creatingvalue

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Photo: Wenche Aale Hægermark, Nofima

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The vital role of food in Norway's security and preparedness

Photo: Ronald Johansen Nofima

Managing Director Bente Torstensen.

In a turbulent world, Norway is preparing to handle crises and unforeseen situations. At Nofima, we contribute to this by developing new knowledge about food, ensuring that people has access to sufficient and safe food in times of crisis. Norway's security depends on robust food systems. Research is essential to strengthening food preparedness.

Nofima leads several research projects that help improve food preparedness. Together with prominent institutions such as the Norwegian Defence Research Establishment, the Institute of Transport Economics, and the Institute of Marine Research, we are mapping the role of seafood in Norway's food preparedness. Despite exporting approximately 38 million seafood meals daily, seafood is only marginally integrated into national contingency plans. The project analyses vulnerabilities in transport and supply chains and will provide concrete recommendations for better preparedness.

Nofima is also developing knowledge on food production, food preparedness, and public health in Northern Norway, a strategic region with particular challenges related to climate and supply security. Here, we examine how food systems can be adapted to future threats.

Our research fosters innovation in product development, sustainability, and processing, ensuring that Norway's food resources are used more efficiently and food waste is reduced. This makes the food industries more competitive and Norway more self-sufficient. Research into consumer behaviour and preferences enables producers to meet the population's needs, even in times of crisis, and ensures access to healthy and safe food.

In this issue of *Creating value*, you can read more about our research and learn how cross-disciplinary research environments, close industry collaboration, and a long tradition of linking food, technology, and society contribute to making Norway robust and resilient when it comes to food and preparedness.

Our research only fulfils its purpose once it is put into practice.

Bente E. Torstensen
Managing Director

Photo: Ronald Johansen, Nofima

The project focuses on the role of seafood as Nofima collaborate the Norwegian Defence Reasearch Establishment, the institute of Transport Economics and the Institute of Marine Research on Norway's preparedness. Magnar Pedersen leads the project on behalf of Nofima.

Seafood and preparedness

What role does food from the sea play when Norway – one of the world's largest seafood nations – must prepare for food security in times of war and crisis?

At present, fish and other marine food make up a vanishingly small share of Norway's overall food self-sufficiency. Only around 2–4 per cent of the calories consumed annually by the Norwegian population come from the sea.

At the same time, it is a well-known fact that Norway exports around 38 million seafood meals every single day of the year.

– If we were to eat all the seafood we produce ourselves, every single person in Norway – including breastfeeding infants – would have to eat eight seafood meals every day. We are talking about enormous quantities, points out business economist and research director Bent Dreyer at Nofima.

The dilemma

The dilemma between the volume of seafood available should Norway need to rely on its own resources, and the role that fish currently plays in national emergency planning, is now being mapped out by a broad consortium of Norwegian research institutions.

The Norwegian Defence Research Establishment (FFI), the Institute of Transport Economics (TØI), the Institute of Marine Research (HI), and Nofima each bring expertise from their respective fields. Together, they will document "The role of seafood and the seafood sector in food systems."

– We will examine food shortages, lack of feed and other critical inputs, rising trade barriers, and the consequences of reduced energy and transport capacity. In addition to contributing to improved food preparedness, this knowledge will be useful both for stakeholders in the seafood industry and for the authorities when developing contingency plans, says Magnar Pedersen, who leads the project on behalf of Nofima.

Recommendations to the authorities

Over the course of two years, the researchers will:

- Document food systems in general, and the role of the seafood sector in particular, both in Norway and internationally, mapping ecosystems, institutional frameworks, production, preservation, organisation, input factors, location, and distribution.
- Conduct vulnerability analyses of seafood systems, identifying drivers of vulnerability, levels of risk, and potential scenarios.
- Map the seafood industry's transport and logistics systems, their organisation, and vulnerabilities.
- Analyse the robustness of Norway's food systems in crisis scenarios relating to food security, feed supply, trade structures, the role of the fishing fleet, and other critical vulnerabilities.
- Produce recommendations for authorities and industry regarding crisis management, self-sufficiency, emergency reserves, and methodological approaches.

"We will examine the entire logistics system behind Norwegian seafood"

Inger Beate Hovi, TØI

– To ensure that the seafood system functions during crises and war, we need to understand the complete picture of its vulnerabilities. This includes the major dependence on energy and ICT – critical inputs that could be disrupted, says Chief Scientist Gunn Alice Birkemo at FFI.

– We will examine the entire logistics system behind Norwegian seafood – who transports it, how it is transported, and where potential bottlenecks may occur. When we gain better insight into how seafood moves from sea to table, we can identify the system's most vulnerable points and determine how to strengthen it. The goal is to make transport more resilient when unexpected events occur, says Senior Researcher Inger Beate Hovi at TØI.

The Institute of Marine Research (HI) plays a central role in the project through its societal mission of advising on the sustainable harvesting of wild marine resources and the use of coastal areas for aquaculture.

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What temperature does to salmon

Salmon raised at different water temperatures grew exactly as expected – until they were moved to the sea.

That's when one group of fish gave researchers quite a surprise.

Before and during smoltification, a process where salmon adapt to life in seawater – temperature is an effective way to control how fast they grow. But in recent years, there's been growing concern that the water used in salmon farming may be too warm. High temperatures could be linked to heart problems, and some people believe that young salmon that grow too quickly don't thrive after they're moved to seawater. The aquaculture industry wants clear answers.

"We need long-term experiments to find out whether high temperatures early in life affect growth and health later on," says researcher Anja Striberny.

At Nofima's research station in Sunndalsøra, Striberny and her colleagues ran experiments in state-of-the-art facilities where it is possible to run experiments with both small and large salmon under various production conditions.

Testing different temperatures

The team followed the salmon from just 10 grams up to about 200 grams – a typical smolt size at seawater transfer. The fish were raised in water at three different temperatures: 8°C, 12°C, and 14°C. In a fourth group, temperature was increased from 8 °C to 12 °C during smoltification. To make the results relevant for the industry, the experiment ran in both flow-through systems and recirculating aquaculture systems (RAS).

Once the fish had adapted to seawater, they were transferred to a facility at Gildeskål. Throughout the entire study, the researchers monitored their health and welfare – both inside and outside.

Most of what they found matched their expectations:

- All fish developed good tolerance to seawater.
- Smolt development was affected by changes in day length.
- Survival rates were high in all groups.

The fish raised in the warmer water were much bigger when moved to seawater – those from the 14°C group averaged 140 grams, compared with just 70 grams from the 8°C group.

"The surprise came when we saw that fish raised in warmer water kept on growing faster even after they were moved to the sea," says Striberny.

Photo: Anja Striberny, Nofima

Experimental fish in flow-through tanks with tightly controlled temperature at Nofima's aquaculture research station in Sunndalsøra.

Photo: Nofima

Anja Striberny (to the right) and research colleagues from Nofima, UiT and staff at Gildeskål research station during the trial.

