavourable compounds. The studies show that arabinoxylan and especially beta-glucan increase the proportion of butyric acid.

“Butyric acid is beneficial because it increases the mucus layer in the intestines, that acts as a protective barrier between the intestine and the bloodstream,” says Ida Rud.

### Do oral bacteria determine what we choose to eat?

A new field of research is emerging; the relationship between sensory perception and oral bacteria. Nofima has strong research environments in sensory and consumer science and microbiology. These wise minds have now joined forces.

Nofima has conducted studies on the relationship between food preferences and sensory sensitivity, i.e. how intensely one experiences tastes.

“In children, we have seen that the ability to sense fatty tastes affects what children like. Children who like fattier food have a low ‘fat sensitivity’. It will be interesting to study whether there is a connection between sensory sensitivity and oral bacteria,” says Senior Scientist Paula Varela-Tomasco. She heads the basic research on sensory and consumer research at Nofima.

Together with colleagues, Ida Rud and Paula Varela-Tomasco have reviewed the research literature showing that there may be a connection between oral bacteria and taste sensitivity. One hypothesis is that oral bacteria can alter taste compounds, but more detailed studies are needed here. Maybe one day it will be possible to change our oral bacteria into liking ‘healthier food’?



*A new field of research is emerging; the relationship between sensory perception and oral bacteria*

Photos: Jon-Are Berg-Jacobsen, Nofima



Paula Varela shows a PROP-test, used to test genetically determined sensory sensitivity to bitter taste.

**Funded by:** The Agricultural and Food Industry Research Funds

**Partners:** (NMBU) Norges miljø- og biovitenskapelige universitet, Bakehuset, Norgesgruppen, Norgesmøllene





Photo: Jon-Are Berg-Jacobsen, Nofima

*Not all ultra-processed food is unhealthy food”, states Senior Nutrition Advisor, Ida Synnøve Grini.*

# What about ultra-processed foods?

Energy-dense, nutrient-poor and a health risk, or ‘easy to like – easy to make’?  
Opinions on ultra-processed foods are divided.

There are various ways to categorise foods. The term ultra-processed was introduced in the 2009 NOVA classification, where foods are divided into four categories from unprocessed and minimally processed to ultra-processed.

Defining the term ultra-processed isn’t easy because there are different understandings of the definition.

“Because there is a wide range in what one might call ultra-processed food, the term is vague and confusing for consumers,” says scientist Dagbjørn Skipnes.

“And the NOVA classification is oversimplified. Not all ultra-processed foods are unhealthy,” says Senior Nutrition Adviser, Ida Synnøve Grini.

## Meat substitutes

One definition Nofima’s scientists can endorse is that ultra-processed foods are composed of ingredients that are made by combining several process steps. Both the ingredients and the processing methods are considered when classifying foods as ultra-processed.

However, the scientists say there is a need for a classification system that distinguishes between healthy foods such as mackerel in tomato sauce and unhealthy ultra-processed foods like sausages and soft drinks.

“Most meat substitutes such as pea protein and soy burgers are considered ultra-processed. How are we to reduce meat intake and at the same time cut out ultra-processed food?” says Dagbjørn Skipnes.

The scientist continues:

“The studies published so far on vegetarian meat substitutes show no increased risk of disease, in some cases reduced risk. Although we need more studies on types of ultra-processed foods, these results clearly show that not all ultra-processed foods are unhealthy,” says Ida Synnøve Grini.

## Consistency and intestinal flora

The effect of consistency on ultra-processed foods and how it affects intestinal flora are also aspects that require more research.

*Because there is a wide range in what one might call ultra-processed food, the term is vague and confusing for consumers*



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**Funded by:** The Research Council of Norway and Research Funding for Agriculture and the Food Industry





# Environmentally friendly packaging

You have never seen such packaging before. Fish is now being packed in smaller and more environmentally friendly packaging.

"This is the first product to be packed using recyclable skin packaging material," says Nofima scientist Anlaug Ådland Hansen.

In the SupremeFilet project that she leads, they have been developing and testing the packaging for two years. Inside the packaging is whitefish from Vesterålen.

Instead of putting the fish in a tray, pulling plastic wrap over and making a pack with lots of headspace taking up space, the pack is as small as possible. Skin packaging means relatively rigid plastic on one side, tight plastic wrap on the other side and no packing gas.

## Thinner plastic wrap

"The packaging is thinner so we use less plastic. For this type of pack, we save just under 30 percent," says Hansen.

