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Project year 2022



25 examples of
useful research



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25 examples of useful research

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Impulse – Response – Effect

Nofima has further developed, focused and simplified its strategy in the past year.

Strategy development is based on the fact that we are facing major global challenges that can only be solved using research-based knowledge, development and innovation. Climate, energy and biodiversity crises pose enough problems on their own. We also see increased challenges related to food and nutrition security. If we as a research institute are to contribute to solving these challenges in a good way and contribute to food production becoming more sustainable, we must deliver relevant, high-quality research. We must also ensure that everything we do has a clear purpose.

We have therefore introduced the term IRE, which stands for impulse, response and effect. What we do must be firmly rooted throughout the organisation. Why are we doing this? How do we respond to the challenges? What do we want to achieve when the research results are used? As a food research institute, we must focus on our vision of sustainable food for everyone and our social mission. We need to think strategically about how we can deliver relevant research that benefits individual companies and creates value. It is therefore important to view food systems from a holistic sustainability perspective.

After two years of pandemic, last year was almost back to normal. Unfortunately, we see that the ongoing war in Ukraine, inflation and rising energy and food prices mean that the economic outlook is not as good as it has been in recent years. The Government has adopted tight budgets and we clearly see the need for restructuring. Despite these challenges, Nofima will continue to deliver high-quality food research.

Our aim is to work even more closely with companies and clients so that we get a better insight into what food producers expect from us. What are the needs of the industry? How can we contribute to innovations that are important for their production? We will actively use these impulses.

With the impulse in place, we will work with companies to develop responses that can ensure research-based solutions and innovations. The response must produce effects for our clients and contribute to more sustainable food production.

Nofima finds that more and more of our projects lead to value creation for our clients. This magazine reflects some of what we have achieved in 2022.

- Dedicated technicians and scientists at our Sunndalsøra station have developed the Wastage Box which was patented and launched last autumn, and which reduces the amount of salmon feed that is wasted.
- We must find new ways of producing healthy and tasty food that has less of an impact on the environment, whilst also being profitable for the producer. The INOBox project has investigated six innovative processing technologies: high pressure, microwaves, pulsed electric fields, ultrasound, UV light and plasma-activated water.
- In the Food(r)Evolution project, Nofima has teamed up with Coor's canteens and food producers Orkla and Hoff to show canteen guests how to eat greener and more sustainably.
- In the ongoing work to develop the use of rapid, non-destructive quality measurements using spectroscopic light, we have, together with industry, developed technology that can detect herring worms in white fish, and technology that can measure the welfare of live fish.
- At the Department of Breeding and Genetics, the scientists have now designed a genomic tool for cod. It means it is possible to breed cod based on the good traits of individuals. For many years, Nofima has led the National Cod Breeding Programme, and the results now provide the basis for a new industry.

This is Impulse, Response and Effect in practice.

Enjoy the read!

Øyvind Fylling-Jensen
Administrerende direktør



Zero feed waste with new invention?

A new Nofima research tool can provide virtually zero feed waste and is now under commercial development for use in the aquaculture industry.

Around 10 percent of fish feed goes to waste in land-based fish farms. This feed then mixes with fish faeces and creates sludge. Feed is a resource that is being lost, and Nofima and Vard Aqua want to do something about it. The invention called 'Spillbox' separates uneaten feed from the wastewater so it can be recycled back to the salmon.

If the commercialisation of the invention goes to plan, it can contribute to virtually zero feed waste in a land-based facility. However, sustainable resource utilisation wasn't the scientists' vision when they started development.

Started with research improvement

For many years, scientists have wanted to measure feed intake and the digestibility of feed more easily. In farmed fish, it is much more difficult to find the exact intake and digestibility of feed than in livestock. In livestock, faeces can be collected from the ground and feed residues from the feed trough. When it comes to fish, however, everything is mixed in the water.

Firstly, the scientists worked with centrifugal technology that sorts particles. They didn't quite succeed with this, and after further discussions, they moved over to filtration, where they tested different grates, objects and shapes beneath the water flow.

After a while, an idea developed that something vertical had to be

involved, where the water enters from the side. The solution they found uses the bounce in the feed pellet versus the more sticky sludge to separate feed and faeces into different fractions.

Solution-oriented scientists and technicians have helped Nofima create a wastage box ready to be developed for the world market.

Research advantages

The Spillbox has three obvious advantages when it comes to research.

"We hope it will give us accurate measurements, make things easier for our trial technicians, and the fish do not have to be handled", says Nofima's Turid Synnøve Aas, who is project manager and one of the scientists involved.

Aas is quick to talk about how Nofima has benefited from the creativity and dedication of research technician Frode Nerland.

"He has put a lot of time into observation and has used his creativity to constantly develop new improvements".

Recently retired scientist Torbjørn Åsgård has also been active in the development.

Benefits for industry

Experts at Nofima have created a solution that separates feed so that it can be reused. Vard Aqua must then find out how to recycle the feed back to the fish. The scientists believe land-

based facilities are the most relevant to use.

"A land-based facility that uses 200 tons of feed a day normally has a feed wastage of 200 kgs a day. It will be very positive if 200 kgs per day become a resource in food production, instead of going to waste", says Aas.

Another advantage for the industry is that the separated sludge becomes drier. This means that additional drying processes aren't necessary, and one can save energy and infrastructure regarding sludge treatment. This type of sludge without feed residues has a higher concentration of minerals.

However, the scientists don't want to count their chickens before they have hatched. The tool must be further developed before commercial use, but trials in closed facilities at Nofima's research station at Sunndalsøra have given positive results in separating feed and sludge.

The collaboration between Nofima and Vard at Sunndalsøra is not something new. The 'Disc Feeder', which many in the salmon industry are familiar with, has been sold all over the world, and Vard's Peder Anders Rød believes it has been important for the company:

"The early collaboration with Nofima has undoubtedly been important for the establishment of our operations at Sunndalsøra.



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Partners: Vard Aqua



 If the commercialisation of the invention goes to plan, it can contribute to virtually zero feed waste in a land-based facility