Photo: Anja Striberny, Nofima

The fish's growth in the sea was best for those that had lived in relatively warm water during the freshwater phase.

Subtle warning signs

Growth and survival aren't the whole story. The researchers are still studying tissue samples and molecular responses to detect hidden effects. Based on what could be seen on the outside, there were only small differences between the groups. But fish that had been raised in higher temperatures showed some signs worth noting – a mild tendency toward cataracts by the end of their seawater phase, and slightly smaller hearts than the others. Salmon raised in recirculated water also had smaller hearts.

Better quality, but with a catch

Since the main purpose of salmon farming is food production, the researchers also examined whether early-life conditions affected the final product.

"Interestingly, fish raised at 12 and 14 degrees had a higher proportion of superior quality salmon and a slightly deeper fillet colour," says Striberny.

Even so, she adds a note of caution for anyone tempted to crank up the heat:

"Remember, temperature was the only factor we changed in this study. Density and water quality were carefully kept within recommended limits and altering those could lead to entirely different results."

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From idea to great food

Nofima's pilot halls let food producers develop and test ideas and products in safe, industry-level conditions.

Here are the pilot plant managers. They help companies with everything from adjusting recipes to developing ideas and products.

Photo: Anders Ellefsen, Nofima

Within these pilot halls, food can be made, packaged, and stored in near-authentic settings. Facilities include process halls for meat, fish, bakery, fruit, berry and vegetables, plus a dedicated packaging hall and a pathogen hall where dangerous bacteria can be studied under real production scenarios. Experimental test runs allow you to evaluate quality, food safety, sensory attributes, and packaging methods all in one place.

Trial production for every raw material

In the **Bakery**, Master Baker Nils Olav Heggdalsvik and scientist Ann Katrin Holtekjølen work with modern industrial technology, from novel cereal qualities to the optimization of recipes and processes. "We recently held a training course for organic bakeries, showing how fermentation time impacts texture, shape and flavour, and how extended fermentation can improve daily logistics," says Heggdalsvik.

The bakery is used in research projects with direct impact for the cereal sector. For example, bread with oat beta-glucan has been developed to achieve lower blood sugar levels.

In the **Fish Pilot Plant**, engineer Arnaud Lefrancois measures texture, colour, fat content and skin robustness in fish, mapping the effects of changes in production regimes or feed. "In a project aimed at increasing Atlantic salmon skin tolerance to winter sores, we examined the impact of urea supplementation in the feed," Lefrancois explains.

In the **Meat Pilot Plant**, Master Sausage Maker Tom Johannessen and Senior Engineer Lene Øverby guide companies wanting to test new raw materials or adapt recipes, using advanced equipment for all major meat processes. "We provide meat processors with the insight needed to understand what and why process changes are required, so they can independently adjust their recipes with greater confidence. Businesses attending our courses experience more stable products and improved profitability," says Johannessen.

The **Fruit and vegetable Pilot Plant** is equipped for professional processing of fruits, berries and vegetables. Advisor Cecilia Midtsund Kippe guides producers through small-scale process development. "We focus on gentle processes that preserve flavour, aroma, colour and nutrients. Vegetable fermentation is one such technique, and our training courses gives producers hands-on experience and confidence in their process choices," Kippe notes.

Safe food and the right packaging

In the **Pathogen Pilot Plant**, Senior Scientist Even Heir can deliberately introduce dangerous bacteria into foods and production environments, testing survival, growth, and effective interventions. Producers get answers on how recipe changes affect safety or learn about suitable alternatives to traditional preservatives. "Rakfisk is a traditional but high-risk product, where Listeria in particular can be challenging. Our research has provided solutions that deliver both a safer product and maintain high quality. Some rakfisk producers have already adopted these practices," reports Heir.

In the **Food Packaging Pilot Plant**, Senior Engineer Magnhild Seim Grøvlen oversees packaging materials and solutions for every food type. Facilities include thermoformers, flowpack, and vacuum chamber machines. "A major advantage is that producers can experiment with us and later implement the best solution directly in their own plant," says Grøvlen.

All products made in the pilot halls are for testing and development only—not for sale—so you are free to experiment, take risks and learn. Together with Nofima specialists, you gain the knowledge and confidence needed before you implement new solutions on your own line.

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Potential for land based red algae

How could Norway produce more food, utilise high nutrient levels in discharge water and create new businesses?

Dulse, or *Palmaria palmata* in Latin, is a red algae that has a relatively high value compared to other macroalgae and is commonly used in food products.

Senior scientist Philip James and colleagues have investigated the necessary conditions to successfully produce dulse with good growth rates and nice colour in the discharge water from land-based salmon production using recirculated water systems (RAS).

– I think this could be a win-win for both salmon producers, new businesses and the environment, says James.

Photo: Lars Åke Andersen

(Left photo) Research assistant Tor Evensen and senior scientist Philip James are researching the growth conditions of the macroalgae dulse. (Right photo) Dulse growing on different concentrations of effluent water from a RAS facility.

This is what the scientists have found

In the trial, discharge water from SalMar's land-based facility was used to grow dulse. The research results show that:

- Dulse grew best on 50 percent discharge water from RAS. That is compared to seawater, 25 percent and 100 percent discharge water from RAS.
- Results show that a dilution rate of 50 percent gave the highest removal efficiency of ammonia and nitrate. However, for phosphate removal somewhere between 25 and 50 percent RAS water was most efficient.
- Dulse grew equally well in salinity ranging from brackish water to full seawater (equivalent to 10–32 grams salt per kg seawater).

Striking potential

For every kilo of fish feed used in RAS salmon farming, 257 grams of dulse could be produced. With Norway's land-based salmon industry consuming around 100,000 tonnes of feed annually, the nutrients in discharge water could provide everything needed for a substantial seaweed industry.

"This underlines the potential for both macroalgae cultivation and utilising RAS nutrients in discharge water as a valuable resource" James says and underlines that challenges remain.

In follow up projects, the scientists will also be testing dulse grown in discharge water from RAS water for nutritional benefits as well as any potential harmful compounds.

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Self-sufficient in plant protein

Nofima researchers have used a processing method that enables Norwegian peas and faba beans to become excellent sources of protein for a variety of foods.

The method is based on conventional milling technology, which could mean more protein-rich foods produced from Norwegian farmland. Interest in protein is higher than ever.

"For faba beans, we can increase the protein content from around 30 percent to up to 65 percent, and for peas from just over 20 percent to up to 55 percent in the concentrates," says senior scientist Svein Halvor Knutsen.

The method for concentrating protein is called dry fractionation or air classification. Dry fractionation involves sieving finely milled flour from beans and peas and using airflows to separate starch granules from protein particles.

"The method differs from traditional protein isolation in that it does not use water, acids, or bases. This makes the process more environmentally friendly and preserves the protein's original structure," Knutsen explains.

More farmers are now interested in growing legumes than just a few years ago, and interest has increased particularly in faba beans. An important reason is that legumes can bind nitrogen from the air, reducing the need for other costly fertilisers.