Nofima, Fresh PL AS, packaging manufacturer Südpack and packaging machine supplier Multivac have visited the fish producer Gunnar Klo AS and tested the new packaging material in practice. The products are already on sale.

## Increasing fish consumption

Oda, which sells the new fish products, is also part of the research project. Part of the goal is to increase the consumption of whitefish in Norway.

"We look forward to offering customers our wide range of whitefish products such as cod, haddock, coley, tusk, monkfish, ling and halibut, packaged in a more sustainable way," says Bent Karlsrud, Category Manager at Oda.

Previously, Nofima has documented that the new packaging is just as good at preserving the quality of fish as the old one - which is not recyclable.

There are strict requirements for plastic that is in contact with food. Not least when it comes to plastic that has been used before and is recycled. Soon, the EU will require packaging to be made from recycled material.

"The main function of packaging is to preserve food. It is important that we ensure a good-quality product to help consumers waste less food," says Anlaug Ådland Hansen.



Photo: Anlaug Ådland Hansen, Nofima

*The first batch of fish being packed in new, recyclable packaging at Gunnar Klo AS.*



Photo: Jon-Are Berg-Jacobsen, Nofima

*Senior scientist Anlaug Ådland Hansen is now able to use less plastic, and more environmentally friendly packaging for the fish.*



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**Funded by:** The Research Council of Norway

**Partners:** Gunnar Klo AS, Fresh PL AS, Südpack, Multivac, Oda and Norsus

# Aquaculture to save the seabed

Sea urchin farming can save kelp forests, while also creating high value products in Norway.



*Tor Hatten Evensen and Philip James are researching the potential of sea urchins in regenerative aquaculture.*



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**Funded by:** EU Horizon 2020, Blue Bio Cofund,  
Regional Research Fund (RFF) Troms and Finn-  
mark

**Partners:** 35 partners in AquaVitae,  
9 partners in Blue Bio Cofund, 6 partners  
in the RFF project





Photo: Lars Åke Andersen, Nofima

Sea urchins on the seabed eat a lot of kelp and cause great damage to the kelp forests along the Norwegian coast.

“Sea urchins have decimated kelp forests along the Norwegian coast for a long time. Once established, they can remain for decades,” says Nofima Senior Scientist Philip James.

However, there is hope for the seabed – kelp forests will grow back if sea urchins are removed. In addition, sea urchins can create a new industry in Norway.

#### **Regenerative aquaculture**

To regenerate means to help something regrow that has been damaged.

Utilising sea urchins retrieved from destroyed kelp forests can be considered regenerative aquaculture, since kelp forests grow back when the sea urchins are removed. After the sea urchins have been retrieved from the seabed, they are enhanced to improve the size and quality of the roe in land-based facilities. Nofima has been working on this for more than 20 years.

“After just a few weeks of feeding, the size and quality of the sea urchins’ roe increases, and so does the market value of the product,” says James.

Sea urchin roe is highly sought after in many countries, and this leads to a very high price per kilogram for the roe. Sea urchin farming in Norway can therefore contribute to high value creation. In addition, many believe that Norway needs to diversify its aquaculture, so it doesn’t just rely on salmon farming and also tackles climate change through low trophic aquaculture.

#### **Major EU investment in low-trophic species**

Since 2019, James has led the EU-funded AquaVitae project. This is a major project on the farming of low-trophic species. Low-trophic species are groups of plants or animals that belong to the lower levels on the food chain, such as macroalgae, oysters, sea cucumbers and sea urchins.

“It has been very rewarding to lead such a major project with partners from different fields and countries. The project has contributed a lot to the development of low-trophic aquaculture in the Atlantic region,” says James.

Low-trophic species could be part of the sustainable food of the future, as researchers in the AquaVitae project have found that farming low-trophic species has a significantly lower carbon footprint than most other types of food production, including red meat, chicken and fish. Production of low-trophic species can even offset some of the carbon footprint from other food production. Part of the AquaVitae project has been dedicated to studying the potential of farming sea urchins sourced in the wild.

#### **Continuation of the project**

James has received funding from the Regional Research Fund in Troms and Finnmark to further study sea urchin potential in regenerative aquaculture. In this project, which starts in December 2023, Nofima is collaborating with stakeholders such as Tarevoktere, a voluntary organisation that removes sea urchins to restore kelp forests. Volunteer groups of Tarevoktere divers collect sea urchins and investigate how effectively kelp forests grow back after the sea urchins have been removed. The collected sea urchins can be used in aquaculture, and to further develop other uses of the sea urchin biomass. Not all sea urchins are suitable for farming, so the project will test what these sea urchins can be used for.

