creatingvalue

Project year 2024

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We will work closely with industry

Photo: Helge Skodvin, Nofima

Managing Director Bente Torstensen.

Nofima is an institute for applied research, our research is not applied until it is actively put to use. Therefore, close contact with industry partners is crucial.

Norway is a small country with a population of 5.5 million inhabitants. Nevertheless, we play a significant role in food production. The Norwegian food industry is world-leading in various areas due to the work of innovators and entrepreneurs. However, those of us in research, politics and administration can also take credit.

The intersect between industry, politics, administration and research is precisely where the key to success lies. A four-leaf clover that, with financiers on board, must interact and maintain strong and consistent dialogue. This is essential for us to succeed in the necessary green transition, perhaps critically, at a faster pace than what we have seen so far.

At conferences, I observe an increasing emphasis on trust-based cooperation. For us at Nofima, it's important to emphasize this. Our mission is to provide the Norwegian food industry with new, research-based insights that contribute to sustainable development. We do it best by cooperating with those who will use the knowledge as concrete solutions in businesses and society.

We must remember that food production accounts for more than 30 percent of climate emissions. Meanwhile, an increasingly growing population demands more high-quality food, especially proteins. Food waste, the increasing scarcity of freshwater and arable land area, and ensuring biodiversity are critical targets that accent this problem.

Meeting this challenge requires political willpower, new knowledge from research and administration, and innovative businesses.

As leader of one of Europe's largest food research institutes, I will do my part for a strong, trust-based, and consistent dialogue with the food industry and the rest of the four-leaf clover. We are here to contribute to concrete solutions shaping sustainable food systems.

Feel free to get in touch.

Bente E. Torstensen
Managing Director

Sustainable feed with algae: how Nofima works

When Nofima researches sustainable feed for salmon, the process involves everything from when a new ingredient is delivered to our feed technology centre, to when the salmon has eaten the feed and grown to slaughter size.

This is because an ingredient has at least two aspects: a technical and a nutritional one.

"If you can't get the ingredient into the feed, you can't get it into the fish," explains senior researcher Tor Andreas Samuelsen, providing a straightforward summary of a complex process.

Replacing fish oil with a more sustainable, oil-rich ingredient is quite complex. Defining what constitutes a sustainable ingredient is a separate issue, but it is reasonable to assume that microalgae are among them, as they are at the bottom of the food chain.

Exemplified by oil from microalgae

Samuelsen has worked with microalgae in feed and uses it as an example of how Nofima works to replace an oil source in the feed.

In the project Millennial Salmon, Nofima sought to determine how much of an algae-based product could be included in a salmon pellet and how it affected the fish that consumed the feed. The algae product Nofima tested (AlgaPrime™ DHA LS) was rich in the marine omega-3 fatty acid DHA and was supplied by Corbion.

"What was exciting in this research was that to be able to design the feeds for the fish trial, we first had to conduct a technical evaluation of the ingredient to determine what levels we could achieve in the fish trial. For this algae product, we simply needed to get to know it technically first," says Samuelsen.

Previously, Nofima tested DHA-rich algae as a dry powder mixed into feed. What was unique about AlgaPrime™ DHA LS was that it was a dried and finely ground microalgae mixed with rapeseed oil to form a liquid product.

A short lecture on feed production

Almost all fish feed is produced using an extruder. Extrusion means that the feed mixture goes through a process in which it is cooked, kneaded, and expanded through dies. It is then dried into pellets with an expanded and porous form. The process is similar to the puffed cereal you might have in a breakfast bowl. For fish feed, it's important to have many small pores so they can be filled with oil in a vacuum coater to make the feed extra nutritious. Samuelsen explains:

"In the extruder, we rely on friction. This is why there is room for a maximum of 11% fat in a feed mixture that goes through the extruder. But that is too little fat for the fish. So, we coat the rest of the oil, which means it's drawn into the pores and stays there," he says.

The challenge is that the pores need to be large enough for the algae particles in the rapeseed oil to enter the pellet, but small enough to prevent the oil from leaking out during storage and feeding in the salmon pens.

Photo: Helge Skodvin, Nofima

Fact box on sustainable feed

- The Norwegian government has set a goal to increase the share of ingredients in fish feed from sustainable sources by 2034.
- There is a particular focus on replacing soy, fishmeal, and fish oil with alternative fat and protein sources with a lower environmental footprint.
- Nofima has been researching this for many years and is a leader in knowledge and technologies related to raw material processing, feed technology, and the nutritional needs of farmed fish.
- Nofima also researches other aspects of sustainable feed, such as market considerations and the sensory properties of salmon fillets fed with new types of feed.

Tor Andreas Samuelsen (right) and colleagues at one of the extruders used in feed research.

This is how it went with the algae-based product in the feed

Testing of algae levels in feed was conducted by researchers at Nofima's Aquafeed Technology Centre in Bergen. They measured technical pellet quality properties, such as hardness, water stability, oil leakage, and pellet pore size. Based on this work, they produced the trial feeds, which were sent to Nofima's research station in Sunndalsøra. There, the salmon were fed the various feeds and monitored and evaluated as they grew.

The results from the trial are now available.

It was possible to add more of the algae product to the feed than initially thought commercially viable. The feeding trial showed that the salmon liked all the experimental feeds and digested the nutrients well. In many cases, it is necessary to rupture the cell walls of microalgae to make the nutrients available to the fish before the ingredient enters feed production. However, the trial documented that this was not necessary with this algae product.

Thus, the trial yielded positive results. In practice, however, the actual level of an oil-rich ingredient in feed production will vary with the fat level in other ingredients, the pore size of the dried pellet, and conditions on the production line.

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MSC's core premise falters

In a recent Nofima report, doubt is cast on whether the MSC sustainability certification functions as intended.

Price premium for MSC certification at ex-vessel level are small or non-existent. MSC thus risks losing support from the catch sector, which covers the certification costs.

"For significant quantities of fish, we find no price premium for MSC certification in the export market," says Geir Sogn-Grundvåg.

The fish in question are all Norwegian spring-spawning (NSS) herring, haddock fillet products (except loins), whole, gutted haddock with and without head, and cod for Eastern Europe.

Marine Stewardship Council (MSC) is today almost the sole provider of third-party certification for sustainable fisheries and has gained a dominant position as a global sustainability label for seafood.

Based on the assumption that such certification is crucial for market access in many of the most attractive seafood markets, the Norwegian fishing industry has invested significant amounts in MSC certification of the most important Norwegian fisheries.

The main findings in the scientific final report conclude:

Cod: The price premium for MSC certified cod varies between market regions: 17 percent in Western Europe, 10 percent in Northern Europe, 8 percent in Southern Europe, 4 percent in the Norwegian market, and no premium in Eastern Europe.