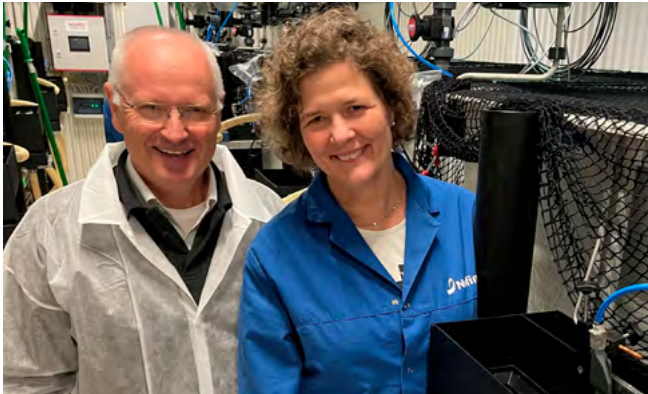


Photo: Morgan Lillegård, Nofima



Photo: Terje Aamodt, Nofima

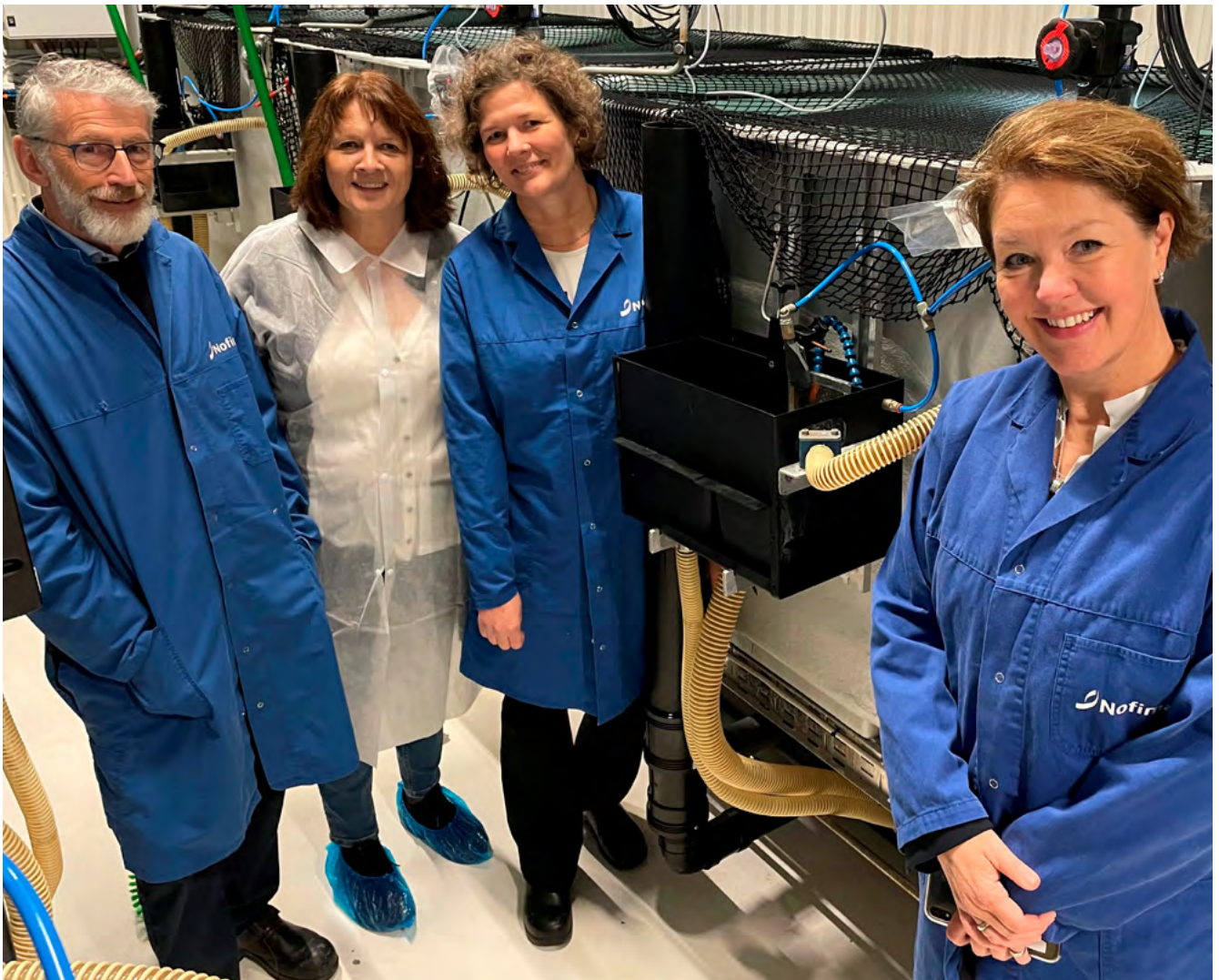


Photo: Morgan Lillegård, Nofima

(Photo at the top left) Peder Anders Rød from Vard Aqua will develop Aas' spill box to a commercial scale. (Photo at the top right) Technician Frode Nerland and scientist Turid Synnøve Aas proudly show off the "Spillbox" they have developed. (Photo at the bottom) State Secretary Kristina S. Hansen flanked by Nofima's Torbjørn Åsgård, Turid Synnøve Aas and Bente Torstensen.



"New technologies can extend the shelf life of food and also save time and energy in production", says senior scientist Tone Mari Rode.

Greener food using new technology

New processing technologies can play an important role in the transition to a more climate-friendly food production.

One third of man-made global greenhouse gas emissions are due to food production. We must find ways of producing healthy and tasty food with less of an impact on the environment whilst also being profitable.

Fast, gentle and energy-saving ways of producing and preserving food have been the focus of the research project 'iNOBox'. Six innovative processing technologies have been investigated in the project: high pressure, microwaves, pulsed electric fields, ultrasound, UV light and plasma-activated water.

Increase shelf life to reduce food waste

One of the most important ways to save the environment is to stop throwing away food. Norway throws away over 450,000 tons of food annually, often because it has passed its expiry date.

"We know that there are major differences between various raw materials and products when it comes to environmental emissions. Fruits and vegetables contribute with a relatively low environmental footprint, and generally have a short shelf life. Therefore, it is very important to extend the shelf life and avoid them end up in the bin", says project manager Tone Mari Rode.

The research results show that food processing using these new technologies can give food products an extended shelf life without compromising quality. Food companies can also save both time and energy in production compared to traditional processing.

Useful tools – you're welcome!

One obstacle to adopting new technologies may be uncertainty about how consumers will accept them. Will they be sceptical, or are they willing to buy products that are made using unfamiliar technologies? Nofima has conducted extensive consumer studies to investigate what information consumers need to accept such products. The results gave slightly different answers for the various technologies and food products and are summarised in a practical guide for marketing communication.

The desire for the research results to be used is the reason why the scientists have put a lot of effort into collecting the knowledge in a web-based tool specially designed for Norwegian food producers.

"In order to produce safe, healthy, and sustainable food, the food industry depends on the production methods being

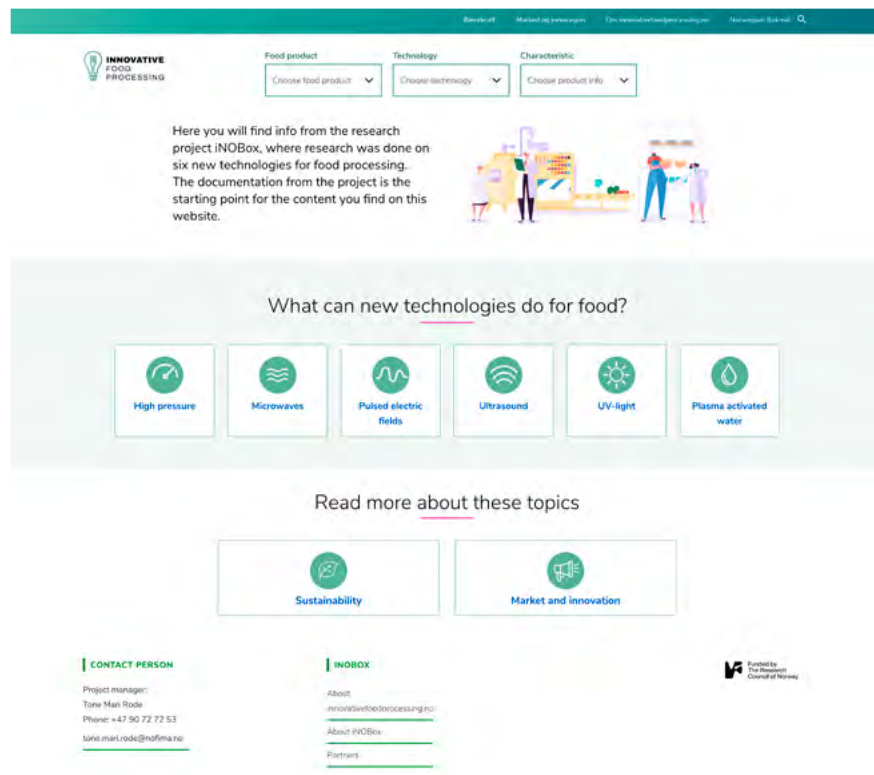
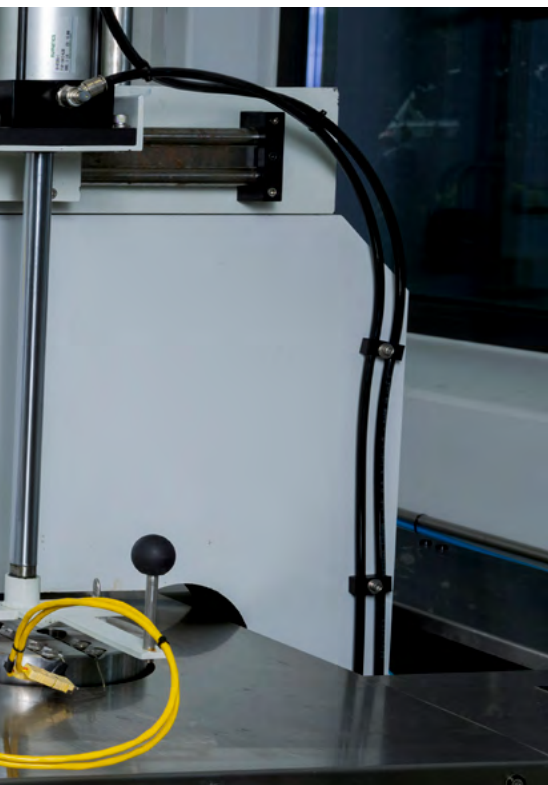


Photo: screenshot of website front page

Visit innovativefoodprocessing.no to find information about six new processing technologies and how they affect food.

efficient, profitable, and sustainable. We want to help them assess new technologies, and have therefore made the documentation readily available”, says Rode.

The website presents knowledge about the six new processing technologies, how they work, their effects on food, and examples of which products they are suitable for. Short, animated films have also been made that explain what happens when food is processed with the various technologies. Sustainability perspectives when using the technologies are also included.

New processing important for greener food production

“The extensive studies carried out in this project show that new technologies have great potential to contribute to more sustainable food production”, says Tone Mari Rode.

Rode hopes the online information will be used, and that interested producers will get in touch. Nofima has equipment available for food producers who want to test different technologies and processes.

“As food scientists we would like to contribute to ensuring that food production takes place in partnership with both people and the planet”, she says.

This was investigated:

Many trials have been carried out by researchers in several countries, in collaboration with both equipment suppliers and the Norwegian food industry.

- **Technologies:** high pressure, microwaves, pulsed electric fields, ultrasound, UV light and plasma-activated water
- **Foods:** meat products, vegetables and dairy products
- **Properties:** food safety, shelf life, quality, nutritional value, protein digestion and allergenicity. Also sustainability, consumer preferences and regulations

 *One of the most important ways to save the environment is to stop throwing away food*



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Lots of delicious local food.



Photos: Jon-Are Berg-Jacobsen, Nofima

Nofima's Meat Technologist Tom Johannesen is popular in the Visitor Scheme and as a course instructor. Local food producers learning butchering skills.