“Previous projects have shown that dried and powdered sea urchin can be used as a fertiliser. This is something the project will focus on, as well as developing methods for catching, harvesting and transporting sea urchins, and further developing the farming method,” says James.



*Sea urchins have decimated kelp forests along the Norwegian coast for a long time. Once established, they can remain for decades*

# The importance of fish welfare

Public interest in catch welfare is increasing. European consumers believe that fish deserve the same protection as other food production animals.

Photo: Rune Stoltz Bertinussen, Nofima



Ragnhild Aven Svalheim conducts research on the welfare of aquatic animals. She has contributed in establishing the Catch Welfare Platform.

"The catch welfare concept can promote profitability and sustainability in wild catch fisheries by reducing fish injuries. More gentle catch and handling methods will also improve fillet quality and reduce catch mortality, so the fish may be slaughtered in a controlled way after being taken on board the vessel. In addition, the increased focus on welfare practices may contribute to an improved reputation of the fisheries sector," says Ragnhild Aven Svalheim.

She has a PhD in how stress affects the quality of trawl-caught cod and haddock. She works as a scientist on various aspects of animal welfare for marine species such as fish and shellfish.

## Catch Welfare Platform, CWP

Ragnhild is also key to the work of establishing an interdisciplinary, international platform for fish catch welfare. The Catch Welfare Platform (CWP) was launched in autumn 2023.

"The platform aims to safeguard the welfare of aquatic animals and promote sustainable practices. It is an arena for research, industry involvement, education and collaboration.

"The goal is to raise awareness about animal welfare, encourage ethical fishing methods and drive positive change in an industry that is crucial for food security and ecosystems," says Ragnhild Aven Svalheim.

The platform will contribute to informed decision-making and responsible resource management.

"The Catch Welfare Platform is an interdisciplinary approach to improve fish welfare in global fisheries," says Svalheim.

## Focussing facts

By bringing scientists and industry together, the aim is to create pragmatic, research-based solutions to improve catch welfare.

CWP intends to:

- Give the industry a voice regarding catch welfare
- Steer clear of opinionated hearsay and focus on facts
- Share knowledge and create realistic expectations
- Create practical and profitable solutions for catch welfare



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**Partners:** Institute of Marine Research, Wageningen University, The Netherlands  
UiT - The Arctic University of Norway, Michelle Boonstera Consultancy, The Netherlands





# More of the healthy plant oils

Correct use of plant oils results in healthy plant-based and animal products without compromising on taste.

“Fats that are liquid at room temperature are the healthiest. Liquid plant oils are high in unsaturated fatty acids, and they are healthier than saturated fatty acids. The challenge in Norway is not that we eat too much fat, but that we don’t eat enough healthy fat,” says scientist Astrid Nilsson.

## ‘Olive oil of the north’

According to nutrition recommendations, no more than 10 % of the energy in your diet should come from saturated fat. The average in Norway is 13–14 %. However, you can eat more unsaturated fats, especially omega-3 fatty acids.

“Rapeseed oil is a good choice”, says Astrid Nilsson, who refers to it as ‘the olive oil of the north’.

Like olive oil, rapeseed oil contains large amounts of unsaturated fatty acids and it contains even more omega-3 than olive oil. Maize oil, sunflower oil and soyabean oil are high in omega-6.

The variety of plant-based products is increasing. A store survey showed that meat burgers contained 18–19 % total fat and 8–9 % saturated fat, while vegetarian burgers ranged from 2.7 to 19 % total fat and 0.2–6 % saturated fat.

## Better solutions

One reason for the large variations in the plant-based products is that using healthy plant oils is not that easy. They are liquid at room temperature and seep out of the product easily. Simple solutions might include reducing the content of healthy plant oil or using firmer plant fats with higher contents of saturated fat, such as palm oil or coconut oil.

Astrid Nilsson and her colleagues are working to find solutions for more use of the healthy, liquid plant oils in both animal and plant-based products. The goal is to use oils low in saturated fat and to make them technologically resemble animal fats, providing the same texture and mouthfeel.

“Oleogels, where oil is bound up in a network of sugar molecules and proteins, may be a solution,” says Nilsson.



Photo: Jon-Are Berg-Jacobsen, Nofima

Senior Scientist Astrid Nilsson refers to rapeseed oil as “Nordic olive oil”. She believes it’s a good choice as a source of omega-3 fatty acids.



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# Local food entrepreneurs inspire

The development has been tremendous. Local Norwegian food is doing well, and local food entrepreneurs contribute to innovation in the food market.