Haddock: Haddock loins with MSC certification achieve a price premium of 14 percent in the export market, while other haddock products do not achieve any price premium.

NSS herring: The loss of MSC had no impact on price formation in the export market.

For some fisheries and products and in certain regions, however, MSC is of great importance.

"The certification is important for cod in certain market regions where we find a significant price premium," says Ingrid Kristine Pettersen.

Photo: Frank Gregersen, Nofima

Nofima scientists conclude that the MSC sustainability certification provides little or no price benefit for several of the most important fisheries.

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Partners:
University of Southern Denmark and University of Florida

Optimal cow feed management

Dairy farmers can now quickly determine optimal feed quantities and ideal grass nutrient content for maximum milk production.

New sensor technology using non-destructive spectroscopic methods is replacing costly and time-consuming analyses in dairy farming.

From research to barn

Scientist Erik Tengstrand is developing prediction models to make these measurement methods user-friendly and reliable. Creating accurate and robust calibrations requires not only knowledge of raw materials and their nutritional composition, but also statistics and data modelling. Nofima's scientists have developed this expertise over decades, benefiting various agricultural and food industry sectors.

TINE, a major dairy company, is investing in this technology to assist dairy farmers, collaborating with Tengstrand to build calibrations that provide swift and reliable results.

"Farmers can use silage analysis results to create feeding plans based on their available feed stocks. These analyses are typically conducted from September to April, ensuring more efficient feed utilisation," explains Tilmann Hettasch, advisor at TINE.

Photo: Wenche Aale Hægermark, Nofima

Nofima scientist Erik Tengstrand take a look at the silage to the dairy cows in the dairy barn at NMBU.

Perfect timing for harvesting

Tengstrand adds, "Grass nutrient content varies throughout the year. Our predictions aim to help farmers identify optimal nutrient levels, enabling them to harvest at peak quality."

However, seasonal variations are not the only factors affecting fresh grass. The composition of pastures and meadows can vary, and weather, soil, and sunlight conditions all play a role. Consequently, there are countless variations in the nutritional composition of fresh grass, all of which researchers must consider when building their calibrations.

The ultimate goal is to provide precise information that helps farmers optimise feeding and milk production year-round.

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TINE

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TINE and NMBU

Dry-cured hams: taste diversity

Nofima's professional sensory assessors have evaluated twelve different dry-cured hams, revealing significant variations in taste and texture.

Photo: Reidun Lilleholt Kraugerud, Nofima

Nofima's professional sensory assessors tasted twelve different cured hams. There were large variations in taste and texture.

"Maturation time is the most crucial factor influencing the flavour profile and texture of dry-cured hams," states sensory scientist Gard W. Karlsnes.

Testing multiple categories

The hams were categorised as salted, smoked, and well-matured (over 12 months). The salted and smoked varieties were typical Norwegian-produced dry-cured hams. The well-matured category included two Norwegian hams, two Spanish Serrano hams, and one Italian Parma ham.

Marked differences were observed between product categories. While variations in taste and texture were also noted among hams within the same category, these differences were less pronounced than between hams with different maturation times and processing methods. Notably, variations were found between individual packages of the same product, particularly among the more affordable options.

Sweet, salty, or smoky

The assessors described the texture of well-matured hams as juicy, soft, and tender. Prominent flavours included sweet, umami, pork, and yeast. While the well-matured hams shared many similarities, the imported hams exhibited varying degrees of boar taint.

Smoked hams presented greater chewing resistance with a harder, tougher consistency. Their flavour profile was dominated by meat, smoke, and bonfire notes. The salted varieties offered a more fibrous, dry, and firm texture, with pronounced salty and metallic taste.

"Our assessors' assessments are objective, focusing on identifying and mapping flavour characteristics rather than preferences," Karlsnes explains. "What is perceived as best depends on context. For instance, with classical Norwegian accompaniments, most would prefer a salty taste and firm texture. However, when wrapping the ham around a melon slice, a more tender, and less salty variant could be more suitable."

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Lighting up marine organisms

Animals that are experiencing physical damage or early signs of stress can be visually identified using excitation light that induces fluorescence.

There is an increasing need for methods that can accurately measure stress in aquaculture species, without harming the organism. Hyperspectral imaging of biofluorescence is such a method, as it can potentially measure early signs of stress in both fish and invertebrates.

The fish and invertebrates that exhibit biofluorescence emit lower energy colored light when they are exposed to higher-energy blue light. This strong fluorescence is not visible to the naked eye, but it can be measured with hyperspectral imaging.

"Fish may exhibit welfare traits in ways that are invisible to the human eye, and one of our objectives is to explore new technologies that can reveal this to us in real-time", says Evan Durland, scientist in aquaculture genetics and project leader.

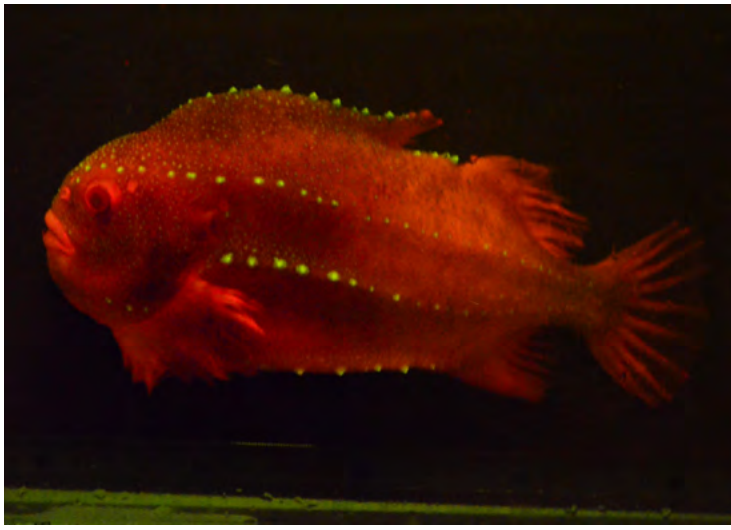
Welfare indicators are important because animals that experience chronic stress are vulnerable to disease, experience less growth, and ultimately have a higher mortality rate. The current methods used to identify early signs of stress in marine species have certain limitations.

Glowing when stressed

Technology scientists Samuel Ortega and visiting PhD student Thomas Juhasz investigated the applications of using hyperspectral imaging of biofluorescence as a welfare indicator for marine species, particularly lumpfish, red king crab, and green sea urchins.

The scientists found that lumpfish and red king crabs produced stronger fluorescent emissions after exposure to stressors. Put in simple words, the animals glowed more brightly when they experienced acute stress. They also found that sea urchins with broken spines or lesions glow brighter in the areas where they are affected.