A quiet, culinary revolution!

For 20 years, the Competence Networks have been of great help to local Norwegian food producers who want to develop and gain more knowledge.

A wealth of new types of cured sausage and cheeses. Bubbling cider and craft beer. Traditional dishes of reindeer, game, fruit, and berries are prepared in new ways. Locally produced food from all over Norway has made huge progress in recent years – and has grown in scope and quality year after year.

The value of sharing knowledge

Five competence networks have worked behind the scenes helping local food producers with the product and process development, quality, test production, food safety, shelf life and hygiene, regulatory and customer requirements, and a million other challenges facing new food production entrepreneurs.

Nofima manages two of the competence networks: Southern Norway and Eastern Norway.

"We have been part of what has been described as a quiet, culinary revolution within locally produced food", says Nofima scientist Aase Vorre Skuland. She heads the Southern region from Stavanger.

Stine Alm Hersleth heads the 'sister network' in Eastern Norway and is based at Nofima's department in Ås. Both speak highly of the value of sharing knowledge.

For whom?

Small food companies with up to 10 employees can receive help with further development and value creation. The target group is primary farmers and smaller food producers who want to develop, refine, and sell quality products based on

local raw materials. Tourism companies involved in product development projects with local food producers are also in the target group.

Some participate in courses involving Nofima's food expertise. Others take advantage of what is perhaps even more treasured among small businesses: The free visiting scheme.

"The goal is to contribute to the production of quality foods that 'stand out' in a competitive market. Knowledge is important. The experts we send out or use in courses must understand the complexity and demands placed on local food producers. We want to promote further knowledge acquisition and sharing", says Stine Alm Hersleth.

Eating food must be safe

"Both small and large companies face the same strict requirements. Eating food must be safe regardless of who made it", says Aase Vorre Skuland.

The two network leaders also state that the knowledge requirements involved in the collaboration with local food producers work both ways.

"Small companies constantly face issues that are interesting for research and has food technology challenges that also can be incorporated into research projects", says Alm Hersleth.

Taste development in cider and listeria in cheese are good examples. The producers join projects and give the scientists specific issues to work on.

The visiting scheme:

The visiting scheme offers companies up to 15-20 hours of free guidance from a food advisor. The visit can also be carried out in Nofima's production plants.

During the visit, specific, practical work can be conducted, in addition to advice and a simple analysis to map the current situation, potential and needs.

Course:

The competence network arranges courses in baking, processing of fruit, berries and vegetables, meat processing, development of dairy products and beverages – such as cider, beer and juice. The network also runs food safety courses.

Facts:

The competence networks are available to everyone, regardless of where in Norway the company is located. Local Food-Norway is divided into five regions.

Nofima heads two of the national networks:

The Competence Network in Southern Norway – covers the counties of Agder and Rogaland.

The Competence Network in Eastern Norway – covers Oslo, Innlandet, Vestfold and Telemark, and Viken.

 *Small food companies with up to 10 employees can receive help with further development and value creation*



Hans Olav Bjerketvedt at the organic apple farm Dyre Gård in Rygge is using Nofima expertise in his cider production.



Founders Gro Hommo (left) and Inger Marie Bakås are baking Telemarkskling and have used Nofima's baker to develop the production processes.

Photos: Wenche Aale Hægermark, Nofima

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Partners: County authorities, county governors, Innovation Norway, industry organisations and other competence networks



Canteens can change eating habits

Canteens can help you eat more sustainably. Four out of ten people will change their eating habits at home if they taste new meals at work.

Photo: Georg Mathisen, Nofima



In canteens at Norwegian workplaces, the Food(R)evolution team with Antje Gonera find out how it is possible to help people change their diet.

1.1 million meals are eaten in Norwegian canteens every day. They are places where it is easy to try new dishes. If you have tried canteen dishes, liked them and got the recipes, senior scientist Antje Gonera believes that it is much easier to then prepare them yourself at home.

Nofima has teamed up with Coor's canteens and food producers Orkla and Hoff to show canteen guests how to eat greener and more sustainably.

The guests: Yes please!

In the first round of tests, more than 5000 guests in 18 different canteens tried 4 new dishes: 2 vegetarian burger products and 2 chicken substitute products made of pea protein. The guests liked all the dishes, and 4 out of 10 said they would change their buying habits if they tried new products in the canteen and liked them. In order to take home inspiration from lunch, guests want the canteens to hand out recipes or talk about the dishes.

The scientists will not only find out whether the canteens can inspire more people to eat sustainable food, but also how and what works best.

"Will there be different results when we change how the dishes are presented, or if we change the name of the dish and don't use 'vegetarian' or 'vegan'?", Gonera asks.

New tool

Coor is working on a new training programme on sustainability and sustainable food preparation. Hoff and Orkla are constantly developing new products and will use canteens as test and innovation arenas to increase accuracy in product development. Foodback is creating a digital solution where guests give feedback via a QR code on the table and Æra develops and tests the business model.

"If we have canteens, guests and a digital tool, it can also be used for other research. This is a whole business model that does not exist today, built by producers, canteens and the research world", says Gonera.



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Photo: JTerje Aamodt, Nofima

Senior Scientist Grete Bæverfjord has revealed that rib fractures, as shown on the screen, are a cause of melanin spots.

Rib fractures cause melanin spots

The answer to dark spots may lie closer to the spots themselves than previously thought. More specifically, in the ribs.

Rib fractures appear to be a major cause of melanin spots. This breakthrough is a result of research at Nofima and the PhD work of Raúl Jiménez-Guerrero at NMBU.

“We have substantiated that there is a connection between rib defects and dark spots”, says Nofima Senior Scientist Grete Bæverfjord.

The seafood industry is eager to find the cause of the spots because fillets with dark spots are downgraded and achieve lower prices.

Wanted to investigate ribs

Turid Mørkøre is a senior scientist at Nofima and a professor at NMBU, with extensive research experience on dark spots.

The idea of a possible link between rib defects and dark spots was followed up at Nofima’s X-ray laboratory in Sunndalsøra.

The scientists followed a group of fish from the freshwater phase to slaughter, and the results were compared with wild

fish. Bæverfjord was surprised by how many rib defects the salmon had, both with and without fractures. The fractures were mainly located in the same place in the fillet as the dark spots.

In both freshwater smolt and wild salmon, there was an average of four rib defects per fish. After transfer to sea, the number had increased to 10 defects per fish. The increase occurred during the final freshwater period and the first months at sea, and remained stable until slaughter.

The scientists believe that we need to focus on what the fish are exposed to in this period, with a view to improving technology and routines so that the problem of dark spots can be prevented.

Rib fractures don’t explain everything

“We find both melanin spots without rib injuries and rib defects without dark spots, so that doesn’t explain everything”, says Bæverfjord.



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Packing salmon in salmon

Scales from salmon skin production can be given a new life as a resource in bioplastic development.

Fish skin is an excellent material that can be used for many things, including handbags and furniture. When the skins are tanned and ready for the market, salmon skin manufacturer Norskin Materials AS is left with large quantities of fish scales that have fallen off during the tanning process.

The company wanted to utilise these scales – but what could they be used for? They found the solution together with Nofima.

Everything can be used

“We extracted gelatin from the scales with a view to using it in packaging. Extracting gelatin has been done before, but we are now using a known method to create something completely new”, says scientist Kjersti Lian.

The skin goes through different tanning process treatments, and there was uncertainty as to how useful the scale gelatin would be after the various processes. Would the gelatin properties be affected, and could damaged scales be used?

“It turned out that the answer was simple: Everything can be used”, says Lian.

Gelatin in bioplastics

Previously, gelatin from fish skin has been tested for food products, but the results have not been entirely positive. In further work, gelatin will be tested in the production of bioplastics, in which the company wants to pack its salmon products.

“The demand for biomaterials is increasing, and we want to utilise all the raw materials we have in our production. We became aware that not only the skin can be a resource for the company – but also the scales”, says Norskin’s Michael Meyer Nilssen.

The process that Nofima has found for extracting gelatin from fish scales can also be used on a large scale.

“It feels good to be able to use our expertise to help companies get started with new and exciting products and processes. This is what we are here for”, says scientist Kjersti Lian.

 *The demand for biomaterials is increasing, and we want to utilise all the raw materials we have in our production*

Photo: Jon-Are Berg-Jacobsen, Nofima



Bioplastics are the target for the gelatin produced from salmon scales – residues from skin production, which in turn are made from residues from salmon production.



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Partners: Norskin Materials AS





Grethe Iren Borge and Stine Alm Hersleth work on developing tasty vegetarian prototypes with high nutritional quality based on Norwegian plant-based materials.



The word cloud shows how the project group in NORSKVegetar envisages collaboration in the project.

Norwegian, natural, nutritious vegetarian

Nofima and the food industry have developed tasty vegetarian prototypes of high nutritional quality based on Norwegian plant-based materials.

Many people want to eat plant-based alternatives that are made from Norwegian produced legumes and vegetables, but the choice is rather limited.

This was the background for the NORSKVegetar innovation project.