"I have investigated different market development practices, and the effects of participating in formal learning networks. Several factors are crucial to success. Respect for food knowledge and experience, openness and a heartfelt desire to make products of high quality are crucial," says scientist Stine Alm Hersleth.

She has identified two types of local food entrepreneurs.

"Entrepreneurs with experience from other industries are more aggressive in their marketing. They are keen to create something new, and use themselves and their history actively when selling products, often to reputable restaurants and grocery stores. Farm-based entrepreneurs focus on creating an attractive supplementary income on the farm. They invest locally, before taking the step into a larger market," says Hersleth.

 *Everyone benefits from local food being of high quality*

## Exclusivity and character

Several of the local food entrepreneurs who want to create something new from their farm's resources have established their own product categories in the grocery market. The products are exclusive, have a distinctive character and also inspire larger producers. These include healthy products made from ancient grains, cured sausages, fresh exclusive desserts and exclusive fruit drinks..

## A generous culture of sharing

Everyone benefits from local food being of high quality. It maintains the good reputation of local food. Most Norwegian producers of local food receive, or have received, help through the Competence network for local food producers. They meet competent and attentive experts who facilitate and encourage a generous culture of sharing.

The network is characterised by a culture of mutual support. Playing to each other's strengths is important. Participants get more contacts and opportunities to learn from each other. Therefore, involvement, willingness to learn and share are important qualities.

Photo: Jon-Are Berg-Jacobsen, Nofima



Stine Alm Hersleth has studied how local food entrepreneurs can succeed with market development and learning in networks.



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**Partners:** Strategic research programmes: FoodForFuture





# The value of measuring food quality

Using smart optical sensors, Nofima scientists measure food quality on the production line. This gives better control and less food waste.



Photo: Jon-Are Berg-Jacobsen, Nofima

*Jens Petter Wold heads SFI DigiFoods. For more than 20 years, he has developed fast spectroscopic measurement methods for use in the food industry.*



*Karsten Heia shows Maritech Eye, based on hyperspectral imaging.*



Photo: Lars Åke Andersen, Nofima

*Tiril Aurora Lintvedt develops applications for Raman technology.*

The research in SFI DigiFoods – Centre for Research-based Innovation is led by Nofima. The goals are to help ensure better utilisation of raw materials, a healthier population and better food experiences.

## Spectroscopic measurements

The scientists use light spectrum measurement methods to identify and check different raw material properties.

“The spectroscopic methods we use are hyperspectral imaging, NIR, Raman and IR. We conduct real-time measurements so that food producers can check the raw materials and food quality all the way from oceans, fields or barns to dinner tables,” says senior scientist Jens Petter Wold, head of SFI DigiFoods.

## Many uses

“We use hyperspectral imaging to give better shelf life estimates for seafood, detect herring worms in whitefish fillets and analyse blood, melanin, fat content and colour in salmon fillets. Models have also been developed to detect

a syndrome that causes jelly-like flesh in Greenland halibut,” says senior scientist Karsten Heia.

NIR technology is the most common for use on feed and food industry processing lines. The scientists are developing measurements for dry matter in potatoes, fat and cheese, distribution between fat, protein and bone in rest raw materials and sugar content in strawberries and tomatoes. Portable NIR sensors are being developed together with SINTEF Digital for use in agricultural robots.

Raman spectroscopy is an emerging food measurement technique. To compare NIR and Raman, scientists use the methods to measure sugar content in strawberries and the content of marine fatty acids in salmon.

“We have developed Raman methods that map fatty acid composition in salmon fillets and fat, protein, bone and collagen in rest raw materials from poultry,” says Tiril Aurora Lintvedt.



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**Funded by:** The Research Council of Norway  
**Partners:** Food Industry, Technology companies and research institute. The main research partners are Sintef Digital and NMBU





# Seasonal patterns and the Paris Agreement

Norwegian fishermen have always chosen to catch the most important species in intense seasons. Will reducing greenhouse gas emissions affect seasonal patterns?



*Having to halve greenhouse gas emissions will affect the seasonal pattern of the Norwegian fishing fleet.*



Through signing the Paris Agreement and establishing the Climate Change Act, Norway is committed to halving greenhouse gas emissions by 2030. One of the most important sources of greenhouse gas emissions is food production. Although the seafood industry has a good starting point, climate measures must also be taken in the fisheries.

"Most greenhouse gas emissions in the fisheries are produced by fuel consumption from catch operations. Having to halve emissions will therefore affect the seasonal pattern of the fleet," says research director and business economist Bent Dreyer.