Photo: Thomas Juhasz



This dominant male lumpfish glows red to stress other males.

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Partners:
Marie Curie PhD student Thomas Juhasz (2022)

Publication on Lumpfish

Publication on Sea Urchin

Is slaughter at sea the future?

Today it's impossible according to Norwegian legislation, but could slaughter at sea become the future for the aquaculture industry?

The Strategic Institute Initiative 'Harvesting at Sea' aims to enhance Nofima scientists' expertise and foster internal interdisciplinary collaboration, generating valuable insights for industry partners.

Only one exemption

"The answer to the initial question is 'yes'. But there's a dynamic here. Slaughter and bleeding at sea will not replace land-based processing but will become a supplement," says senior scientist Bjørn Roth.

Currently, fish from Norwegian fish farms are mainly brought ashore for slaughter, and then transported by air or road to the markets.

Only one ship – Hav Line's "Norwegian Gannet" – has an exemption from the Regulations on Quality of Fish and Fish Products, thus allowing it to bleed, slaughter and transport farmed fish to market in a single operation. "Norwegian Gannet" travels to a specially built receiving facility in Hirtshals, Denmark, with salmon and trout sourced from Norway and slaughtered on the boat.

"The processes that started with farmed salmon in pens are now spreading to fisheries. Electric stunning and bleeding aboard fishing vessels is becoming more common – both for quality and welfare considerations.

Photo: mariuslitu - stock.adobe.com

More slaughter and bleeding at sea appears to be the future for Norwegian fish farming - as a supplement to land-based processing.

We need to better understand how this works, as this is the future," says Bjørn Tore Rotabakk.

Bleeding boats

Bleeding boats are already well established in the aquaculture industry. However, in such vessels, only killing and bleeding are performed, and the fish is transported to land-based facilities for further processing.

Approximately 50 percent of Norwegian fish farms use bleeding boats.

"Capacity and volume in the aquaculture industry are increasing, and land-based facilities can't

always keep up. But with more bleeding boats and the introduction of slaughter boats, capacity can be fine-tuned across the country," says Bjørn Roth.

Colleague Rotabakk adds:

"Once the fish is killed, the boats can be smaller, because the fish can be transported at significantly higher density than if they were alive. The disadvantage of delivering fish that has been killed and bled on board is that it can go into rigor mortis – become stiff – before delivery."

This raises the question: Is it possible to do the entire slaughter process at sea?

"The alternatives today are either to kill at the pen edge and then transport the fish to slaughterhouses and subsequently transport it further by road to the markets. Or pump the fish three times; aboard the well boat, then into holding pens and finally up to the factory for slaughter," says Bjørn Tore Rotabakk.

"However, there's also the perspective of mortality during transport for fish that are transported alive. This is a challenge that's avoided with bleeding boats," adds Bjørn Roth.

Hindered by production fish

The obstacle preventing anyone who wishes to slaughter at sea and set course directly for the markets is a 2019 amendment to the Regulations on Quality of Fish and Fish Products.

It states that so-called production fish, meaning salmon and trout with deformities, wounds or injuries, must legally be corrected in Norway before export. Therefore, all slaughter boats without exemption must stop at a Norwegian port to deliver production fish. This would have a major impact on profitability.

Despite this obstacle, researchers continue working to increase knowledge about the topic as much as possible.

"Through collaboration across the diversity of disciplines at Nofima, we will be able to document what's possible to achieve with new methods, what it could mean for the industry, what savings and environmental effects could be achieved, and of course also what disadvantages sea slaughter would entail for Norwegian land-based facilities," says Bjørn Tore Rotabakk.

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Partners:
Hav Line – Norwegian Gannet

Research boosting vegetable consumption

Our researchers are working across multiple areas to ensure consumers eat more Norwegian vegetables, fruits and berries.

Photos: Anders Ellefsen, Jon-Are Berg-Jacobsen og Joe Urrutia, Nofima

Jens Petter would, Grethe Iren Borge, Gesine Schmidt and Hanne Larsen research various areas to increase sales of Norwegian fruit and vegetables.

Improved quality and shelf life, differentiated products and efficient production significantly impact sales and opportunities to reduce food waste. Our research helps strengthen the competitiveness of the Norwegian fruit and vegetable sector, whilst promoting a healthier and more sustainable diets. Some examples:

Optimal storage and packaging

Fruits and vegetables contain high water content and continue to 'breathe' (respire) after harvesting. Consequently, they quickly become wrinkled and deteriorate in quality if the temperature is too high

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or packaging inadequate. Better storage methods and packaging solutions can reduce food waste and increase shelf life.

"In collaboration with BAMA and others, we have developed a knowledge-based testing system for selecting the right packaging for fruits and vegetables. This streamlines testing of future solutions for existing and new products," says Senior scientist Hanne Larsen.

Temperature during storage and preservation significantly affects quality and shelf life, with different vegetables require different temperatures.

"Our studies show that carrots and swedes keep best refrigerated, while tomatoes, cucumbers and peppers prefer 10°C. Even short periods at room temperature are unfavourable," says Hanne Larsen.

The scientists have also investigated how light and temperature affect potatoes greening as green potatoes in shops leads to food waste. Room temperature potatoes green much faster than at 4-6°C, but there are significant variations between different potato varieties.

The chemistry of sweetness

Nofima is using sensor technology to measure chemistry - primarily sweetness - in berries, fruits and vegetables. This offers several possibilities, one being to ensure harvesting at precisely the right time.

Non-destructive methods can be used to measure sugar content and flavor in strawberries and tomatoes. Precise measurement methods for quality and ripeness can ensure that food products maintain high quality and thus meet consumer expectations.

"We have calibrated the rapid sensors against Nofima's ten professional taste assessors, who confirm that the measurements are accurate," says Senior scientist Jens Petter Wold. The next step is to develop sensors for automatic sorting on packaging lines.

Significant differences in cabbage

Norwegian cabbage comprises numerous flavours, aromas and healthy plant compounds. Nofima researchers and sensory assessors have examined a wide range of cabbage varieties within the types of head cabbage, cauliflower and leafy cabbage.

The results show significant variations in taste, smell and content of aroma and healthy plant compounds between different varieties. Cabbage is rich in vitamin C and glucosinolates, a plant compound with potential cancer-preventive properties. The most flavourful varieties contained the most healthy plant compounds.

"We found everything from mild, sweet varieties to more flavour-intense and bitter variants. In other words, something for every palate and occasion. These findings can increase cabbage consumption in the population by offering a wider range of products tailored to different preferences and uses," says Senior Researcher Grethe Iren Borge.