Norwegian ingredients

The prototypes developed in the project contain combinations of raw materials, protein fractions and texturising ingredients based on Norwegian legumes, grains and vegetables. Developing technology for the best possible processing the plant-based raw materials is a key topic in the project.

"The legumes, grains and vegetables must be processed so it functions well when combined with other ingredients in order to produce a high-quality product", says senior scientist Grethe Iren Borge.

The goal is ingredients with stable quality and shelf life that can be easily used.

"We show what is technically possible, while producers must decide what is desirable and profitable for them to invest in", says Borge.

Innovative processes

"Firstly, we identified the suitable raw materials, ingredients and technologies we have available. We selected three focus categories in workshops with the partners", says innovation scientist Antje Gonera.

"Focus is also placed on process aids used in vegetarian products, such as emulsifiers, texturisers and colours. We will gain more knowledge about how natural raw materials and fractions from the processes can work in the products", explains Grethe Iren Borge.

Nofima and project owner Jæder, who has focused greatly on development and large-scale testing, conduct workshops with the project partners to test prototypes, make tastings and discuss findings.

"The goal is to learn from prototype testing in real situations with customers so we can make improvements during the development process and therefore make more of an impact in the market when we launch", explains senior adviser Stine Alm Hersleth.



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Partners: Jæder Ådne Espeland AS (project owner), Igeløsa Life Science AB and 12 Norwegian industrial partners





Photo: Jon-Are Berg-Jacobsen, Nofima

Nofima experts Tom Johannessen and Rune Rødbotten sort the meat before it is sent to the kitchen for preparation and tasting.

Meat adapted to the elderly

Many elderly people struggle to chew meat because it is tough and dry. Tenderness and juiciness are key criteria for elderly people's food choices.

Nofima is conducting trials on how mechanical tenderisation and various brines affect the tenderness and juiciness of beef. The results indicate that top round and eye of round cuts of beef can become as tender as tenderloin.

It is well known that meat can be made tenderer by using mechanical tenderisation, still such processing is rarely used in Norway. Mechanical tenderisation involves cutting small incisions in the meat. This is the same as tenderising the meat by pounding it. The purpose of Nofima's trials is to make beef more accessible to the elderly, but others will also find the meat tenderer and therefore better.

Effects of mechanical tenderisation and brine

Scientist Rune Rødbotten and Nofima's meat technologist and sausage-making expert Tom Johannessen are now studying how beef is affected by mechanical tenderisation.

They are also testing if the meat becomes even more tender and juicier by adding brine. They are testing various brines, including one with a protein mixture based on rest raw materials.

"Meat contains a lot of water, and the contents of the brine help the meat to retain its own liquid, even during heat treatment. In many countries, it is common to add brine to ensure juicier meat", Tom explains.

The cuts of meat have been processed using both mechanical tenderisation and brine. Either a standard brine consisting of water, salt and phosphate, or a brine containing protein from side streams. Three beef cuts with different initial tenderness levels were used in the study. After processing the beef cuts were evaluated by Nofima's professional sensory assessors.



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“Even though tenderloin is far more tender than the other cuts of beef, the combination of mechanical tenderisation and brine made top round and eye of round just as tender and juicy as the unprocessed tenderloin”, says Rune.

Elderly people need a protein-rich diet

The trials carried out by Tom and Rune are part of the Eat4Age EU network project led by Nofima Senior Scientist Paula Varela Tomasco. The project aims to develop tasty, nutritious and easily digestible food to help prevent malnutrition in the elderly.

“Pure cuts of meat are an important source of protein and a food that many elderly people are used to eating and enjoy. However, many elderly people stop eating meat because they struggle to chew and digest it. Therefore, it is important to develop tenderer and juicier cuts of meat for this target group”, says Paula.

She has been researching elderly people’s diets for a number of years and says that the texture and mouthfeel of the food (the physical sensations in the mouth caused by food) are of great importance regarding the food elderly people prefer.

 *Pure cuts of meat are an important source of protein and a food that many elderly people are used to eating and enjoy*



This is how mechanical tenderisation takes place in Nofima’s Meat Pilot Plant. Small knives that are placed closely together cut small incisions in the meat.

About Eat4Age This project has received funding from the Norwegian Research Council under the umbrella of the European Joint Programming Initiative “A Healthy Diet for a Healthy Life” (JPI HDHL) and of the ERA-NET Cofund ERA-HDHL (GA N° 696295 of the EU Horizon 2020 Research and Innovation Programmet).

“Dry and chewy textures are not to many people’s liking. On the other hand, people aren’t too keen on a sticky texture either. Think brioche dough; its sticky texture is not suitable for people who have difficulty swallowing. Also avoid astringent tastes because they cause a dry-mouth-feeling”, says Paula.

Investigating other cuts of meat

Det er ikke bare eldre som foretrekker møre og saftige kjøttstykker. Derfor ønsker fagfolkene å gå enda grundigere til verks.

It is not just the elderly who prefer tender and juicy cuts of meat. Therefore, the experts want to focus more on this field.

“Next, we want to find out whether other cuts of meat which currently cost less money, such as stewing beef, can be tender enough for older palates, and tastier for others”, says Tom.



This is what a cut of top round beef looks like after mechanical tenderisation.

Photo: Jan-Are Berg-Jacobsen, Nofima

Funded by: The Research Council of Norway and EU Horizon 2020

Partners: NRAE, The Norwegian School of Sport Sciences, Technion, The University of Leeds, and Teagasc Food Research Centre. Nortura and GatFoods



Advances in cod genetics

Scientists have developed a tool that makes it possible to lift cod breeding from family selection to individual selection – thereby increasing genetic gain.



An SNP panel can be seen in the background, which scientists Anne Kettunen and Luqman Aslam can use to breed better farmed cod.

“We have now tailored a genomic tool for cod, that is, we can breed based on the good traits of individuals. The tool is openly available and well timed seeing that cod farming is on the rise again. It can contribute to more efficient seafood production”, says scientist Anne Kettunen.

Nofima senior scientist Luqman Aslam is a specialist in developing such tools and has done so together with Kettunen.

From family breeding to individual breeding

Although siblings inherit half of their genes from their mother and half from their father, siblings are often very different from each other. Just look at the people around you. These differences are the starting point for the new ‘SNP panel’ tool (SNP is pronounced snip and stands for ‘single nucleotide polymorphism’).

“This is probably the first medium density SNP panel suitable for both research and commercial use in cod breeding programmes”, says Aslam.

Nofima’s cod breeding programme currently uses family selection based on relationships, i.e., they breed from siblings of cod that have been tested for selected traits and passed. But siblings can be very different, despite them having an average of 50 percent of the gene variants in common. A cod can have significantly more or less than 50 percent in common with its siblings, just like us.

So-called genomic tools now allow cod breeding programmes to consider that siblings inherit different gene variants from their parents. In the same way that DNA samples from traces and suspects are compared in criminal cases, we can compare cod and calculate how related they are. We can then select siblings with the closest relationship to the cod that did best in the test, to become parents. We then move from family breeding to individual breeding, including those traits that cannot be measured on the breeding candidate itself. This type of selection is called genomic selection.

It provides higher accuracy and higher selection intensity. We increase genetic progress.

Such tools exist for breeding livestock, salmon and sea bass, and the tool developed by Aslam and Kettunen can be of great importance for efficient cod breeding.

How they developed the tool

Aslam and Kettunen have used the Norwegian population of farmed cod and wild cod to create this SNP panel. The work has involved finding variation in the Norwegian cod population genome. This information is in the SNP panel, with a total of 21,000 markers.

The scientists can now use the SNP panel to find QTLs (Quantitative Trait Loci). These are areas in the genome that strongly influence the traits one is interested in improving in cod breeding.

“We have found QTL for growth. We can also use the SNP panel to find QTLs for different health traits and sexual maturation”, says Kettunen.

An example of an important QTL is the one for the salmon disease called IPN. QTL could be used to weed out salmon predisposed to IPN, and since its arrival, IPN has decreased drastically in salmon farming.

Useful for cod farmers and breeding companies

The SNP panel is useful for industry because it provides more accurate selection, QTLs can be found in cod, and it can reduce the use of trial fish.

The scientists have thus developed a tool that everyone is free to use. One can genotype one’s own cod to calculate relationships between fish or look for beneficial gene variants.

“You don’t become a good carpenter simply by buying a good hammer. To benefit from the tool, you need expertise and good material in the population to breed from”, says Kettunen.

Kettunen and Aslam will use the tool themselves in research projects. For example, they will study resistance to the bacterial disease francisellosis in the new ‘Frantic’ project and use the tool in routine selection in the cod breeding programme.

 *The SNP panel is useful for industry because it provides more accurate selection, QTLs can be found in cod, and it can reduce the use of trial fish*



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Light can measure salmon welfare

For the first time, spectroscopic analysis has been used to demonstrate the welfare and seawater adaptation of live fish.

Over 300 million salmon are put out in Norwegian net-pens each year, and up to 200,000 salmon can swim in each net-pen. The large number makes it almost impossible to examine the condition of every single individual.

Fish farmers monitor fish welfare by extracting groups of fish and examining them for various welfare indicators, such as damage to fins, eyes, skin and lice infestation.