Fuel is one of the largest operating costs of a fishing vessel.

"Consumption is at a minimum during seasons where catches have a high market value and are caught with high catch rates on fishing grounds that are located close to buyers. In other words; The Paris Agreement reinforces the incentives for seasonal catches from our most important stocks," says Dreyer.

Developments in vessel and catch technology or structuring of catch operations do not seem to have reduced the tendency to fill quotas in the shortest possible time.

"There are fewer and bigger catches in the season. Nor do annual quota fluctuations have a significant impact on the seasonal pattern," says the research director.

### Many attempts to change the catch pattern

Attempts have been made in fisheries policy to develop management schemes that reduce seasonal fluctuations. There has been a strong belief that fishing industry companies can achieve this by gaining control over catch operations.

"Some onshore facilities have therefore been granted an exemption from the Participation Act to own fishing vessels, hoping that this will contribute to changing the current catch pattern. However, years of arguing over this scheme indicate that

*One of the most important sources of greenhouse gas emissions is food production*

the good intentions have not yielded the desired results", says Dreyer.

Another approach has been to use quotas to motivate fishermen to change their catch patterns. Here, too, the conclusion is that the effect is not as great as desired.

Today's fragile quota distribution principles may have to give way to distribution keys that emphasise greenhouse gas emissions more strongly than historical fishing rights.

"Perhaps we will find ourselves in a situation where a vessel is unable to fill its fishing quotas because it has used too much of its emission quotas too early. This will make it necessary to establish a market where both greenhouse gas and fishing quotas can be exchanged. For example, a vessel that has filled its fishing quotas and still has a lot left of its climate quota can either rent extra fishing quotas or loan out its greenhouse gas quotas," he says.

### Fish are not governed by politics

Nofima's models of why we have seasonal fisheries and what affects fishing fleet energy consumption can help develop framework conditions based on the following principles:

- Manage stocks well – high biomass results in high catch rates.
- Prioritise species that give high value and low energy consumption.
- Catch during periods of the year that give high catch rates and high quality.
- Catch close to the shore.

"All these factors are about adapting catches to biology and migration patterns that cannot be controlled by politics," says Bent Dreyer.

Even though the fish cannot be controlled, the industry's technology choices can be influenced. The choice of fishing gear and vessel design affects greenhouse gas accounts. To reduce greenhouse gas emissions, Dreyer recommends fishing gear that gives high catch rates, high raw material quality and is energy efficient.

"The choice of vessel design is also important. Greenhouse gas emissions are lowest in vessels that are easily run, have high load capacity and are not powered by fossil fuels," says Dreyer.