With optimal land use, Norway could produce 50,000 tonnes of faba beans and 40,000 tonnes of peas annually. That corresponds to 20,000 tonnes of pure protein – enough to replace most of the imported legumes currently used for food.

"Norwegian legumes are just as suitable as imported ones. Both protein concentrates and starch from legumes open up exciting opportunities for food innovation, such as ingredients in various meat alternatives, baked goods, and other foods," Knutsen points out.

The food pilot facility at Nofima makes it possible to compare varieties of peas and faba beans and study their suitability for large-scale production.

Photo: Joe Urrutia, Nofima

Beans and extruded bean ingredients that can be used in, for example, plant-based burgers.

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Haddock frozen too fresh, turns yellow

When is the optimal time to freeze fish? Definitely not when it is too fresh, according to new research from Nofima.

"The fresher, the better" is often the common refrain when it comes to food – perhaps especially seafood. However, haddock that was processed and frozen pre-rigor – that is, so fresh that rigor mortis had not yet set in – consistently turned yellow after just 20 weeks in frozen storage.

"Yellowing as a result of 'rigor energy' has not been described in the research literature. There is reason to believe that the industry has not been fully aware of just how significant this factor can be" says scientist Svein Kristian Stormo.

Different rigor statuses refer to the stages before, during, and after rigor mortis in the fish's muscle. The researchers wanted to determine the effect of rigor status on thaw loss, subsequent drip loss, and sensory qualities such as colour and texture during chilled storage after freezing.

Historically, much of the fish frozen onboard vessels has been handled in a way that makes it reasonable to assume that relatively little of it is actually pre-rigor at the moment of freezing. However, there are many indications that the opportunities to freeze raw material pre-rigor will increase in the future.

"This is due to new routines with smaller hauls, better handling onboard vessels, and an increase in the proportion of catches delivered live to shore. In addition, cod farming will make the handling of pre-rigor raw material increasingly relevant," says Svein Kristian Stormo.

"Delaying freezing is one solution to avoid this effect, but at the same time, other degradative effects will begin to occur if the period is too long. For quality and practical reasons, it is important to determine the optimal freezing time," he concludes.

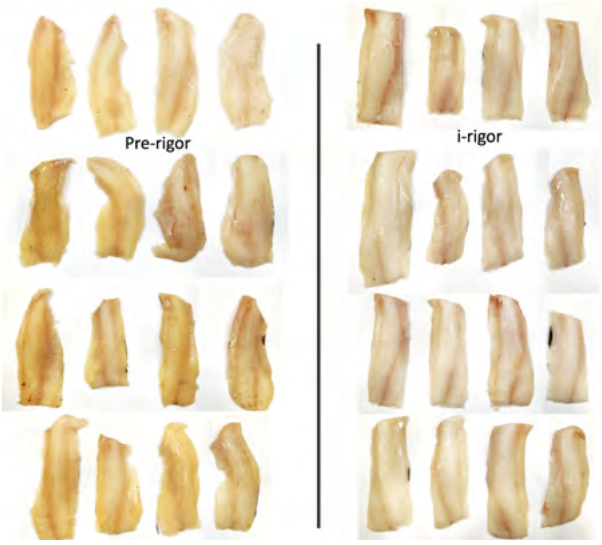

Photo: Nofima

The yellow haddock on the left was frozen before rigor mortis set in. The white one on the right was frozen while the fish was in rigor.

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The offal is full of value

Great value is lost when most of the offal from whitefish such as cod and haddock is discarded at sea.

Photo: Anne-May Johansen, Nofima

Offal from whitefish could mean a major increase in value creation and sustainability, scientist Marte Jenssen says.

The small portion of offal that is currently utilised is used for low-value products such as animal feed and biogas. However, Nofima's researchers in marine biotechnology have other plans for these leftovers.

"The offal is valuable. We're talking about a high content of nutrients the body needs – including proteins, healthy fats and essential vitamins," says researcher Marte Jenssen.

"It could mean a major increase in value creation and sustainability if all of the residual raw materials were better utilised, especially from the ocean-going fleet," she points out.

Innards and viscera made up a full 55 per cent of the available residual raw material from the whitefish sector in 2024.

While coastal vessels retain almost all their by-products, ocean-going vessels manage only around 43 %.

"Large quantities of fully usable raw material are therefore thrown overboard before the fish is landed", says Jenssen.

In Norway, effective methods and technology have been developed to preserve the offal.

"What we can extract from the innards are nutrients that can be used in high-value products such as food ingredients, dietary supplements, biomedical products and cosmetics – as well as in feed ingredients and even packaging materials," explains the marine biotechnology researcher.

New technology is already mature and ready for large-scale implementation, and a better system could lead to increased value creation, healthier food and less waste entering the sea and the environment.

"We have both the knowledge and the equipment needed. All that remains is to make it economically viable and practically feasible," says Marte Jenssen.

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Bread wheat = improved food security in Norway

Characterization of wheat cultivars will contribute to increased use of Norwegian bread wheat and strengthen food security preparedness.

Photo: Nofima

Shiori Koga has been responsible for analyses and baking trials and has contributed to proposing the new classification system for bread wheat.

Researcher Shiori Koga and her colleagues analyze the breadmaking qualities of different wheat cultivars. The research helps the industry optimize the use of Norwegian bread wheat.

"We examine key quality parameters, such as protein content, water absorption, and dough properties, and perform baking trials. Millers need wheat with varying breadmaking qualities to produce flour products with consistent and specific qualities," Koga explains.

The new classification system opens new opportunities

The report "Adaptation of wheat production to the Norwegian market" proposes a new classification system for bread wheat. The new system suggests dividing winter wheat cultivars into two classes: C, "stronger", and D, "slightly weaker", instead of a single class as in the current system. Additionally, the minimum protein content for class D is set slightly lower than that of the existing winter wheat class to better meet market demands.

The researchers evaluated the breadmaking quality of nine winter wheat cultivars and lines grown in three different environments. The results revealed varying baking qualities, enabling to classify these cultivars in a new system that may soon be adopted.

"Once the new system is implemented and wheat cultivars are classified, the market will have the opportunity to use more Norwegian winter wheat than it does today. Some winter wheat cultivars are just as strong as certain spring wheat cultivars. With the new system, these can be used in flour blends like spring wheat if the protein content is sufficient," says Koga.

Weather conditions and breadmaking quality

Another important factor in assessing breadmaking quality is the effect of growing conditions. While genetics primarily determines breadmaking quality, environmental factors also play a significant role. Every autumn, Nofima's experts evaluate the gluten quality, one of the key parameters for breadmaking, of the new harvest of Norwegian wheat cultivars.

"We have data from over 20 years. Recently we examined the relationship between weather conditions during grain filling and gluten quality. It turns out that the weather around heading and physiological maturation has the greatest impact on gluten quality," says researcher Erik Tengstrand, who was involved in the data analysis.