About the research

The research was conducted in the following projects:

- Storage and packaging of fruits and vegetables: REforReM and Holdbarsjekken
- Storage and packaging of potatoes: Grønne poteter i butikk, ReducePack and FutureFoodControl
- Sensor technology for strawberries and tomatoes: DigiFoods and Precision
- Taste and plant compounds in cabbage crops: KålSmak and SusHealth

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Photo: Terje Aamodt, Nofima

Norwegian farmers' goals for the lowest acceptable color in salmon fillets vary – between 24 and 27 on the SalmoFan grading.

Status of fillet color in farmed salmon

Nofima has mapped the status of, and challenges with pigmentation in salmon fillet. The mapping also provides insight into solutions to work further on.

The study reveals that many mechanical delousing treatments have a negative effect on fillet color. This effect has not been documented previously and can have several causes. It may be increased breakdown of an antioxidant like astaxanthin when the fish becomes stressed. But it could also be reduced feed intake and lower slaughter weight, which has a significant impact on fillet color. So, if the fish is slaughtered at a lower weight to avoid more delousing treatments, this will have a further negative effect on color.

"Historical data shows that the color intensity in Norwegian salmon fillets has decreased somewhat from 2012 to 2021, with a small increase after that"

The findings are based on questionnaires answered by Norwegian salmon producers in 2023, on data on fillet color in the period 2012 to 2023 from commercial productions, and from Nofima' s R&D licenses.

"There is largely agreement between what the farmers respond in the survey and what we see affecting pigmentation in the data analysis, so there is reason to believe that it provides a realistic picture of the situation", says Ytrestøyl.

Variable fillet color

Not all farmers perceive inadequate fillet color as a problem. Some say they experience reduced coloration on two percent of slaughtered fish, while others report having problems with 20-40 percent of the production.

It also varies what they consider as acceptable filet color, between 24 and 27 on the SalmoFan grading and between 5 and 7 milligrams of astaxanthin per kilo of fillet.

Historical data shows that the color intensity in Norwegian salmon fillets has decreased somewhat from 2012 to 2021, with a small increase after that. There is also more variation in fillet color now than before, which supports the findings of the survey; some farmers have more problems than others with pigmentation.

Measures require planning and few lice

Almost all respondents had taken measures to improve coloration. There is currently more astaxanthin in the feed (50-70 mg per kg) than before and some have also added more of the omega-3 fatty acids EPA and DHA as well as vitamins in the feed.

"This seems to have had a positive effect, but it is expensive, and we have tried to find the underlaying causes of reduced coloration", says Trine Ytrestøyl.

There are seasonal variations in pigmentation, and this can be taken into consideration when planning a production. Smolts transferred to seawater in the autumn had better fillet color at slaughter than smolts transferred in the spring. Slaughter in the spring was associated with poorer color, and so was rapid growth, while the color increased with increasing slaughter weight. There was also a clear negative effect of many mechanical lice treatments.

What surprised the researchers was also that there was a significant difference in color at slaughter between suppliers of smolt. The reason for this is not known, and they want to look more closely at this, to find out what the smolt phase means for pigment levels when the fish is slaughtered.

The mapping contains a range of data that is useful for farmers to look more closely at.

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Partners:
Norwegian industry players

The number crunchers behind the ripple effect reports

Meet the number crunchers who deliver annual profitability and structural analyses of Norway's seafood industry.

The reports analyse large portions of the seafood industry down to the municipal level. Last year, a value creation and ripple effect report was released for the entire industry. Another report covered the aquaculture industry, and a third analysed the supplier industries.

Curious about how the researchers work? We can lift the veil a bit:

The story dates back to 1976 when Nofima researchers began the profitability surveys for the fishing industry. Over the years, data collection has expanded, and now they examine the accounts of all companies in the seafood industry.

Seafood industry increasingly important

Researcher Audun Iversen explains:

"In Norway, we have the advantage that all accounts are accessible. Nofima have also gained trust-based access to internal accounting data such as purchasing data. Nofimas forskere has developed its own ripple effect model called LEIF. The model, combined with good industry understanding and quality-assured databases, helps researchers understand the seafood industry's significance for the Norwegian economy."

The number crunchers consist of experienced researchers plus some younger talents who have further developed data processing methods. Bjørn Inge Bendiksen is the veteran, having worked with accounting data for well over 30 years. Roy Robertsen and Audun Iversen also have extensive experience. Thomas Nyrud is the key person behind the model used, while Silje Steinsbø and Helene Jensen represent the new expertise.

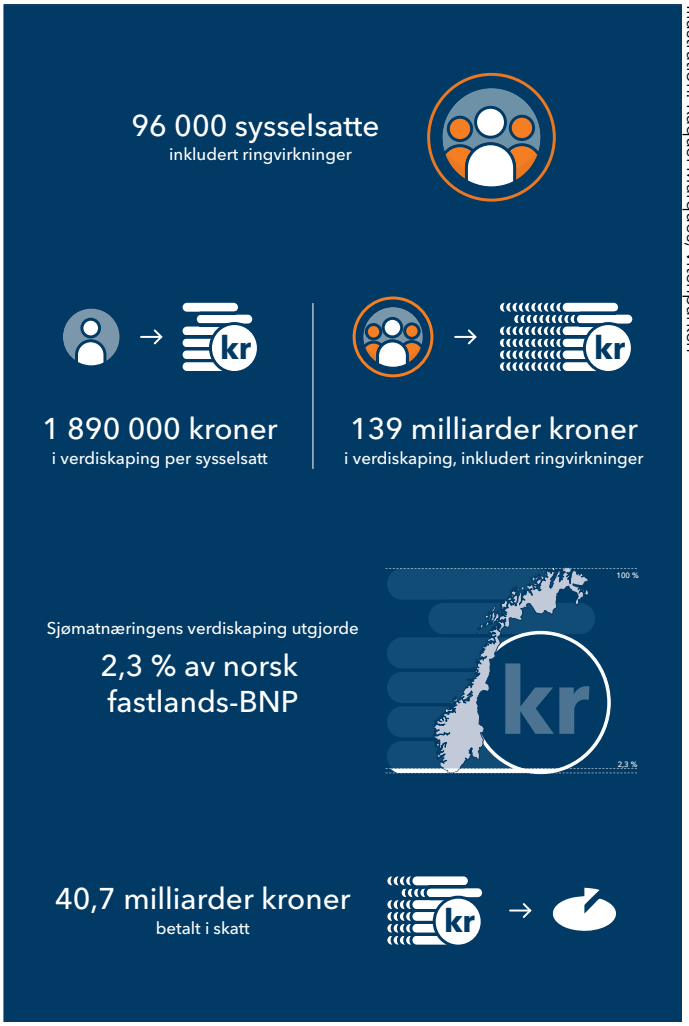

Illustration: Raquel Marques, Vitenparken

The figure shows the status of Norwegian seafood industry in 2023.