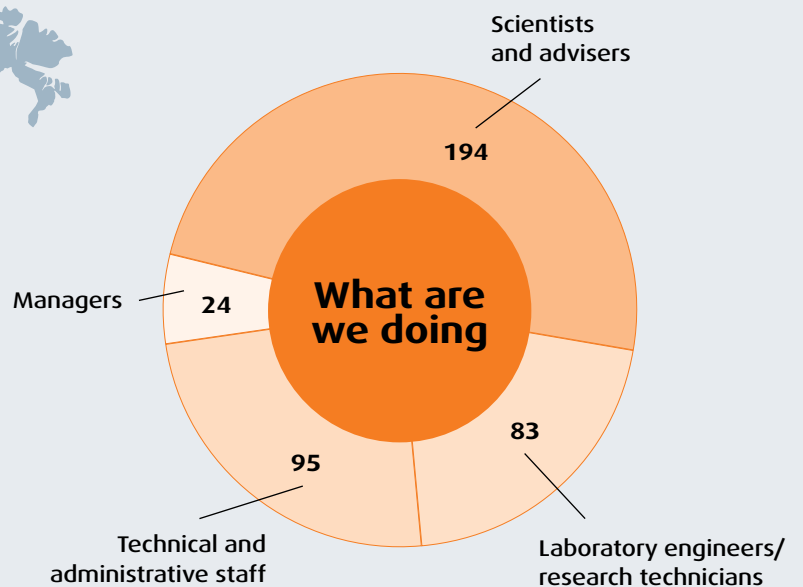
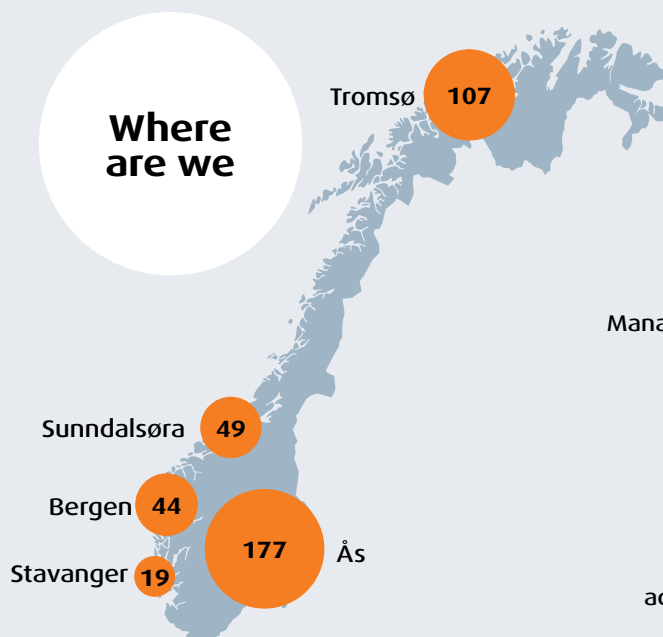
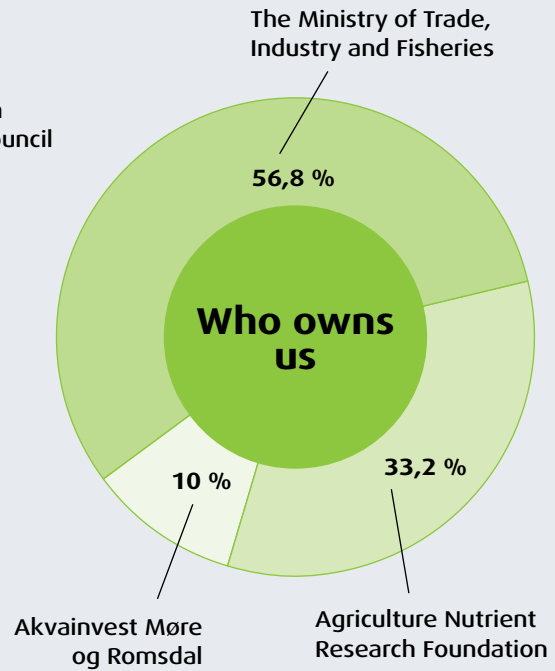
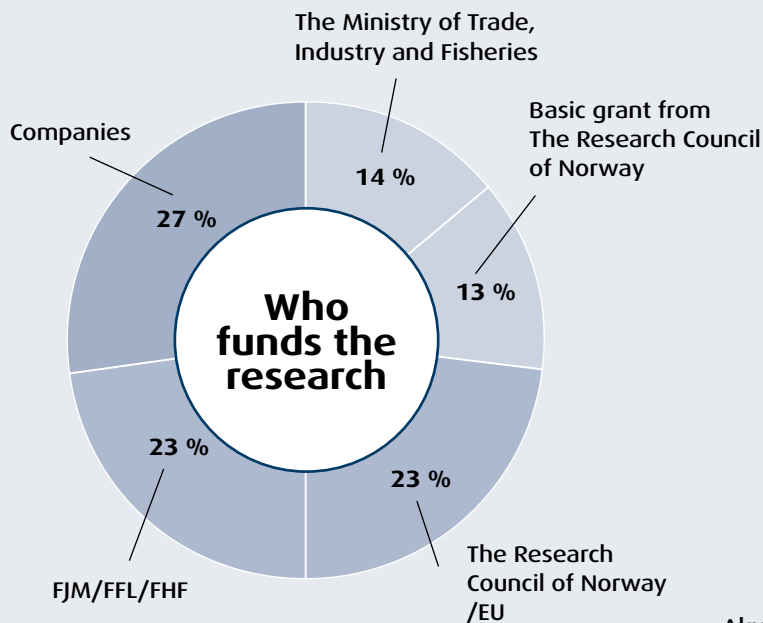
Illustration photo: Geir Sogn-Grundtvåg, Nofima



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**Funded by:** Nofima

# Behind the research





### The following are our largest funding providers:

#### THE MINISTRY OF INDUSTRY AND FISHERIES (NFD)

is responsible for fisheries and aquaculture management, seafood safety, fish health and fish welfare, the framework conditions for seafood trade and market access for Norwegian seafood. NFD funds Nofima's research infrastructure.

#### THE FISHERY AND AQUACULTURE RESEARCH FUND (FHF)

manages the funding scheme for industrial research and development work within fisheries and aquaculture to contribute to sustainable value creation and growth in the industry.