Making these assessments manually is time-consuming, and there is a risk that the assessments are not done in exactly the same way.

Tested on live fish

Nofima scientists have therefore investigated whether hyperspectral imaging technology can make such assessments. The technology involves illuminating the fish, and when the light is reflected, specific measurements can be made. Nofima has used spectroscopic methods on slaughtered fish and other raw materials, but the technology has never been tested on live fish before.

"The idea behind the method was to document welfare in a quick and objective way based on the fish welfare system Fishwell", says scientist Stein-Kato Lindberg. The idea came from research colleague Gareth Difford at the Breeding and Genetics Department. Testing is done by the Seafood Industry Department, with the work being headed by Lindberg.

Well suited

Through four trials, the automatic measurements were compared with manual assessment. In the trials, the fish were laid on a conveyor belt at a speed of 10-20 cm per second, and imaged with hyperspectral cameras on both sides. The same fish were then assessed manually by technicians and their assessments were used as reference data.

"The spectroscopic measurements were just as accurate as human observations. The conclusion is therefore that spectroscopy is well suited for measuring the welfare of farmed salmon", says Lindberg.

"Faster assessment also reduces stress if done on live fish."



Photo: Nofima

Scientist Evan Durland is the project manager for the research. The picture shows salmon being measured at the Marine Facility in Tromsø.



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Photo: Nofima

The development of capacity in the fishing fleet has given rise to limitations in the design of vessels.

Knowledge about capacity is important

The fishing fleet must be adapted to stock developments, achieve profitability that provides a reasonable return on capital, and provide competitive wages for crew.

Increased knowledge about capacity development in the fishing fleet is therefore important regarding framework conditions for the fishing fleet.

“Knowledge development will also help authorities and politicians assess whether actual developments are in line with the political objectives for allocation between different fleet groups. This has been particularly emphasised in the framework conditions for the coastal fleet” says Nofima Research Director Bent Dreyer.

Continuous changes

He has led the work on the recent report ‘Capacity development and competitive conditions. Selected groups in the coastal fleet’.

Norwegian fisheries and the fishing fleet in particular are continuously undergoing structural changes. Structural development is driven by technology, resource situation and economy. While most other industries are relatively free to choose how to adapt, the room for manoeuvre in the fisheries is more limited.

“In addition to regulation protecting fish resources against overfishing, other policy objectives such as maintaining a varied fleet structure, stable resource allocation, avoiding excessive concentration, and the highest possible employment rate must be taken into account”, says Dreyer.

Significantly changed fishing fleet

The scientists point out that this has resulted in restrictions on vessel design, the amount of quotas that can be merged, who can own fishing vessels and the geographical affiliation of the vessels.

“The analysis shows that such regulations are carefully adapted to the challenges in the fisheries in which the coastal fleet participates. The study also shows that even small adjustments to such restrictions can lead to major structural changes. We have gained knowledge that is useful when the consequences of adjustments are to be assessed before they are introduced”, says Bent Dreyer.



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Lingonberries – a possible health bomb

Norwegian lingonberries can replace cranberries, both in terms of taste and health-promoting properties.

Over a period of 3 years, Nofima scientists have studied lingonberries from all over Norway to find out if there are differences in their chemical composition. They have focused especially on the healthy polyphenols, which have many health-promoting properties: limit blood sugar increases, reduce the risk of cardiovascular disease, fight cell damage and prevent urinary tract infection just as well as cranberries.

Berries from all over Norway had similar constituents. A lingonberry is mostly made up of water, fibre, sugar and acids. However, Nofima scientists have devoted most of their attention to constituents that are found in small quantities, but which give the berries their distinctive character and benefits.

In what ways can you use lingonberries?

“Stirred lingonberries are a classic that many people find delicious. Mix frozen berries together with sugar and serve as an accompaniment to many main courses”, scientist Kjersti Aaby suggests.

Or lingonberry sorbet. Mix frozen berries in a blender and add sugar and some milk. Check the taste and freeze again. Take it out of the freezer and enjoy.

“To best utilise the health-promoting properties of lingonberries, it is a good idea to use whole berries; you eat everything that is in the berry. Freeze the berries if you wish to store them, this preserves the constituents, says Aaby.

Innovation opportunities

Nofima scientists have also investigated the innovation and development opportunities for Norwegian lingonberries. They have studied what it takes to succeed with products such as powder, freeze-dried berries and lingonberry capsules.

“In order to see the innovation opportunities regarding wild berries, it has been important to include different disciplines, such as the perspectives of chefs. We have been impressed by culinary dishes which do not have to be reserved for creative restaurants”, says scientist Sveinung Grimsby.



Photo: Wenche Aale Hægemark/Nofima

Nofima scientists Sveinung Grimsby and Kjersti Aaby visit Røyland Farm in Agder, the only major producer that processes Norwegian lingonberries.



To best utilise the health-promoting properties of lingonberries, it is a good idea to use whole berries



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Sterile farmed salmon are doing well

Scientists have documented that salmon sterilised according to the 'Nofima method' are just as healthy as fertile salmon.



Photo: Jon-Are Berg-Jacobsen, Nofima

Øivind Andersen and colleagues are now working on different strategies for large-scale production of sterile salmon.

Sterile farmed salmon are in demand from several quarters, as this can limit the impact escaped farmed salmon have on the wild salmon in our rivers.

Before the Nofima method is upscaled into practical large-scale production, it should be documented that the sterile fish grow well and are healthy.

The method developed by Nofima senior scientists Øivind Andersen and Helge Tveiten blocks a factor that is required for the development of reproductive cells at the embryonic stage, so the fish never become sexually mature. Apart from the small reproductive organs that do not produce roe or milt, sterile salmon have the same appearance and characteristics as fertile fish.

Just as healthy

The scientists have now studied how well sterile salmon have fared throughout life compared to fertile farmed salmon. They have conducted investigations into fish growth, smoltification, stress tolerance, salmon lice attacks and mortality at sea.

The sterile salmon show production traits that are at least as good as fertile farmed salmon, including the ability to cope with severe salmon lice attack. The scientists have also documented that the sterilised salmon had no reproductive cells from embryonic stage to time of slaughter.

Differs from other methods

Salmon can be sterilised in several ways, such as triploid salmon and genetically modified salmon. However, triploid salmon have been rejected in Norway due to welfare issues, and genetically modified salmon continue to be prohibited.

Andersen and Tveiten are now working together with a PhD student on different strategies for large-scale production of sterile salmon. They are also working with sterile cod in a new MABIT project. MABIT is an independent, industrial R&D programme within marine biotechnology in Northern Norway.



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We should choose Norwegian wheat

Norway is not self-sufficient with wheat, thus we need to increase the demand for and the production of Norwegian wheat.

Wheat quality is like weather: It varies.

Just as the weather differs from one summer to the next, the quality of the Norwegian wheat differs from year to year. The milling and baking industries will face challenges if they are to use more Norwegian wheat. To minimise variation, the milling industry needs to import to make sure that the bread consumers buy today has the same quality as the one they bought a year ago.

Quality research

Shiori Koga is a researcher at Nofima investigating how to increase the use of Norwegian wheat in food production. Her project has focused on how temperature influences the bread-making quality of Norwegian wheat.

“The quality of Norwegian wheat is often poor when summers are cold. But our study showed that low temperature itself does not cause poor bread-making quality. There are other factors inherent to low temperatures such as rain. Humid conditions are favourable for fungi to infect grain which can lead to poor quality”, she says.

Milling wheat with poor quality is often downgraded to animal feed.

Proteins are important for bread-making

“When the protein content is low, the industry cannot use wheat because of its poor bread-making properties. Not only the content, but the quality of protein is also very important”, says Shiori Koga.



Photo: Georg Mathisen, Nofima

Kristin Hollung wants to increase self-sufficiency in wheat. “The Partnership is enthusiastic about achieving this goal together”, she says.

The millers blend wheat with different qualities to make sure that their products have the same quality, not only within the season but also between the seasons. Variations in flour quality can result in inferior products and increased food waste. If the content and/or the quality of protein is low, the dough rises poorly, and the bread will be different. As Norwegians eat more wholemeal bread, the protein content and quality are especially important.

Over the past two years, yield, protein content, and quality in Norwegian wheat have been high. Farmers managed to produce more than 70% of the domestic demand.

Moreover, increasing self-sufficiency has been recognized as important for food security. The war in Ukraine and high fertilizer prices may make importing wheat more difficult.

“Norway really needs to produce more of its own food”, says the scientist.

Cereal Grain partners

In the Cereal Grain Partnership, farmers, grain traders, millers, bakeries, grocery chains, and research institutions have joined forces to ensure that more Norwegian wheat is used for food production.

“Our goal is to achieve 90% self-sufficiency in wheat by 2030. This will require major restructuring in the value chain to achieve this goal”, says Kristin Hollung.

She is a research director and Nofima’s representative in the partnership.

Hollung encourages consumers to be more aware that the grains they eat are produced in Norway.

“If retailers demand that 90% of the wheat should be Norwegian, it will have a knock-on effect on the value chain”, says Kristin Hollung.