Photos: Nofima

These are the number crunchers at Nofima who create insightful reports about the seafood industry in Norway each year.

"The seafood industry has played an increasingly important role for the Norwegian economy in recent years. From representing 0.8 percent of Norway's GDP in 2004, the industry now accounts for almost 2.5 percent. It's important that we provide knowledge showing the industry's significance for suppliers and society at large. The industry creates 96,000 jobs directly and indirectly. That's substantial," says Iversen, who leads the project.

Even more precise analyses

For more precise estimates, researchers work meticulously. They measure ripple effects like employment and value creation among suppliers and their suppliers across 10 levels; roughly summarised from the industry's own purchases of vessels and aquaculture equipment, via bunkers and equipment, to lawyers, accounting, health services, and down to hairdressers and local shops. High-level number crunching.

The work has expanded in recent years. FHF (Norwegian Seafood Research Fund) has invested more than before in the research project, enabling even more precise industry analyses. In 2025, there will be a main report in autumn plus several thematic reports.

Terms

Value creation: Value creation (gross product) is the added value a company creates from purchasing raw materials to selling finished products. Value creation consists of employee wages, owner profits, and government taxes.

Net value creation: Value creation minus capital depreciation.

Employment: Employed people are the sum of employees and self-employed individuals, including part-time and seasonal workers.

Work years: A work year is the work done by a full-time employee for one year.

Ripple effects: Ripple effects are created through the industry's (core business) purchase of goods and services. Nofima's researchers measure ripple effects as employment and value creation among suppliers and their suppliers and so on (calculated across 10 levels).

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Funded by:
FHF – Norwegian Seafood Research Fund

Valuable products from cod milt

With modern extraction methods, cod sperm milt can be turned into new, valuable products such as oil and protein powder.

Photos: Rune Stoltz Bertinussen, Nofima

Researcher Birthe Vang confirms that the focus on residual raw materials such as cod milt is in line with the government's bioeconomy strategy. Cod sperm – called milt – is full of components that can become valuable products in both food and cosmetics.

Nofima scientists use hydrolysis to extract the components – which in turn can become both food and beauty products.

In the research project "TOPP – Cod milt: Oil and protein processing" – the goal is to develop and improve hydrolysis processes. In the process, proteins are split using enzymes. The enzymes act as a kind of "scissors", which cut larger proteins into small, water-soluble proteins. These are called peptides and can then be dried to form a protein powder.

"We are testing whether the peptides from cod milt have health-promoting effects related to lifestyle diseases", says project manager Birthe Vang.

"To understand the potential for value creation of offal from white fish using methods such as hydrolysis, it is a prerequisite that we manage to gain increased knowledge in the area. This way we will be able to create added value for the Norwegian white fish industry and contribute to increased value on the entire raw material", says Birthe Vang.

Nofima currently operates the national pilot plant Biotep for marine bioprocessing. Both researchers and operators at the institute have thus acquired great knowledge and expertise in all phases of marine by-product utilization. Combined with NTNU's expertise in cooling and handling, new technology from NUAS Technology and cod milt from Nord-Senja Fisk, all the pieces are in place.

Extracting new products from cod milt will represent a significant increase in value of the raw material.

"This is in line with the Norwegian government's bioeconomy strategy, which has "More sustainable and efficient resource utilization" as one of three overarching goals", Birthe Vang states.

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Funded by:
FHF – Norwegian Seafood Research Fund

Partners:
Nord-Senja Fisk AS, NUAS Technology and NTNU

Key to better welfare in RAS

Researchers have identified new knowledge about H_2S that could have significant implications for fish health and welfare for salmon in RAS facilities.

A study on how Atlantic salmon smolts respond to prolonged exposure to low levels of hydrogen sulfide (H_2S) in water has been published in Ecotoxicology and Environmental Safety. The results can contribute to improved risk assessment and setting of limit values for H_2S in recirculating aquaculture systems (RAS).

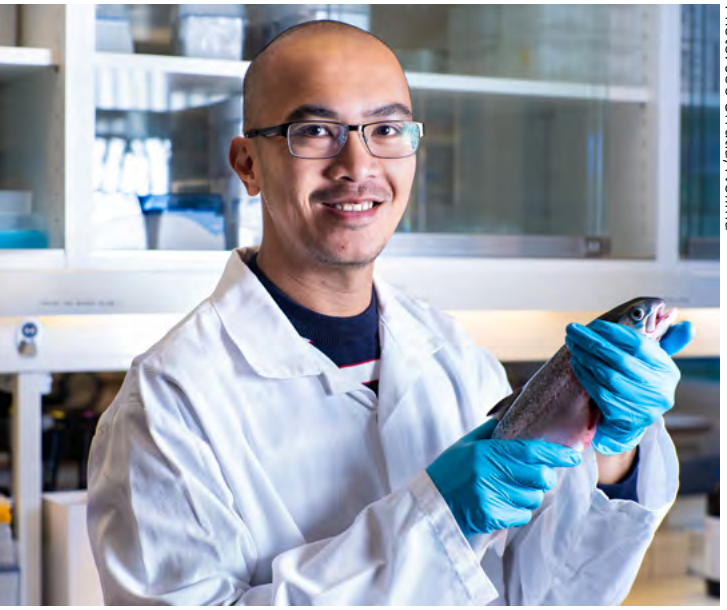

Photo: Joe Urrutia, Nofima

Nofima scientist Carlo C. Lazado and international colleagues have identified new knowledge about H_2S in water in RAS facilities.

H_2S is a toxic gas that can form in RAS facilities, particularly employing higher salinities. Even low H_2S concentrations occur during normal production and have been linked to health problems and mortality in salmon. The recently published study has investigated how long-term exposure to low, non-lethal levels of H_2S affects salmon's mucous membranes, which are the first line of defense against environmental threats and pathogens.

The researchers found that the fish's natural sulfide-degrading enzymes are induced even at low H_2S levels in the water. Another important finding is that the gills and olfactory organ react to the gas by activating genes important for immunity, allowing the fish to better cope with the toxicant.

– Our findings suggest that salmon can largely adapt to the low H_2S levels tested without serious negative health effects, says project leader Carlo C. Lazado from Nofima and adds: – This is good news for the aquaculture industry, but I also emphasize the importance of careful monitoring and control of H_2S levels in RAS facilities.

The study represents an important step towards more sustainable and efficient land-based salmon farming with a focus on fish welfare and control of the production environment. By monitoring and controlling H_2S levels, as well as implementing measures to strengthen the fish's natural defenses, farmers can create an optimal rearing environment that promotes the health and welfare of the fish.