**THE RESEARCH FUNDING FOR AGRICULTURE AND FOOD INDUSTRY AND PARTNER COMPANIES (FFL/JA)** organization finances research and innovation for the entire value chain. The projects should cover key knowledge gaps and ensure good user involvement.

**HORIZON 2020 AND HORIZON EUROPE** is the EU framework programme for research and innovation. Its goal is to ensure Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation..

**THE RESEARCH COUNCIL OF NORWAY (NFR)** is a research policy adviser for the government and the ministries which allocates NOK 10 Bn. annually for research and innovation. The Research Council's mission is ensuring that this funding goes to the best research and innovation projects. The organization is at the forefront in developing research of the highest quality and relevance.

National research funding is under pressure, and there are many actors competing for the same pot. Nofima's strength is that we work closely with the industry to find good solutions that can resolve societal challenges leading to sustainable food production.

We have succeeded in carrying out many good research projects in 2023, where we collaborate with both small and large companies. This gives us good insight and enables us to develop solutions for the industry. The EU's framework programmes are also important to us. In 2023, we have completed three projects that we have coordinated, and we have just started coordinating a major, new EU project.

To ensure that the company continues to experience a robust financial situation, we must adapt to changes in funding, increased costs, and make sure that we have sufficient capacity and the right expertise among our scientists and engineers. Development and learning are also important for our administrative and technical staff. In 2024, we are placing extra focus on educating and developing our project managers and managers so that they can structure quality projects in an even better way and provide the best support for good project implementation.

Grete Sollesnes Winther  
Økonomidirektør



### This is Nofima

Nofima has some 400 employees, and a turnover of NOK 707 million i 2022. The research in Nofima is organized into three divisions, each organized in research departments:

#### Division Aquaculture

- Breeding and genetics
- Nutrition and feed technology
- Fish health
- Production biology

Director  
Linn Anne Bjelland  
Brunborg

#### Division Seafood

- Marine biotechnology
- Marketing research
- Industrial economics
- Processing technology
- Seafood industry

Director  
Bård Thomas Østvang

#### Division Food Science

- Food and health
- Raw materials and process optimization
- Consumer and sensory sciences
- Food safety and quality

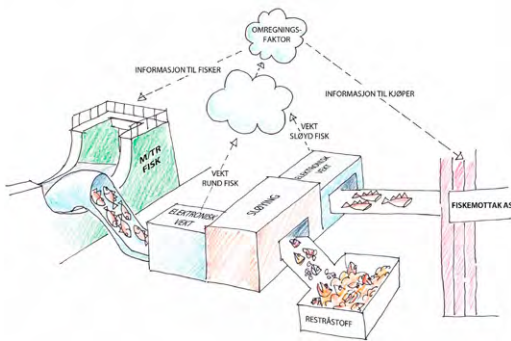
Director  
Camilla Røsjo

# Sustainable food for everyone

**Nofima's vision**

At Nofima, we have identified six strategic areas to focus on in the coming years.

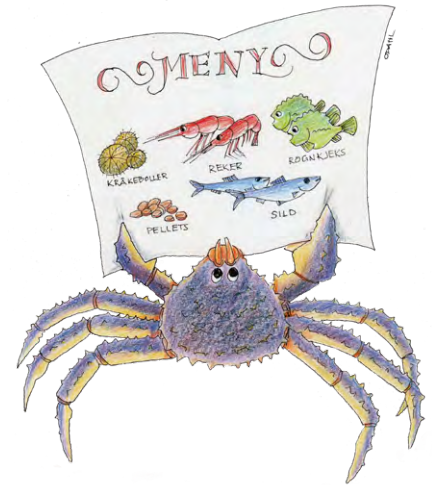
Using these we will fulfil our social mission of producing new knowledge that helps advance Norwegian food industries:



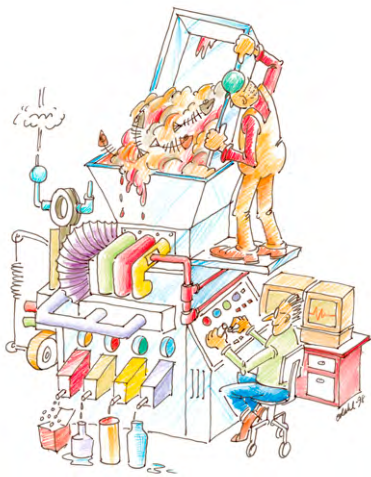
**Efficient and intelligent food production and processing**



**Safe, healthy and good food**



**Food and feed raw materials of the future**



**Full and circular resource utilisation**



**Good animal welfare**



**Food system interaction**

Illustrasjoner: Oddvar Dahl, Nofima



# Idea book for safer food

In the EU project SafeConsume, scientists and industry have gathered ideas and developed prototypes and concepts that can reduce food waste and prevent food poisoning at home.