Annual analysis of new harvests is a longstanding collaboration with NIBIO and NMBU. The results show considerable variation, especially in seasons with adverse weather during grain filling and maturation.

Early quality forecast of Norwegian bread wheat

The annual analysis of new harvests has expanded since 2022, when it was initiated as a pilot project by the Partnership for Norwegian Cereal Grains and Plant Proteins. Nofima conducts comprehensive testing on samples from different grain reception facilities in major wheat-growing regions. The results assist the market regulator in forecasting the amount of Norwegian bread wheat available in the market and assessing the potential need for importing bread wheat.

"When the Norwegian share increases, these annual quality analyses become even more important for planning the efficient use of Norwegian wheat. If we succeed in this, we can enhance Norwegian self-sufficiency and decrease the need for imports," concludes Shiori Koga.

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Omega-3 and zinc: a powerful duo

It has now been documented that the interplay between nutrients in feed is crucial for salmon to achieve optimal growth, robust health, and high fillet quality.

Scientists particularly point to two synergies: Between the mineral zinc and the omega-3 fatty acids EPA and DHA, and between the lipid cholesterol and saturated fat.

Yes, you heard correctly. Saturated fat and cholesterol, which are often associated with adverse health effects in humans, are important for salmon.

Over the past decades, fish oil has been gradually replaced with vegetable oil in feed, and during this time, the salmon's requirement for saturated fat has not received sufficient attention, explains Nofima scientist Nini Sissener:

"Saturated fat has a greater impact on fillet quality than previously thought. Fishmeal and fish oil possess a unique composition of omega-3, saturated fats, and cholesterol. It is therefore important to assess what these changes mean for the quality of salmon raised on today's plant-dominated feed", says Sissener.

Sissener carried out this study while employed at the Institute of Marine Research.

The research revealed that frozen salmon fillets lost more liquid during thawing when sourced from fish that had received insufficient saturated fat during the growth phase. Additionally, low cholesterol level in the feed reduced the fillet's firmness and red coloration.

Photo: Tone-Kari K. Østbye, Nofima

Bente Ruyter finds one of the most exciting aspects of nutritional science is uncovering the complex interaction of nutrients and how this impacts many characteristics in the fish.

Juvenile salmon require sufficient zinc and omega-3

Scientists have also studied how zinc levels affect health and resilience in small salmon in the freshwater stage.

High zinc and omega-3 levels have positive effects on scale development, wound healing in the skin, increased bone density, and overall growth.

"Together with omega-3, zinc enhances skin health, and more omega-3 improves the utilisation of zinc. They are truly a powerful duo in salmon feed and act synergistically", says Bente Ruyter, senior scientist at Nofima.

For robust growth under optimal conditions in land-based tanks, research shows that 6 per cent omega-3 of total fatty acids in the feed is sufficient.

Salmon in sea require more

Trials were also conducted on larger salmon in sea cages, where scientists found that fish lost minerals and had lower harvest weights when fed low zinc diets. However, mineralisation improved when both omega-3 in the feed increased, and total fat levels decreased.

Bente Ruyter has led this project and has long researched omega-3 fatty acid requirements in salmon feed. Ten years ago, omega-3 levels in Norwegian salmon feed were lower than today. When earlier research showed that salmon needed more omega-3, the industry quickly adjusted the feed composition.

Research from this project shows that salmon raised under challenging conditions in sea cages require more omega-3 for optimal growth, health, and fillet quality than those kept under ideal conditions in land-based tanks.

For example, salmon that received 11 per cent omega-3 of total fatty acids in the feed resumed feeding more quickly after delousing than those fed 6.5 per cent. Since feed intake typically drops after delousing, Ruyter emphasizes that a rapid return to feeding is essential.

Nutrient interactions are highly significant

"What's exciting about these findings is that the interaction between nutrients plays a key role in skin health, red coloration, energy metabolism, membrane fluidity, and the salmon's ability to adapt to new production environments," says Ruyter.

And if there's one ability today's Norwegian salmon need, it's adaptability:

"Today's production involves various technical solutions, warmer seas, and more sea lice. To thrive through the production cycle with good growth, health, and fillet quality, salmon need the right feed," Ruyter concludes.

"Together with omega-3, zinc enhances skin health, and more omega-3 improves the utilisation of zinc"

Bente Ruyter

Photo: Terje Aamodt, Nofima

New research shows that nutrient interactions in feed are crucial for skin health, red pigmentation, energy metabolism, and membrane fluidity.

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Pink Salmon – resource and problem

How should we approach pink salmon when it is clearly both a pain in the neck, yet also a fantastic food resource?

According to Nofima's researchers, two things are especially important:

1. That the state reaches an internal agreement on how best to manage the pink salmon.
2. That fishers and the processing industry are aware of how to catch the fish gently, bleed it properly, and cool it quickly.

"Pink salmon is an excellent food fish, but if we want to build an industry around it, quality is crucial," says Stein Harris Olsen.

A Climate Winner on the Rise

Olsen, who has researched pink salmon for many years, believes the species – also known as Pacific salmon – is a climate winner that is here to stay in Norwegian waters. Through the research project BLUSH-Salmon, Nofima's scientists have studied how to ensure efficient and profitable utilisation of this invasive species.

Trends show that the species is advancing rapidly, with catches increasing from 382 tonnes in 2021 to 695 tonnes in 2023. Assuming a portion size of 200 grams per person per meal, that amounts to roughly 3.5 million meals.

"For the fishing industry, it is challenging that the pink salmon appears every odd-numbered year," Olsen says.

According to him, feedback from buyers of the fish has been excellent.

"Many would like to buy more pink salmon if it maintains the same quality as the fish delivered last summer. Pink salmon has the potential to become valuable – not only for recreational anglers but also for businesses in coastal communities," Olsen concludes.

He explains why pink salmon is considered a climate winner perfectly adapted to Norwegian sea and river temperatures:

"Pink salmon thrives in temperatures between 5 and 15°C, which is common in Norwegian waters, and it does not die until temperatures reach 26°C. Put simply, if the water continues to warm, it will not significantly affect pink salmon's living conditions," Olsen says.

Foto: Nofima

For the fishing industry, it is challenging that pink salmon invades Norwegian waters every odd-numbered year.

Fisheries Management and Legislation

The current unclear management system for pink salmon is, however, an obstacle to optimal use of the resource.

Research Director and fisheries economist Bent Dreyer draws a parallel to the king crab, which initially

posed a similar challenge as an invasive species that created major problems but also can make nutritious and delicious food.

Today, the authorities aim to manage the king crab sustainably through an intricate quota system. Bent Dreyer argues that clear regulations would exist if fisheries management practices were applied to pink salmon, treating it as a valuable food resource.

"We have extensive and robust legislation in place for this. For example, the Marine Resources Act, states that fisheries resources must be utilised to achieve environmental, economic, and social sustainability. The Ministry of Fisheries can establish a management plan, set total quotas, and distribute them. They also work to establish requirements for fishing patterns, catch monitoring, regulation, marketing, and food safety", says Dreyer.