“Consumers should also be engaged in buying baked and cereal products made of Norwegian wheat.”, says Hollung.

The Norwegian partnership for cereal grain and plant protein

The partnership includes the Federation of Norwegian Bakers and Confectioners, Coop, Felleskjøpet Agri, Fiskå Mølle, Graminor, Hoff, Lantmännen Cerealia, FoodDrinkNorway, Nibio, NMBU, Nofima, The Norwegian Agrarian Association, Norgesgruppen, Norgesmøllene, The Norwegian Farmers’ and Smallholders’ Union, The Norwegian Agricultural Extension Service, Orkla, Rema 1000, Strand Unikorn and Tine.



Photo: Georg Mathisen, Nofima

“Quality variations make it difficult to use Norwegian wheat”, says Shiori Koga, who is investigating how wheat quality can be stabilized.



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The Maritech Eye spectroscopic imaging and its analysis are now as fast as the production lines in the industry.

Finding worms using new technology

Technology is now in place that can detect and remove roundworms from fish fillets before they end up at the dinner table.

The herring worm is a roundworm that can be found in fish fillets. The fishing industry wants technology that detects and removes the parasite before products go to the consumer.

Maritech Eye quality measurement technology has been developed by Nofima, Maritech and Norsk Elektro Optikk, and is already used in the fishing industry to assess the quality of whole whitefish and salmon fillets. In collaboration with Nofima scientists Karsten Heia and Samuel Ortega, the technology has also been tested at the fish producer MareDeus in Portugal, that wanted to check whether it could find herring worms in whitefish.

Unequivocal results

At MareDeus, as with most Norwegian whitefish producers, the conventional method of scanning fillets using candling tables and then manually trimming the fillets is used.

"Spectroscopic measurements quickly made it clear to both us and MareDeus that the hand-trimmed fillets weren't as 'herring worm-free' as we had expected. There is no reason to believe that it is any different in Norway – or other countries", says Samuel Ortega.

The new tests were carried out under industrial conditions for speed, temperature and humidity. The results are unequivocal:

"The technology can also detect herring worms in whitefish. Maritech Eye is becoming a multi-tool" says Karsten Heia.

The spectroscopic imaging and its analysis are now as fast as the production lines in the industry.

"From my point of view as a scientist, it is very satisfying to test that the technology works in new areas" says Heia.

Cosmetic problem

Herring worms are unpleasant and unappetising. They are usually not dangerous, but they are a cosmetic problem for the fishing industry.

"Our partners were very satisfied with the processing, and they can now guarantee herring worm-free fish products in their stores", says Samuel Ortega.



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Health test developed for smolt

Salmon that adapt from a life in fresh water to a life in salt water need a solid immune system in order to make the transition.



Senior scientist Aleksei Krasnov and colleagues have developed a health test for salmon smolt. Photo: Joe Urrutia, Nofima

Nofima scientists have developed a test that measures the immune status of salmon smolt. The test provides information that fish farmers will benefit from when transferring salmon to the sea. The results can help increase the smolts' chances of survival.

Every year, around 15% of farmed salmon die after being transferred from land-based freshwater tanks to net-pens at sea. Most of the fish die shortly after transfer. The test is therefore highly relevant.

What is the test?

It is a diagnostic test that measures the activity of 44 genes that are important for the immune system. A sample is taken from the gills or dorsal fin without harming the fish.

"A few years ago, we found that the immune system was weakened during smoltification. We decided to develop a test to measure the immune status of salmon during smoltification", says Aleksei Krasnov, senior scientist at Nofima.

Krasnov and his colleagues studied many genes and found those that provided the most information about immune status. The activity of the selected genes was analysed on salmon from different sites, different fish groups, and different environmental conditions.

Revealing the body's plan

Scientists measure the activity of carefully selected genes to assess salmon's immune status and health. They have found the normal activity level for each of the 44 genes in a fish of good condition.

"We are able to see which fish are in good condition and which are not. We know which fish seem healthy, but in reality are not", Krasnov says.

He sees the benefit of also using the test in other projects, for example to test if different ways of producing large smolt in closed-facilities affect immune status before transfer to sea, and in projects where nutrition scientists test if feed ingredients affect fish health.



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Sensitive to toxic gas

Hydrogen sulphide (H_2S) poses a risk to salmon farmed in recirculated seawater facilities. Scientists now know how sensitive the fish actually are.

In land-based fish farms, salmon live in fresh water until they become smolt. Once smoltified, they are transferred to seawater. When this seawater is recirculated in a closed facility on land, the water passes through a biofilter that purifies it. However, H_2S gas can quickly form in the biofilter causing the fish to die.

It is only in recent years that the production of large salmon in land-based facilities has developed, and H_2S has become an important research topic. Little knowledge exists about why the gas is formed, and almost no knowledge about what it does to the fish.

Nofima's Carlo C. Lazado has led a project in which scientists have exposed salmon to short-term and long-term H_2S in the water. The fish which were exposed for only one hour were analysed after 24 hours. The fish that were chronically exposed to H_2S over four weeks were analysed after 0, 2 and 4 weeks.

Ability to cope with stress

The trials were carried out at Nofima's brand new facilities in Sunndalsøra. These units, where there is one recirculation unit for each tank, made it possible to investigate the consequences of various operational changes at system level. In addition, these systems require relatively fewer fish to support the biomass necessary for the RAS unit to function optimally.

Two weeks after H_2S exposure, the fish were forced closer together (crowded) in order to test how fish previously exposed to H_2S reacted to stress. When the scientists have finished analysing these data, they will know more about how H_2S exposure affects fish welfare and the ability to cope with stress.



Photo: Kevin Stiller, Nofima

Carlo C. Lazado's hydrogen sulphide trials inaugurated the new 'one-tank-one-RAS' infrastructure at Nofima in Sunndalsøra.



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Nose and skin are sensitive to H₂S

The analyses showed how many genes in the various organs were activated during and after exposure to H₂S, and the number of genes activated indicates how sensitive the organ is.

The trials show that the nose is the organ that reacts most strongly to H₂S gas during chronic exposure. The scientists also investigated gills and skin, which, like the nose, are part of the first line defence that is in contact with the water. The skin was the most sensitive organ during short-term trials, but least sensitive during long-term trials.

“There are more groups of genes in the nose that react to H₂S than in other organs. These include genes linked to stress, healing damaged tissue and the immune system. Previous research suggests that the gene activity in the nose’s immune cells has some similarities with how the human cells react to H₂S”, says Lazado.

After a long period of exposure, salmon can also change their behaviour, and the scientists noticed visible skin colour changes near the head. Some fish died in the group that was exposed to the highest level over time.

No problems coping with low levels

“We see that salmon cope well when exposed to low levels over time, and that peaks cause the problem. The aquatic environment in RAS is dynamic, so there will always be some H₂S present. The knowledge we now have about how the short- and long-term levels affect fish health allow us to carry out risk assessments during production”, says Lazado.

He believes this depends on whether you have fast and reliable measuring tools that can detect both minute levels and also measure very high levels. Lazado confirms that companies developing more sensitive sensors have shown great interest in the project.

Other good news regarding RAS facilities is that hydrogen peroxide is an emergency solution that can reduce the level of H₂S in less than half an hour. The Danish scientists working on the project found this out.

The project scientists have minimised the use of trial fish, in accordance with 3R guidelines: replace, refine and reduce the use of laboratory animals.



We see that salmon cope well when exposed to low levels over time, and that peaks cause the problem



Photo: Terje Aamodt, Nofima

The nose is the organ that reacts most strongly to the gas during chronic exposure to H₂S.



Nofima has mapped the economic and environmental effects of supercooling salmon during transport to Europe by lorry and air transport to Asia.

Superchilling can save billions

If all Norwegian salmon production was supercooled before transport, the industry could save NOK 1.5 billion annually in transport costs.

The startling figures have been published in a recent Nofima report.

“Supercooling eliminates the need for ice in the boxes, thus allowing for more salmon in each box. More fish in each box reduces transport needs, energy consumption and transport costs. It also significantly reduces the use of packaging”, says Nofima scientist Bjørn Tore Rotabakk.

NOK 1000 + 540 million

The study’s topic is the economic and environmental effects of supercooling salmon. The effects are highlighted through two important commodity flows: salmon to Europe by lorry and salmon to Asia by air transport.

“Supercooling will reduce packing and distribution costs by close to NOK 0.70 per kg produced for lorry transport

to Europe. If all Norwegian salmon production was supercooled before transport, the industry could save NOK 1 billion in transport costs. Savings on air transport are even greater: around 2.70 per kg, or around half a billion for the entire industry”, says Nofima scientist Audun Iversen.

By using less ice, the industry saves costs on ice production, keeping the ice cooled and, not least, transporting it all the way to the market.

“Without ice, each box can contain more fish. Therefore, fewer lorries are required. This will also reduce packaging use and reduce shipping costs”, says Audun Iversen.

He points out that supercooling can reduce the use of packaging and transport by up to 20 percent. This means that around 15,000 lorry loads of salmon, and as many returning lorries, can be removed from the roads. There is also the transport of boxes from box factories to the slaughterhouses.