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Funded by:
The Research Council of Norway

Partners:
NIVA, Technical University of Denmark

Photo: Jon-Arne Berg-Jacobsen, Nofima

Nofima has been researching Listeria for a number of years. Here are some of the professionals working with Listeria.

Listeria research frontrunners

For over 30 years, Nofima scientists have contributed to increased understanding and improved control of Listeria in food production.

"We have sampled over 70 Norwegian food companies, mapped Listeria transmission routes using whole genome sequencing, and investigated how Listeria can be controlled in the environment and in products," says senior scientist Even Heir, who leads the strategic research programme FutureFoodControl, where Listeria research is a central component.

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The Research Council of Norway, The Agricultural and Food Industry Research Funds (FFL/JA) and Norwegian Seafood Research Fund (FHF)

Origins of listeria

Listeria monocytogenes, which can cause serious foodborne illness, poses challenges for many food producers - especially those producing refrigerated ready-to-eat foods where these bacteria can grow.

The bacterium is highly adaptable and widespread in nature – particularly in soil, vegetation, water and animals. For food companies, the main problem is that Listeria can establish itself in the production environment, forming so-called "house strains". These are difficult to eliminate and can contaminate food products.

House strains are typically found in damp areas, on floors and in drains, as well as on equipment and machinery that are difficult to clean, such as conveyor belts, slicers, and filleting machines.

Whole genome sequencing reveals transmission routes and bacterial characteristics

Nofima has sequenced (detailed genetic mapping) 1073 Listeria isolates from approximately 25 food companies and external environments. This work has helped clarify contamination sources and routes in many Norwegian companies, providing valuable information about the distribution and characteristics of the bacteria.

"It was surprising to find nearly identical Listeria house strains in food companies from different parts of the country. In some cases, we found that the cause was the transfer of used equipment between companies. In other instances, we suspect that Listeria may have originally come from the same raw material supplier," says scientist Trond Møretrø.

He continues: "We also see that only a small proportion of Listeria types found in nature manage to establish themselves in food companies. The dominant house strains more often have genes for stress tolerance and biofilm formation."

Controlling listeria

In collaboration with industry and other stakeholders, Nofima scientists have investigated methods to control Listeria. They have tested new disinfection methods, optimisation of cleaning routines, and the effects of drying production environments.

Senior scientist Even Heir shows parts of Nofima's collection of Listeria strains. The strain collection contains thousands of bacteria from decades.

The scientists are developing and testing new methods to control Listeria in high-risk products such as refrigerated ready-to-eat foods and rakfisk (fermented trout). They have mapped risk factors in rakfisk production and proposed improved production methods to reduce the risk of Listeria in the final product.

"Complete growth inhibition of Listeria in rakfisk was achieved with a combination of protective culture, glucose and buffered vinegar. This rakfisk was also considered good by the producers Other compounds, such as nisin, further enhanced the effect. Nisin is permitted in some dairy products but not yet in rakfisk," says Even Heir.

Good production hygiene, rapid processing after slaughter, temperature control and correct salt concentration are other important measures to ensure safe rakfisk.

Useful guides and reports

Nofima has published several practical guides and reports for Listeria control. These are collected under the QR code to the left.

Salmon secrete substances that attract sea lice

New research has enhanced our understanding of why sea lice are predominantly attracted to salmon.

Photo: David Fields

The team working with chemical signalling in salmon, gathered for trial at the Institute of Marine Research in Norway.

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Funded by:
FHF – Norwegian Seafood Research Fund

Partners:
12 partners from science and industry. In particular, Rothamsted Research (UK), University of Gothenburg (Sweden), Bigelow Laboratory of Ocean Science (USA) and Nofima (Norway)

"Overall, the findings suggest that host-parasite communication is highly complex and likely involves multiple cues"
Aleksei Krasnov

The study investigates the chemicals released by Atlantic salmon that serve as attractants to these parasites.

The encounter between a salmon louse and its host begins when the louse is in its free-swimming larval stage, known as a copepodite. But being tiny organisms in a vast ocean, how do they locate salmon as their host? "Chemical signalling is believed to play a key role in host-parasite communication, and scientists have confirmed this," says Nicholas Robinson from Nofima.

Will enhance resistance to sea lice

Robinson is coordinating the CrispResist project, which brings together a leading team of scientists from Norway, the UK, USA, Canada, Sweden and Australia. Their goal is to uncover the mechanisms behind cross-species variation in host resistance to sea lice and apply this knowledge to enhance Atlantic salmon resistance in aquaculture.

A crucial objective is to identify and document genes and mechanisms responsible for the difference in sea lice resistance between salmonid species. It is well-established that certain Pacific salmon species are resistant to sea lice and can kill them in the early stages of parasitism, whereas Atlantic salmon are highly susceptible.

Senior fish health scientist Aleksei Krasnov at Nofima is involved in studies of chemical communication between lice and salmon. Working with the global team, Krasnov identified putative semiochemicals or compounds of biological origin that affect the behaviour of animals of the same or other species. The type of semiochemicals called kairomones help lice find salmon by scent.

Tested lice behaviour

The discovery involved a wide range of chemical analyses and lice behaviour tests. Water that was conditioned with Atlantic salmon, Pacific salmons and other fish species was analysed. Twenty-one candidate semiochemicals were selected for lice behaviour tests.

Additionally, mucus from Atlantic salmon families with high and low resistance to lice was studied to determine whether resistance could be linked to the chemical composition of the mucus. Behavioural tests were carried out in Norway and a few in Sweden using different methods.

Further findings

The research showed that water conditioned only with salmon stimulated copepodite activity, confirming the presence of kairomones. Interestingly, conditioned water also contained compounds that deterred lice, suggesting that Atlantic salmon can repel lice as well.

Moreover, the tests suggested that semiochemicals may be produced in various tissues of Atlantic salmon, especially the skin.

Salmon from families susceptible to sea lice were found to produce mucus that had a higher stimulatory effect on lice than salmon from families with high resistance to lice.

Future research

One of the key outcomes of the study was the identification of compounds for further research. "Overall, the findings suggest that host-parasite communication is highly complex and likely involves multiple cues," says Krasnov.

Krasnov believes that developing molecular tests is the most promising approach for continuing semiochemical research in this field.

Live-landed provides increased quality

Haddock delivered live to fish receiving stations and filleted early provides significantly better fillet quality.

This emerges from the report of an extensive research project conducted by Nofima and the Institute of Marine Research.

Researchers document how good fish welfare during capture and transport has a direct correlation with good quality and yield. Live-landed haddock that has been handled optimally provides fillets with less gaping, firmer consistency, less blood, and longer shelf life than haddock that arrives dead at the facility.

For seine-caught haddock, it has been proven that quality is markedly better with live landing at the dock, compared to ordinary seine catches.