"The Food Safety Authority may establish rules on how the catch should be handled and stored to ensure that as much as possible is processed into valuable food for human consumption", he adds.

At present, responsibility is divided between two ministries:

The Ministry of Climate and Environment is responsible for some aspects of management as pink salmon migrate up the rivers. The Ministry of Trade, Industry and Fisheries, on the other hand, oversees activities related to harvesting from the sea. According to the biology of pink salmon and the Food Safety Authority's requirements for food intended for human consumption, the resource is most valuable when caught at sea.

"Therefore, these two ministries should meet to discuss how best to utilise the pink salmon resource", says Bent Dreyer.

Foto: Nofima

Pink salmon is an invasive species, which has caused significant problems, but it can also become nutritious and tasty food

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Funded by
FHF – The Norwegian Seafood Research Fund

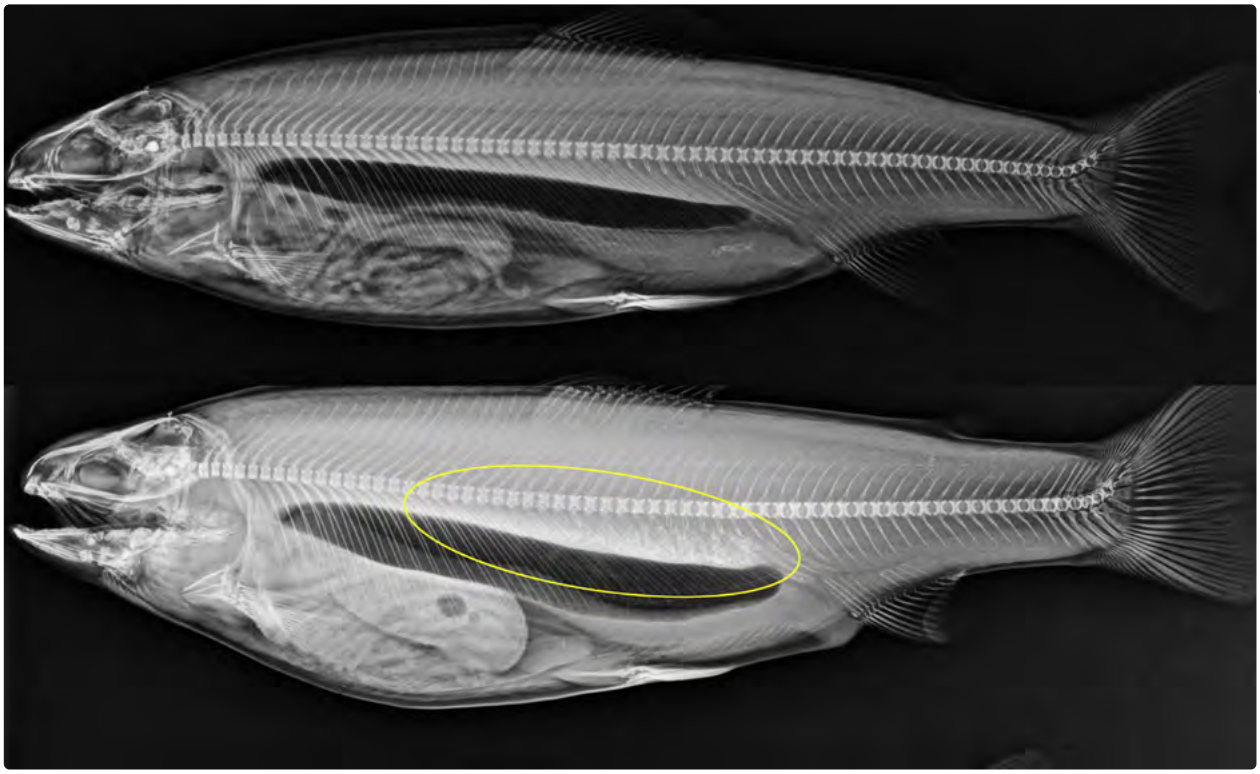

Photo: Terje Aamodt , Nofima

In addition to diagnosing rainbow trout in X-ray laboratory in Sunndalsøra, Nofima can perform the procedure in the field.

CO_2 is a cause of kidney stones

Research shows that the amount of carbon dioxide in the water has a clear link to the development of kidney stones in farmed rainbow trout.

In short, the results indicate that the higher the concentration of carbon dioxide (CO_2) in the water during the juvenile stage, the greater the proportion of fish that develop kidney stones – also known as nephrocalcinosis. There is also a clear correlation between CO_2 concentration and the severity of the condition.

Why is there carbon dioxide in the water?
During the juvenile stage, rainbow trout (and salmon) are farmed in tanks with freshwater on land. If fish density is high and water exchange low, CO_2 levels rise. As fish breathe, they absorb oxygen through their gills and release carbon dioxide. In practice, there is therefore always some CO_2 in the water of a farming tank.

«The extent and severity of kidney stones increase steadily as CO_2 concentration rises»
Ingrid Lein

A general recommendation for farmers is to keep CO_2 levels below 15 milligrams per litre in juvenile facilities, but this advice has not been well documented. Nofima's research now shows that at 13 mg CO_2 / litre, 5% of rainbow trout developed kidney stones. When fish were farmed in water with 26 mg CO_2 / litre, more than 40% developed kidney stones.

"The extent and severity of kidney stones increase steadily as CO_2 concentration rises," says researcher Ingrid Lein, noting that she does not believe CO_2 is the sole cause of nephrocalcinosis in rainbow trout, but that it is clearly a very important causal factor.

"For salmon, we know the picture is more complex, but there is every reason to believe that CO_2 is also an important part of the cause in salmon," she adds.

Rapidly increasing kidney disease

Nephrocalcinosis is a rapidly increasing kidney disease in farmed salmonids. The kidneys are responsible for filtering the blood and are among the fish's largest blood-forming and immunological organs. When smolts are released into the sea with damaged kidneys, they cope less well with marine challenges, even though CO_2 concentrations there are very low.

"It's uncertain how painful it is, and when it becomes truly severe. The fish can appear perfectly healthy on the outside but have severely reduced kidney function," says veterinarian Kirsti Hjelde at Nofima. She has helped to further develop X-ray diagnostics that allow kidney stones to be detected in live fish at the tankside.

Key to more knowledge

To measure the effects of different treatments, Nofima uses large-scale X-ray imaging on live fish. With X-rays, researchers can detect kidney stones, which are crystals in the kidneys. Previously, diagnosis was limited to tissue sampling and killing the fish to study the kidneys.

"With X-rays, we avoid harming the fish, and we can monitor development over time" notes Kirsti Hjelde.

"We now have a model system where we can induce kidney stones in rainbow trout and measure the effects on the fish. With this setup, it becomes easier to investigate other risk factors, interactions, and measures against kidney stones in farmed fish," says André Meriac at Nofima.