A refrigerator thermometer and a drying rack for dishcloths. Cutting boards that change colour, coolers for left-overs, and 75 other ideas are collected in the online 'Book of Ideas'.



The ideas are available free of charge to anyone who is interested.



*The results from SafeConsume led by Senior Scientist Solveig Langsrud (left) are of great value. Senior Scientist Antje Gonera led the work on developing the ideas. Photo: Jan-Are Berg-Jacobsen, Nofima*

## SAFE CONSUME



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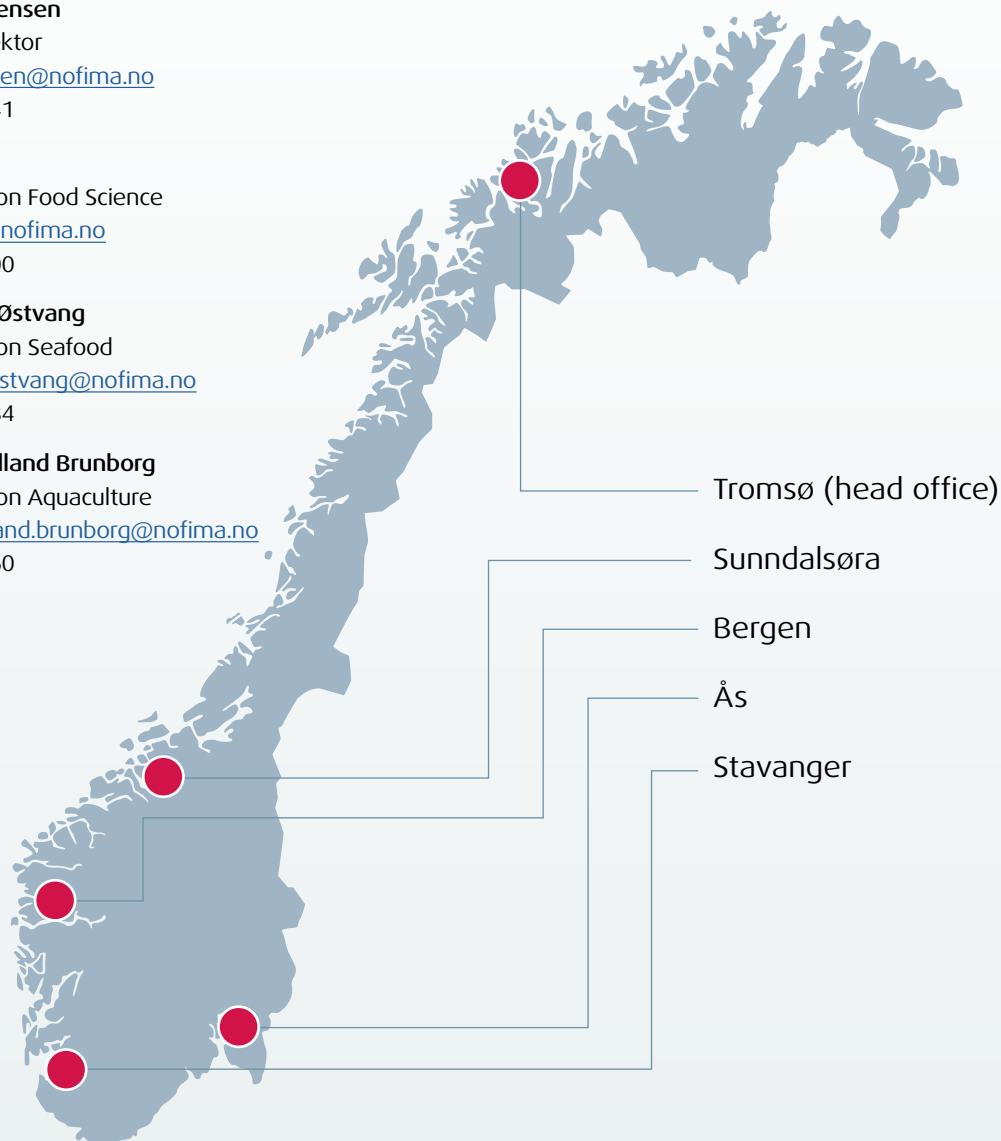
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