Illustration: Frank Boston, Stock-Adobe.com



Photo: Jan Inge Haga, Nofima

"Supercooling eliminates the need for ice in the crates, thus allowing for more salmon in each box", says Nofima scientist Bjørn Tore Rotabakk.

Reduced energy use

Supercooling the salmon before transport also saves on energy costs at the slaughterhouse. Additional energy consumption associated with tank cooling amounts to 7 KWh per ton of salmon produced. The company also saves 21 KWh per ton of salmon produced on ice production, resulting in a net reduction in electricity consumption of 14 KWh per ton of salmon produced. There is also increased use of salt – 52.5 kg per ton of salmon. And extra water, 1500 litres per ton of salmon. All environmental effect calculations are made with an assumption of 26 kg of salmon per box instead of 21.5.

"Not using ice also means there is no runoff of meltwater on lorries. This is a major advantage in terms of road safety and reputation, but we have not tried to value it here", says Bjørn Tore Rotabakk.

Eliminated runoff is also good for the environmental accounts, but is a small factor compared to other environmental benefits of supercooling.

Reduced greenhouse gas emissions

The report also concludes that greenhouse gas emissions related to slaughter, packing and transport of salmon can be greatly reduced. The reduction is estimated at around 15 % for salmon transported by lorry to Europe, and around 17 % for salmon transported by air to Asia.

"Transport to the market accounts for only 5 % of the total emissions for salmon transported by lorry to Europe, while feed accounts for almost 70 % of emissions. However, when fish are sent to Asia by plane, transport accounts for more than half of the emissions. Therefore, a change of 17 % has a major effect on the total emissions, which is reduced by almost 9 %", Audun Iversen points out.



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Nofima scientists Annette Fagerlund and Even Heir are well equipped with both knowledge and equipment in the tireless fight against food bacteria.

Equipped for hunting food bacteria

The fight against bacteria in food is constantly taking new paths. Scientists have now identified differences between the most common and the most dangerous listeria bacteria.

The listeria bacteria most commonly found in food are usually not the ones that make you ill.

“The bacteria most commonly found in food, are not found in a large proportion of patients”, says Senior Scientist Annette Fagerlund, who has conducted extensive research to characterize and prevent the spread of the dreaded listeria bacteria.

These bacteria are transmitted through food and can lead to listeriosis in humans. The disease is not very common, but of those who actually become ill, 15–20 % die.

Resistant

Fagerlund and her colleagues have now identified why some of these bacteria predominate at the slaughterhouse. They have studied bacteria that were found in more than one factory. The results show common features: genes that make the bacteria resistant to disinfectants often used in the industry, genes that enable biofilm formation, and gene mutations that affect how easily the bacteria make people ill. The bacteria have thus become better at withstanding cleaning and disinfection. They have become better at settling on surfaces and multiplying there. On the other hand, they have become less adept at making people ill.

“They are not the most virulent”, says Annette Fagerlund.



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Partners: Norwegian Veterinary Institute

Valuable to research

In listeria, as in other bacteria, there are different variants within the same species.

“They are exactly the same species but behave differently. You can compare it with the Delta and Omicron variants of the COVID-19 virus: They are also the same species, but they do not show the same rate of transmission, and they have varying potential for making people seriously ill”, says Fagerlund.

Nofima scientists are well equipped to compare different variants and species of food bacteria. They have collected thousands of bacteria over many decades. This enables them to follow the development of food bacteria over time.

“Nofima has collected bacteria from food and the food industry over many years and has a strain collection which is worth its weight in gold. It allows scientists to study isolates from several decades. Modern technologies such as whole-genome sequencing are important tools for studying the development of the bacteria and their properties”, says Senior Scientist Even Heir, who works with Annette Fagerlund at Nofima’s Department of Food Safety and Quality. Both have made good use of the bacterial strain collection in their work.

No cause for concern

Nofima’s bacterial collection has recently been used in the work to detect and combat antibiotic-resistant pseudomonas bacteria. Over time, these bacteria may develop resistance so that they can no longer be killed by antibiotics. Pseudomonas is a group of bacteria that is very prevalent and also dominant in many food and food processing environments.

“There are varieties that cause disease in humans, but the pseudomonas bacteria that we find in food have mainly other properties that enable them to survive in food production environments, to be transmitted to food and thus contribute to food spoilage providing reduced shelf life, reduced food quality and increased food waste”, says Scientist Birgitte Moen.

“Therefore, this type of bacteria is a problem for many food producers. They may pose an even greater challenge if antibiotic resistance is a prevalent trait in bacteria that we find in significant numbers in both food and food processing environments”, says Even Heir.

In the study, Nofima’s strain collection made it possible to identify and compare pseudomonas bacteria from Norwegian chicken over a period of 26 years.

The scientists found no reason to sound the bacterial alarm after the study. That is good news for Norwegian food producers.

 *The bacteria have thus become better at withstanding cleaning and disinfection. They have become better at settling on surfaces and multiplying there*



With the bacterial strain collection, Nofima was able to identify and compare pseudomonas bacteria from Norwegian chicken over a period of 26 years. Photo: Joe Urrutia, Nofima



Bacteria may come from feed

Studying intestinal flora is an interesting part of research on fish feed. Norwegian research sheds new light on study quality.

Nofima scientists conducted a trial where they fed farmed salmon over a period of time and measured the fish's feed utilisation and bacterial profile in the intestine.

It was a very common type of trial, where the methods used met current scientific standards. However, the scientists suspected that the bacteria found in the salmon's intestines were wrong.

Using DNA sequencing, fish health scientist Christian Karlsen and bacterial scientist Ida Rud found out that the bacteria they detected in the salmon's intestines partly originated from the feed. Most of the previous sequencing studies have not taken into account that bacteria detected in the gut may be dead bacteria that comes from fish feed.

Many bacteria in feed

The raw materials in fish feed contain many nutrients that various bacteria utilise. Even if these bacteria die during processing, their DNA can be carried by the feed and into the fish's intestine. For example, lactic acid bacteria.

"Bacteria love to snack on the raw materials in fish feed", says Ida Rud.

She believes that the shortcomings of many studies may be due to an assumption that fish are much like other animals, which have a complex bacterial community in their gut. However, just a few bacterial groups seem to dominate fish intestines.

Must be done differently

The Nofima scientists don't believe the findings will greatly affect farmed fish or fish farmers. However, they are important for research on fish feed and interpreting the feed's effect on intestinal flora.

The scientists say that anyone conducting feed studies to map intestinal flora must organise things differently.

Karlsen and Rud believe there is a long way to go to understand the role played by bacteria in fish intestines regarding the digestion of the feed and further impact on fish health.



The research by Christian Karlsen and Ida Rud sheds new light on the quality of studies of intestinal flora in farmed fish. Photo: Joe Urrutia, Nofima

 *Bacteria love to snack on the raw materials in fish feed*



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Photo: Jon-Are Berg-Jacobsen, Nofima

The scientists have developed methods to automatically recognise the sweetest strawberries.

Sensors find the best strawberries

All strawberries are picked by hand, but robots might be doing the job in just a few years. It will involve finding the ones with the best chemistry – and taste.

Nofima scientists are developing sensors that can measure berry ripeness. They have analysed the chemistry of strawberries, tested them with sensory panel and developed spectroscopic applications that can ‘see’ the chemistry without picking the berries.

“We prefer sweet strawberries, but a little acidity is needed to bring out the freshness”, says scientist Mari Øvrum Gaarder.

New measurement methods

Trials are underway to get robots to select and pick strawberries, but the success rate is not good enough. To ensure that the robots pick the perfect berries, methods are needed that also measure the chemistry of the strawberries.

This is where spectroscopic methods are used. They use light spectrum or laser to ‘see’ the chemistry of each berry and can measure the amount of sugar and acid.

“The next step is for Nofimas sensory assessors to check the results of our chemical analyses and models”, says scientist Petter Vejle Andersen.

Checked by a sensory panel

Professional sensory assessors work at Nofima’s sensory laboratory. Their job is to describe and evaluate food characteristics.

“When the assessors assess whether the spectroscopic models are able to identify the sweetness of each strawberry, they evaluate smell and taste based on tartness, sweetness, bitterness, berry, fruit and total intensity”, says Øvrum Gaarder.

The assessor’s assessment of sweetness corresponded very well with the measurements. This suggests it will be possible to measure taste using spectroscopic methods.

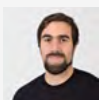
In order to offer technology that can be installed and used in a robot that picks berries, new analysis and measurement methods must be developed.

Once the scientists have mapped how to use results from chemical and sensory analyses, they can develop the methods so that the same analyses and measurements can be made for other types of fruits and berries.



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Partners: SFI DigiFoods and participating partners

Can cod farming become profitable?

High production costs require high market prices in order for cod farming to be profitable.



Photo: Silje Kristoffersen, Nofima

Farmed cod is biologically ready for commercial operations. But is it possible to achieve sales prices that outweigh costs?

This is the conclusion of a Nofima report which highlights the potential of farmed cod – quality, market perception and economy. Eleven Nofima scientists with different professional backgrounds have compiled the report.