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Funded by FHF – The Norwegian Seafood Research Fund

Partners Various stakeholders in aquaculture

Cardboard can replace plastic

Packaging made from cellulose can replace plastic, but it is not suitable for all types of food.

Photo: Wenche Aale Hægermark, Nofima

The coatings applied to packaging trays must withstand moisture and provide good gas barrier properties.

Global plastic consumption must be reduced. In the case of food packaging, this can be done either by replacing plastic with alternatives such as cellulose-based materials, by reducing the thickness of plastic, by reusing it or by using recycled plastic.

For cellulose-based materials, high requirements are set on the coatings applied to the packaging trays if they are to withstand moisture and provide effective gas barrier properties. Barrier properties describe how well a material prevents gas, moisture, light, odour, and fat from passing through the packaging.

Nofima scientist Agnete Jordhøy Lindstad has, in her doctoral research, studied how cellulose-based packaging, such as cardboard and paper, can replace plastic in food packaging. She investigated whether a protective coating between the cellulose and the food can provide the same properties as plastic. To answer this, she studied various types of coatings based on different materials.

Three major challenges

The cellulose-based packaging and its coating must withstand both moisture and fat, while also functioning as a barrier against the gases used in packaging certain types of food, such as meat and fish.

"It is important that we view the environmental effects in a wider context. An eco-friendlier material is not automatically an environmentally friendly solution if it leads to poorer food quality or a shorter shelf life – as that could increase food waste and ultimately cancel out the benefits," the scientist points out.

To extend the shelf life of food, a method called modified atmosphere packaging (MAP) is often used. Here, a gas mixture is introduced into the packaging to slow down bacterial growth and keep the food fresh for longer. This requires optimal barrier and good sealing, which is a major challenge with cellulose-based materials.

"We succeeded in developing a cellulose-based tray with a biodegradable coating with proper sealing that could be used for MAP. This is a result that has proven difficult to achieve so far," explains Agnete Lindstad.

At the same time, she emphasises that the barrier against CO_2 of the studied material is not sufficient, which shortens the shelf life. This is important to know, as meat and fish are often packaged with CO_2 to remain fresh.

Protects both the food and the environment

An important finding from the doctoral research is that, even if the packaging has good protection against O_2 and seals well, a high transmission of CO_2 can limit how well it is suited for modified atmosphere packaging (MAP).

Following her doctorate, Agnete Lindstad will continue as a scientist at Nofima, working further to reduce plastic use without compromising food quality and shelf life.

"The goal is to develop packaging that protects both the food and the environment. To succeed, we must work closely with industry and continue testing solutions in practice," says the scientist.

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SLNF – The Agricultural and Food Industry Research Fund

Young adults ignore eco labels

Young adults eat less seafood than before – despite increased awareness of sustainable choices. Could modern technology hold the answer to why?

Photo: Audun Iversen, Nofima

Researcher Kamilla Bergsnev shows the Varjo XR-4 VR headset used in the research project

Virtual reality (VR) is a technology that allows you to experience and interact with a computer-generated world that feels real. Consumer researcher Kamilla Bergsnev and her colleagues at Nofima used the technology to create a virtual grocery store resembling a typical Norwegian supermarket. Their goal was to find out how consumers' emotions, attitudes and preferences influence their choices.

In the VR store, participants could choose between seafood products such as salmon, Norwegian cod, gourmet cod, fish gratin, prawns, saithe, pickled herring and whale steak. A total of 18 young adults between the ages of 18 and 35 took part in the study.

Unique insight

Equipped with VR headsets that tracked their gaze and hand sensors measuring emotional activity, participants were asked to select two of nine different seafood products and place them in their virtual shopping basket. Some of the products carried food labels such as "Nyt Norge", "Nøkkelhull" and "MSC".

The method gave researchers unique insight into how participants used their vision and assessed the products – and whether the food labelling influenced their decisions.

"There is great potential in using VR as a research tool in marketing studies. We can observe behaviour in a far more detailed way than in physical grocery stores," says Bergsnev.

After the VR session, the participants were interviewed about their choices and reflections on sustainability and seafood.

Taste and habit

The results show that choices are often governed by taste and habits. Products such as salmon and trout were the most popular, followed by Norwegian cod.

"Our cooking skills play an important role when we, as consumers, decide what to buy and eat. Several said that salmon and trout are easier and quicker to prepare than other kinds of fish," says Bergsnev.

Even though the products in the VR store were not labelled with prices, some participants justified their choices by referring to cost. When asked what kind of information was most important in everyday shopping, most cited price.

They emphasised that they care about where the fish comes from and considered Norwegian products to be more sustainable than foreign ones. Reducing food waste was also mentioned as a way to live more sustainably.

"There is great potential in using VR as a research tool in marketing studies. We can observe behaviour in a far more detailed way than in physical grocery stores"

Kamilla Bergsnev

Illustration: Nofima

This is what the VR grocery store looks like.

"Several also expressed scepticism towards fish farming, yet they often chose farmed salmon or trout in the VR store. Many said they preferred fillet products over processed options such as fish gratin, and many were wary of ultra-processed foods," says Kamilla Bergsnev.

"Most people want to make more sustainable choices when shopping for food, but they find it difficult or even impossible. Many said they did not know what is actually sustainable and referred to a lot of contradictory information," Bergsnev adds.

The young adults wanted clearer and more visible sustainability information on packaging.

At the same time, both the eye-tracking data and the interviews showed that most participants had little knowledge of the labels currently in use. The eye-tracking results revealed that participants focused mainly on the brand name, country-of-origin label such as 'Norwegian', and the product image.

"Several participants lacked trust in various forms of food labelling, particularly when issued by commercial actors. However, they had a high level of trust in Norwegian public authorities," says Kamilla Bergsnev.

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Funded by
Norwegian Ministry of Trade, Industry and Fisheries

Photo: Det Norske Måltid, FABEL media

Kristin Austigard, leader of Det Norske Måltid, surrounded by happy winners.

Contests boost local food

Many local food producers are eager to reach new customers and taking part in food contests can be the way forward.

Researchers at Nofima have found that by participating in food contests such as the national Norwegian food competition *Det Norske Måltid*, producers receive professional assessments, gain increased visibility, and build valuable networks that help them grow.

"Food contests are an important arena for learning for local food producers. They provide confidence, inspiration, and practical advice for developing both products and businesses. It can just as well be about new knowledge of packaging and storytelling as about the product itself," says Stine Alm Hersleth, researcher at Nofima and project manager for Kompetansenettverk Lokalmat Øst (the Competence Network for Local Food).

The study shows that producers actively use the jury's feedback and evaluations. For many, participation becomes a turning point.

- 78 per cent of finalists use their contest status in marketing
- 35 per cent take part in more contests afterwards
- 19 per cent improve their packaging design
- 18 per cent place greater emphasis on local origin
- 18 per cent improve the storytelling around the product

"Local food producers who take part in food contests are investing in the future. They showcase both their products and the stories behind them, building pride in local food," says Hersleth.