Live is better

It has been widely understood that rapid bleeding is essential for achieving good fish quality. This is not necessarily the case anymore.

"Bleeding is still important, but the principle of keeping fish in good condition and alive until slaughter time is in a completely different league when it comes to quality," researcher Torbjørn Tobiassen firmly states.

Photo: Torbjørn Tobiassen, Nofima

The quality difference between live-caught and traditionally caught haddock is noticeable - even to the naked eye.

"One fact is indisputable: You get the best quality from fish that are alive and minimally stressed at the time of slaughter. If increased quality of raw materials is the goal, live catch and/or live landing and live storage is the solution. The principle that fish must be well-treated to achieve top quality is broadly documented," adds colleague Sjurdur Joensen.

The latter is editor of "Handbook for Live Catch and Live Storage of Fish – Better Quality and Welfare" which was launched in August 2024.

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Funded by:
FHF – Norwegian Seafood Research Fund

Partners:
The Institute of Marine Research, Båtsfjordbruket AS, Lerøy Norway Seafood AS and seine vessel MS Julie Pauline

"As the title suggests, the handbook provides an introduction to proper handling of fish that are to be kept alive. In other words, the path to good quality and welfare both in live catch and in ordinary fishing," says Sjurdur Joensen.

High survival rate with proper treatment

In the project with seine-caught haddock, researchers have investigated various vitality measurements to assess which fish are suitable to withstand live storage, and which should be slaughtered on board. Perhaps the simplest and most effective method is to assess the eye reflex of the haddock.

"A live haddock in good condition will adjust its eye. Typically, the eye looks downward when the fish lies on its side. A dead or reduced fish stares straight out, and it should not be selected for live landing," says Torbjørn Tobiassen.

"The most important thing for haddock survival after capture is to ensure the supply of clean, oxygen-rich water through the bottom of the storage tanks, since most of the fish rest there during transport," he points out.

Significance for the industry

Gentle capture methods used during live catch of haddock provide better survival and thus better quality. Live landing gives the industry better control over the slaughter process and the possibility of early filleting, which provides products of supreme quality.

Fillets from live-landed haddock have little or no gaping, which gives the industry significantly better yield during filleting, and a larger proportion of the fillets can be used for premium products.

"The project paves the way for increased gains for both fishermen and the fishing industry, and can in the long term provide more profitable utilisation of haddock resources," summarises Torbjørn Tobiassen.

"The principle that fish must be well-treated to achieve top quality is broadly documented"

Sjurdur Joensen

Health effects with beta-glucan

Ten years ago, Nofima Scientists had the idea to develop bread with high content of the dietary fiber beta-glucan. Now the bread is ready – and tastes good.

The goal was to create a healthier bread that can help prevent diabetes and cardiovascular diseases, and the plan seems to have succeeded. The next step is to scale up production from pilot to industrial scale at a medium-sized bakery.

It's beta-glucan that makes this bread healthier than most other breads. Beta-glucan is found in oats and barley and is a type of dietary fiber that can reduce levels of unfavorable cholesterol and reduces blood sugar spikes after a meal.

The goal is to tempt more people to eat healthier

"What we're doing is expanding the range of foods that can have beta-glucan as an ingredient. The goal is to tempt more people to eat healthier. The bread we've developed looks like a typical whole meal bread, but it contains a significant amount of beta-glucan. The intention is that the foods we develop should have a real health effect," says senior scientist Simon Ballance.

In the bakery, several baking techniques and different types of equipment have been tested. There have been several baking technical challenges in producing a good dough that yields bread with the desired health properties while maintaining good bread quality. The baking process is so complicated that this is not something to attempt at home. Moreover, oat flour enriched with extra beta-glucan is not currently available in the grocery store.

The bread has been baked and tested in a large clinical trial in Europe.

"It qualifies for the health claims about reduced cholesterol and dampened blood sugar rise after meals. Now we're investigating whether the bread also has positive long-term effects on blood sugar levels," says scientist Anne Rieder.

Instead of trying to control what people eat, scientists are trying to make a difference by starting with what most of us eat every day.

"There's a high threshold for getting most people to eat enough of a food to provide a lasting health effect, but for bread this will be possible because the daily intake of bread in Norway is high," says Ballance.

Facts about health claims

Only health claims approved by EU legislation (European Food Safety Authority: EFSA) can be used for food labeling in Norway. Currently, beta-glucan from oats and barley has two approved health claims that can be used under certain conditions.

- The claim "lowers cholesterol levels" can be used on products containing 1 g beta-glucan per serving (with additional information that the daily intake must be 3 g per day to achieve the effect).
- The claim "reduces blood sugar rise" requires that the food contains at least 4 g beta-glucan per 30 g available carbohydrate.

The bread developed by Nofima's experts satisfies both these requirements.

The goal of health claims is to provide credible information to consumers about foods that can prevent diseases such as diabetes and cardiovascular diseases, and so on.

"What we're doing is expanding the range of foods that can have beta-glucan as an ingredient. The goal is to tempt more people to eat healthier"
Simon Ballance

Photo: Wenche Aale Hægermark, Nofima

Nofima scientists Simon Ballance and Anne Rieder are baking the new, healthier bread with high content of the dietary fiber beta-glucan.

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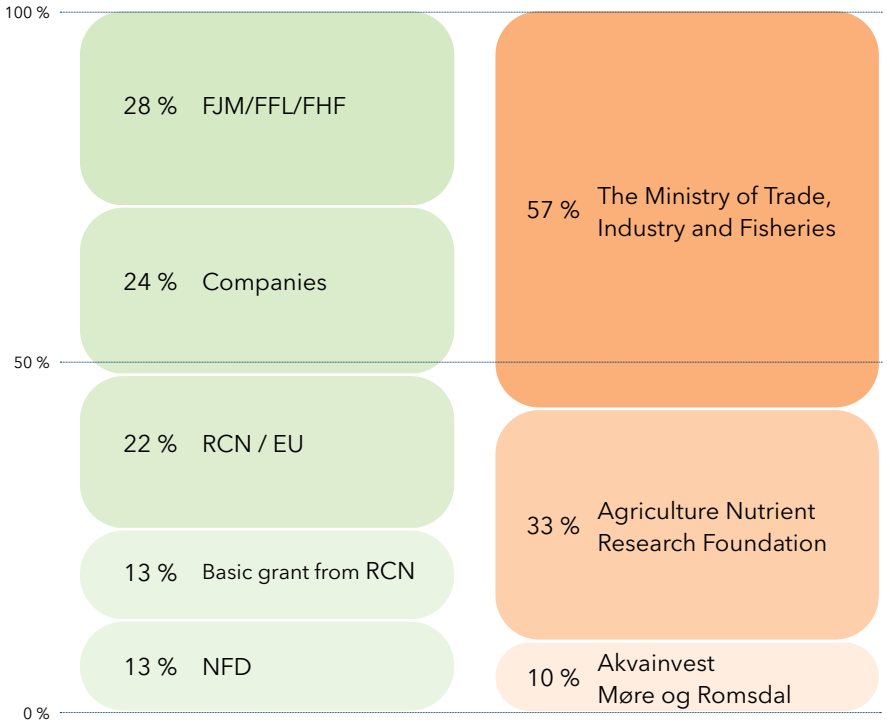
Funded by:
FFL – The Fund for Research Fees on Agricultural Products and the Research Council of Norway