"It is inspiring to see that Nofima documents how important *Det Norske Måltid* is for local value creation and development. For producers, participation is not only about honour and recognition – it provides professional input, builds stronger networks, and helps elevate the food industry. It is a tribute to the knowledge, raw materials, craftsmanship – and the people behind them," says Kristin Austigard, leader of *Det Norske Måltid*.

"Food contests strengthen the entire local food industry," emphasises Stine Alm Hersleth.

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Funded by Nofima

Partner Det Norske Måltid

Three months shorter production time

Selective breeding is a powerful tool to enhance desirable traits in fish and livestock – a fact well established in the industry. Now Manila clam has its own dedicated breeding programme.

Naturedulis, based in the nutrient-rich Goro Lagoon in Italy, operates a hatchery for clams. The company supplies juvenile clams to other shellfish farmers in the region. Their ambition was to harness the natural potential of these clams through selective breeding, enabling better utilisation of the lagoon's nutrients and boosting production.

This ambition has become reality through a project called Bivalvi. The basis of the breeding programme builds on Naturedulis' and its customers' expertise on clams, combined with Nofima's experience in breeding science.

At the beginning of 2025, farmers began seeding the first clams selected specifically for rapid growth.

"We expect these clams to be market-ready by Christmas 2025, slashing the production cycle by at least three months," said Leonardo Aguiari of Naturedulis in November.

He added that the Bivalvi project has been pivotal for the Italian hatchery Naturedulis and local clam-based economy.

Since the 1960s, Nofima has worked to develop breeding programmes for a wide range of species in collaboration with industry partners. This includes cold-water species salmon and cod, as well as the warm-water tilapia. The sophistication of these programmes varies and develop over time.

"Manila clam is the latest species to benefit from breeding work by Nofima's geneticists," says project leader Anna Sonesson.

She is proud to be involved in breeding a low-trophic species such as clams:

"Shellfish breeding is not common in Europe. Even though a driver of sustainable food production is to move down the food chain, there is still very little breeding of low-trophic species. This means missing out on improved production efficiency, health, quality and lower mortality," Sonesson explains.

Researchers at Nofima have contributed to making Manila clam farming a viable industry in Europe.

This is what a spawning Manila clam looks like.

Photos: Evan Durland, Nofima

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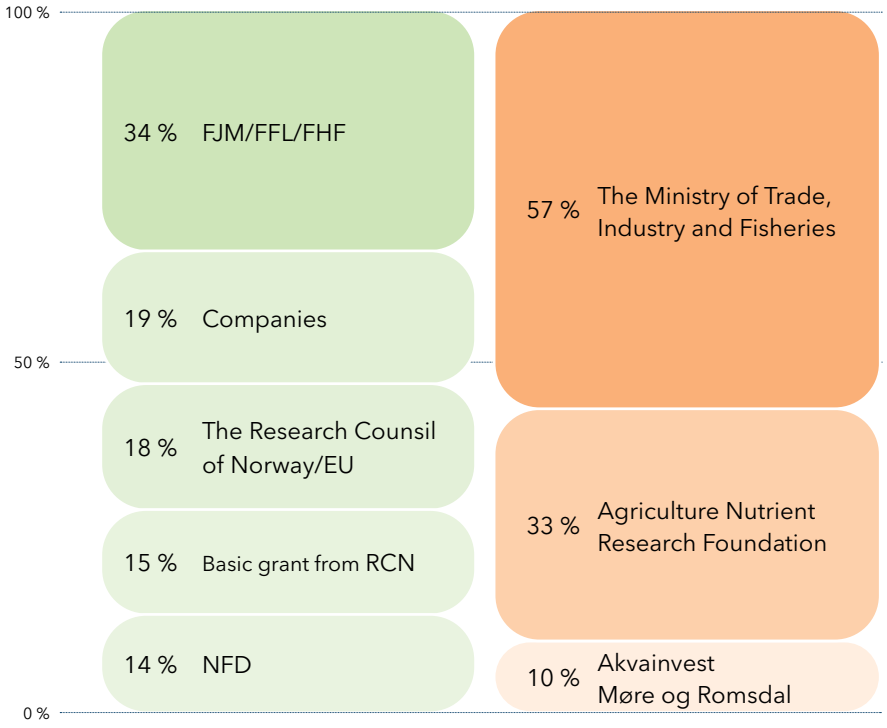
Funded by ERA-NET BlueBio

Partners Naturedulis and the University of Bologna

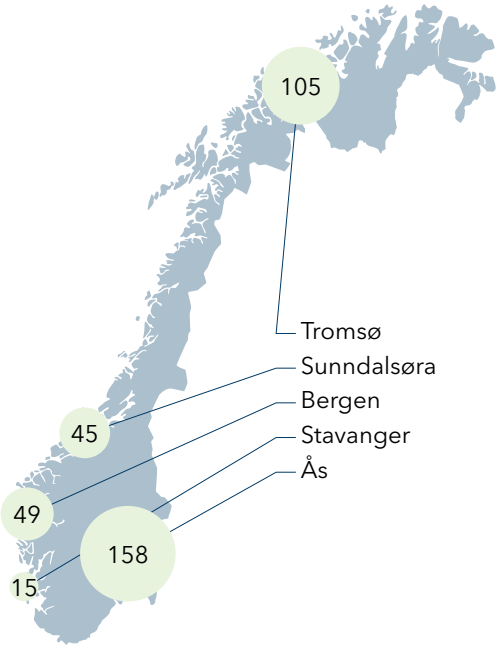
Behind the results

Who funds the research

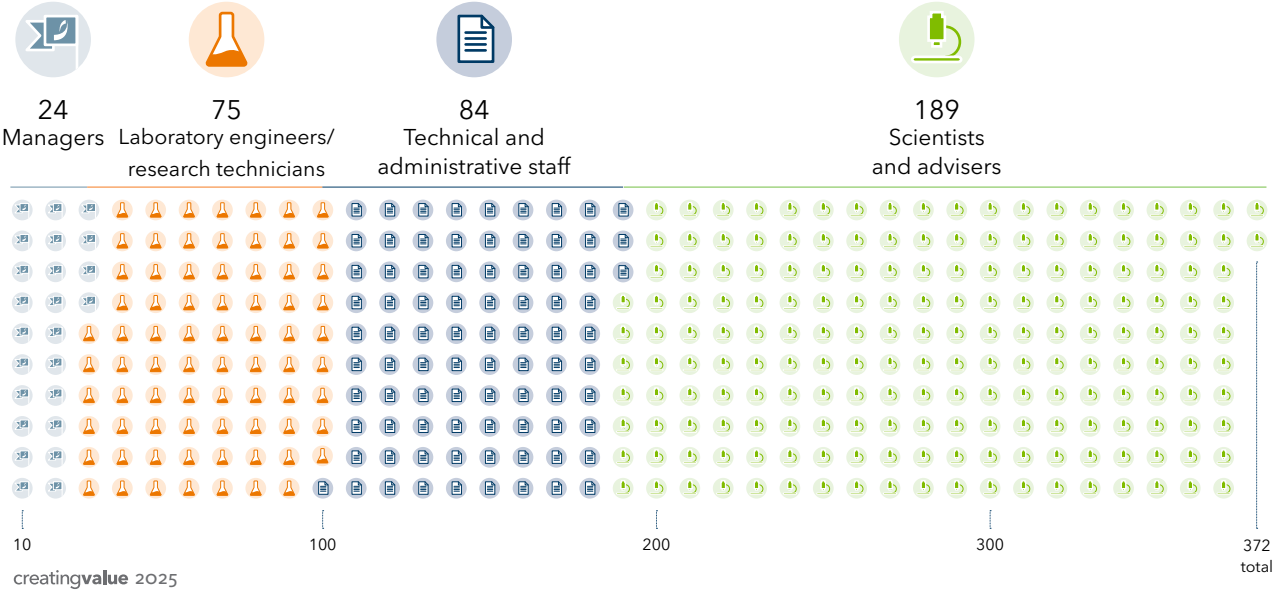


Who owns us

Where we are



What are we doing



The following are our largest funding providers:

The Ministry of Trade, 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.

Foundation for Research Levy on Agricultural Products organisation finances research and innovation for the entire value chain. The projects should cover key knowledge gaps and ensure good user involvement.

Horizon Europe are the EU framework programme for research and innovation. Their goal is to ensure that 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 (RCN) is a research poliy adviser for the government and the ministries which allocates NOK 11 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.

Nofima's researchers, engineers, and technicians develop and contribute their expertise to approximately 550 research projects each year, in practice delivering solutions ready to be applied by industry and public management.

Nofima is undergoing a period of transition to adapt its operations to a changing research market. This restructuring presents challenges for the organisation, but is necessary to balance income and expenditure and, in the longer term, to secure sound financial results for the company. The rise in public research funding has not kept pace with increasing costs, making it essential for the company to strike an effective balance between opportunities for research funding and the altered cost structure.

In times of change, it is also crucial to be equipped with the appropriate research and industry expertise to win calls for proposals and to have relevant infrastructure to conduct trials and analyses that industry requires. Altogether, these factors enable us to develop the best solutions for sustainable food production.

We continue to prioritise the development of digital skills among our staff and introduce solutions that enhance and streamline work processes. We also remain at the forefront in effective research communication and project management, making us an attractive partner for industry and other research environments.

Grete Sollesnes Winther
Chief Financial Officer

This is Nofima

Nofima has some 400 employees, and a turnover of NOK 736 million in 2024. 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
Finn A. Weltzien

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
Kristin Hollung

Photo: Wenche Aale Hægermark, Nofima

Program leaders Even Heir, Valérie Almli, Kjersti Aaby og Nils Kristian Afseth are featured here, with a broad team of specialists behind them.

Science for a better food sector

FFL programs ensure long-term research on agricultural products and help meet future competence needs in the food sector.

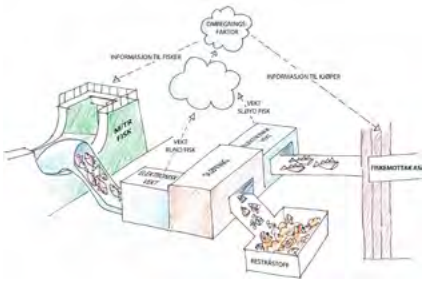
Here is a selection of what our professionals deliver, with clear impact for both industry and society:

- We use whole genome sequencing on molds to map transmission routes in the food industry. Some species can survive in bakeries for over a year. These findings enable businesses to adapt cleaning routines and reduce food waste.
- We are testing new packaging solutions for lamb meat, among other things. Packaging is designed to be reusable and/or recyclable to meet updated EU regulations.
- We map individual differences in consumer attitudes, sensory perception and food practices. These insights help food businesses develop products tailored for different target groups.
- We work with method development in sensory science. Our sensory assessors use sensory ethnography to register all impressions from food and surroundings, to understand what creates a holistic food experience.
- We identify biological markers which can explain why chicken develops muscle defects known as "wooden breast". This could enable breeding for improved animal welfare and meat quality.
- We are developing sensor technologies to improve measurement of sugar content in vegetables and fruits. This contributes to increased resource efficiency. We investigate how light affects the development of chlorophyll and toxic glycoalkaloids in potatoes and develop analytical methods to detect risk varieties and test different ways to reduce the content.
- We test potato peel extract and other plant-based antioxidants in foods. Measurements show that the potato extract do not cause undesirable odour or taste. This opens opportunities for improved utilization of side streams and reduced use of synthetic antioxidants.
- We are investigating bread baking processes and the baking properties of grains with varying quality. This may increase the use of Norwegian raw materials and improve the nutritional quality of bread.

Forskningsmidlene
for jordbruk og matindustri
Fondet for forskningsavgift på landbruksprodukter (FFL)

Sustainable food for all

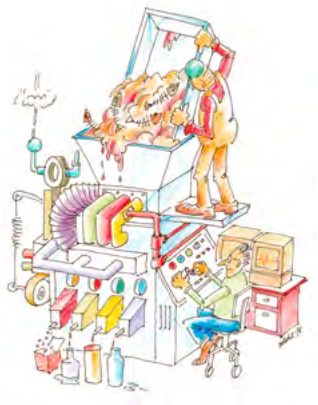
At Nofima, we have identified six strategic areas to focus on in the coming years. Using these as management tools, we will fulfil our social mission of producing new knowledge that helps advance Norwegian food industries:



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

Illustrations: Oddvar Dahl, Nofima

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Bente is Nofima' s top leader and ensures a steady course towards the vision "Sustainable food for all". Research-based solutions are implemented when food industries and research work together for future sustainable food systems.

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Kristin leads the research to ensure sufficient, healthy and safe food, with a focus on land-based production. We work with raw materials, food safety, preventing food waste, processing, technology, sensory science, consumer studies and innovation, among other things.

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Bård Thomas is responsible for research and innovation that contributes to sustainable food and good management of resources from the sea. This includes industry, technology and innovation, as well as business economics and markets.

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Finn leads a team of dedicated experts in aquaculture. He is committed to ensuring that our research in genetics, feed and nutrition, fish health and production biology benefits the aquaculture industry and society.

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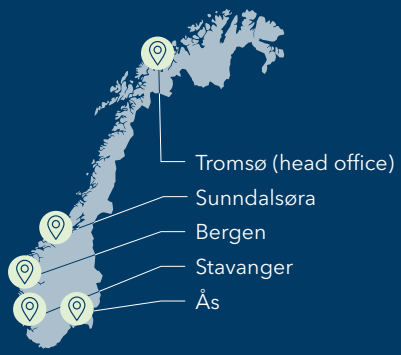
Asbjørn leads Nofima's communications department. It helps ensure that research results become known and are put to use in the food industry. Dissemination takes place through websites, media, social media, and participation at relevant arenas.



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