Partners:
Chalmers in Sweden, and the universities in Paderborn, Leipzig, and Bergen

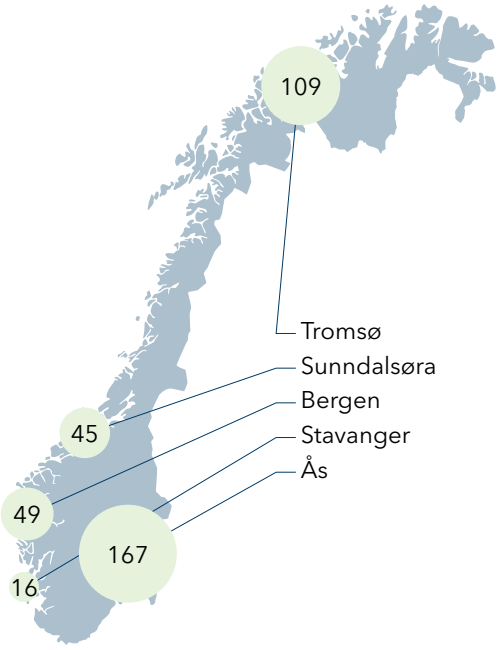
Behind the results

Who funds the research

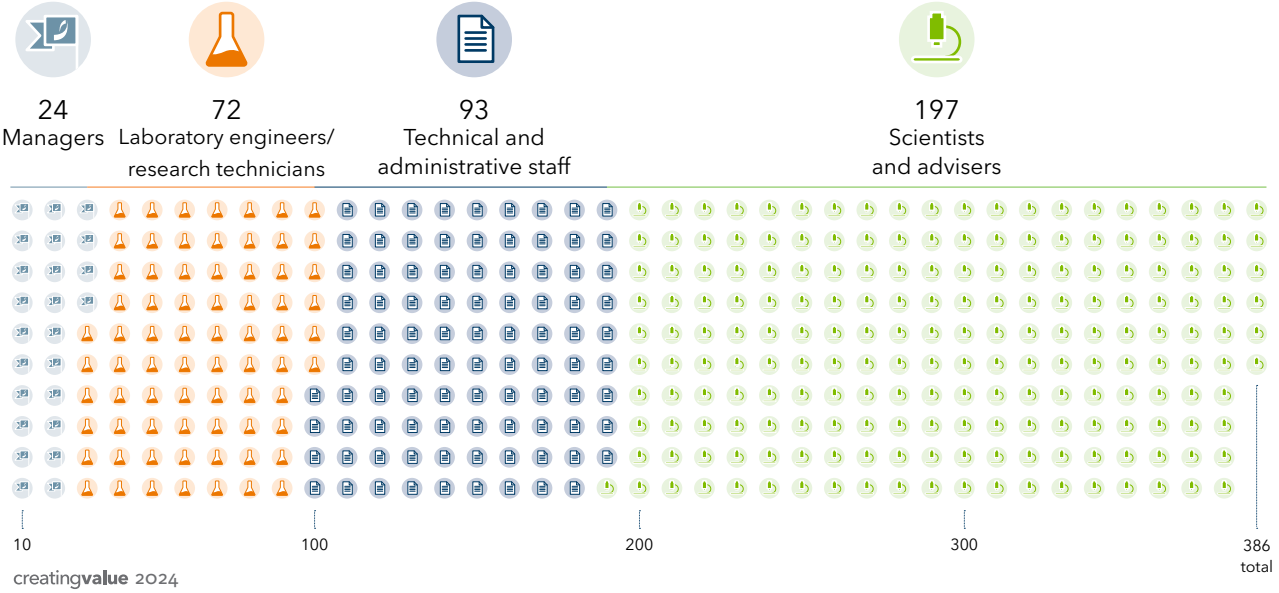


Who owns us

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 2020 and **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 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
Chief Financial Officer

This is Nofima

Nofima has some 400 employees, and a turnover of NOK 721 millon i 2023. 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 A. B. 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 Røsjø

Photo: Jan Inge Haga

Sustainable food for the future

The four strategic research programs, funded by the Foundation for Research Levy on Agricultural Products, contribute research that can shape the future of food production.

Our scientists develop methods and technology that contribute to sustainable food production and other agricultural policy objectives: increased food security and preparedness, agriculture throughout Norway, and increased value creation.

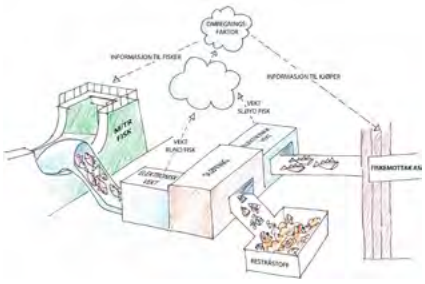
We develop, among other things:

- Smart sensors and data analysis for process control in food production
- Knowledge that strengthens local food producers and inspires the food industry to innovate
- Innovative baking technology that preserves the health benefits of oats in bread
- Sustainable packaging that extends food shelf life
- Advanced technologies for microbial tracking and hygiene control in food production
- Analyses of gluten quality in Norwegian food wheat varieties
- Insights into food texture to promote healthier eating habits
- Biotechnological processes for the production of high-quality protein products

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

Sustainable food for everyone

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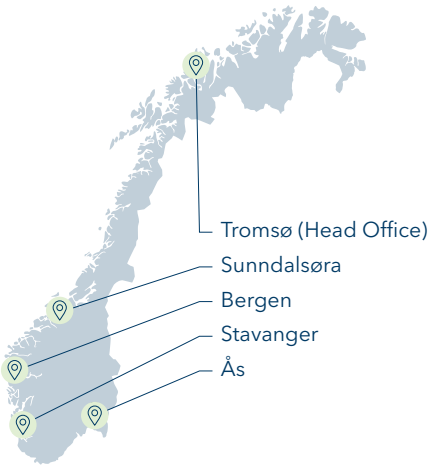
Linn Anne leads a team of dedicated experts in aquaculture. She is committed to ensuring that our research in genetics, feed and nutrition, fish health and production biology benefits the aquaculture industry and society.



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