“Profitable production requires that one achieves sales prices that outweigh the costs”, says Nofima senior scientist Morten Heide.

It can cost between NOK 40 and 43 per kilogram of round weight to farm a cod ready for slaughter.

“A profitable industry requires either high prices for wild cod, or that cod farmers are able to separate farmed cod from wild cod so that one can justify production costs in terms of price”, says Heide.

Biologically ready

The sixth generation of farmed cod is being raised at the Centre for Marine Aquaculture, which Nofima runs on behalf of the Ministry of Trade, Industry and Fisheries. In just five or six generations, the cod has become ‘livestock’ which grow well and no longer escape. Today’s farmed cod have better

characteristics in terms of survival, growth and behaviour than has been the case in the past.

“Biologically speaking, farmed cod is ready for commercial operations”, says Øyvind Hansen. He is head of the cod breeding programme at Nofima.

Bioeconomic model

There are very few available economic studies related to cod farming. Since there are few commercial actors currently engaged in cod farming, there are no statistics on production costs. Therefore, the scientists had to resort to a bioeconomic model of a production cycle to calculate these costs. The model is based on several conditions with varying degrees of uncertainty.

“We calculate the sum of fixed and variable costs during production in order to estimate the average costs per kilogram of cod produced. The largest variable costs are linked to feed, slaughter and packing”, says scientist Katrine Eriksen.



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Photo: Jon-Are Berg-Jacobsen, Nofima

"Chicken thigh fillets keep just as well in recyclable material and can consist of up to 100 % recycled PET in the middle layer", says Marit Kvalvåg Pettersen.

More recyclable food packaging

Reducing the environmental footprint of food packaging and ensuring that quality is maintained is sustainable packaging system that is important for Nofima's scientists.

"Our studies show that it is possible to obtain similar quality and shelf life for chicken fillet products when they are packed in recyclable packaging made from recycled plastic compared to conventional and nonrecyclable plastic materials", says Nofima Senior Scientist Marit Kvalvåg Pettersen.

She has been leading the project and the research in the ReducePack innovation project, and responsible for the packaging trials where Nofima's experts and Norsk Kylling AS have tested and compared recyclable packaging materials with more complex materials.

The same quality

They packed and stored chicken leg fillets in two different types of trays. The leg fillets were packed at the same time and under identical conditions. One tray was a mono-material, i.e. it consists of only one type of plastic (polymer). The other tray consists of different types of plastic, called multilayer.

The advantage of multilayer packaging is that plastics with different properties can be combined, resulting in very good

barriers against gases such as oxygen. The disadvantage is that they cannot be mechanically recycled.

"We stored the fillets for up to 16 days and performed relevant microbiological analyses after 7, 12, and 16 days. We investigated the development of typically spoilage bacteria. There were no significant differences between thigh fillets packaged in mono-materials and thigh fillets packaged in multilayer packaging", says Marit.

She adds that these are promising results in terms of replacing nonrecyclable food packaging with food packaging that is both recyclable and can contain recycled plastic without compromising the food quality and shelf life.

Key sustainability measures

"100% of our packaging will be made of recyclable material. We will achieve this without compromising quality, food safety or increasing food waste. We are well underway and are proud of our collaboration with Nofima in ReducePack, which further contributes to achieving our goals", says Hilde Talseth, Director of Sustainable Innovation at Norsk Kylling.



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Partners: BAMA, Norsk Kylling, Grilstad, Mills,
Moltzau, Wipak, Døvingen, Berry Bewi, FoodTech,
Lexit, Lund University and Østfoldforskning

Small change in salmon feed

A report on raw materials for salmon and trout shows that producers of Norwegian salmon feed are using totally new ingredients.

For the fifth time since 2010, Nofima has compiled an overview of ingredients used in Norwegian salmon feed. The documentation is based on feed in 2020 from the four largest feed companies. It shows that the composition of feed for Norwegian farmed salmon is roughly the same as in the 2016 report.

Insect meal and microalgae in feed

However, there is one small and important change.

“New ingredients are being used, such as insect meal, single cell protein, fermented products and microalgae”, says scientist Turid Synnøve Aas.

These accounted for a small proportion, only 0.4 % of the total volume in salmon feed, or 8000 tons in total. In 2020, 1.98 million tons of ingredients were used and 1.47 million tons of salmon and 90,000 tons of rainbow trout were produced.

Little from Norway

“The government’s goal is that all aquaculture feed must come from sustainable sources by 2030, thus creating a new industry in Norway.

Nofima’s report does not assess whether the ingredients are sustainable. However, the scientists have examined certifications. The majority of marine raw materials are certified under various schemes.

The scientists have also documented the country or area of origin for almost all the ingredients.

Large volumes required

In 2020, salmon feed consisted of around 12 % fish meal, 10 % fish oil, 41 % vegetable protein sources, 20 % vegetable oils, 13 % carbohydrate sources and 4 % micro-ingredients. In addition, 0.4% of new ingredients such as insect meal and microalgae were used.

“Huge volumes of an ingredient are required to make up a large proportion of salmon feed. It is very demanding to develop a new ingredient on a large scale, but it is underway. We support large and small producers who dare to invest, because this determines how much and how fast the salmon’s food supply changes”, says Bente Torstensen, Division Director for Aquaculture at Nofima.

Photo: Frank Gregersen, Nofima



New feed ingredients such as insect meal, single cell protein, fermented products and microalgae accounted for just 0.4 % of the total volume of salmon feed, or 8000 tons in total.



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Partners: BioMar AS, Cargill, Mowi Feed AS and Skretting AS



Young people want to eat more seafood

Young adults are motivated to eat more healthy seafood. However, they need inspiration to get started, preferably from influencers!



Mia Eline Kaarstad from Hardanger and Marthe Sollied Nordgård from Senja gain inspiration from Tik Tok when they cook.



Photo: Audun Iversen, Nofima

In the study involving 26 young adults, sushi was described as an exciting dish. Appetising images on digital platforms inspired them to cook food.

In Nofima's 'Seafood as an everyday dinner' survey, scientists investigated what motivated and prevented 26 young adults from eating more seafood for dinner.

"We must inspire them via the right channels", says Nofima scientist Siril Alm.

Mia Eline Kaarstad from Odda in Hardanger and Marthe Sollied Nordgård from Senja agree.

"I get a lot of inspiration from my mother and stepfather, but Tik Tok also plays a role in my food choices", smiles Mia Eline Kaarstad.

Declining seafood consumption

Despite the fact that people have become more concerned with having a healthy diet, seafood consumption in Norway has been declining for several years – especially among the younger population. Norwegian health authorities recommend eating seafood for dinner two to three times a week so as to provide a basis for good health.

But it is not going to happen on its own. The Nofima study shows that the seafood industry can:

- Market products and recipes on social media via influencers.
- Create digital cooking classes that motivate young people to make seafood dishes
- Collaborate with restaurants, chefs and food box suppliers to promote seafood recipes

"Young adults are potentially a very important customer group for food producers – including seafood producers. Young people are not that influenced by habits, are receptive to new impulses and food trends, and want to try new dishes and ingredients", says Siril Alm.

Sushi and poke bowl

Most of the young consumers wanted to reduce their consumption of red meat and eat more sustainable foods such as cod, vegetables, chickpeas and beans.

Many of the participants said that they rarely cook seafood because seafood recipes were not promoted in the channels they used as inspiration.

"Sushi and poke bowl are among the seafood dishes the young people wanted to eat more of", says Siril Alm.

 Norwegian health authorities recommend eating seafood for dinner two to three times a week so as to provide a basis for good health

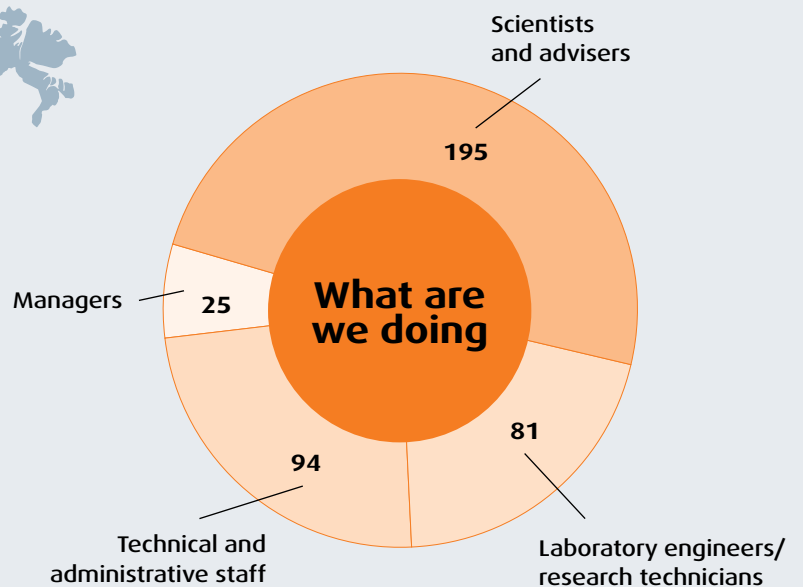
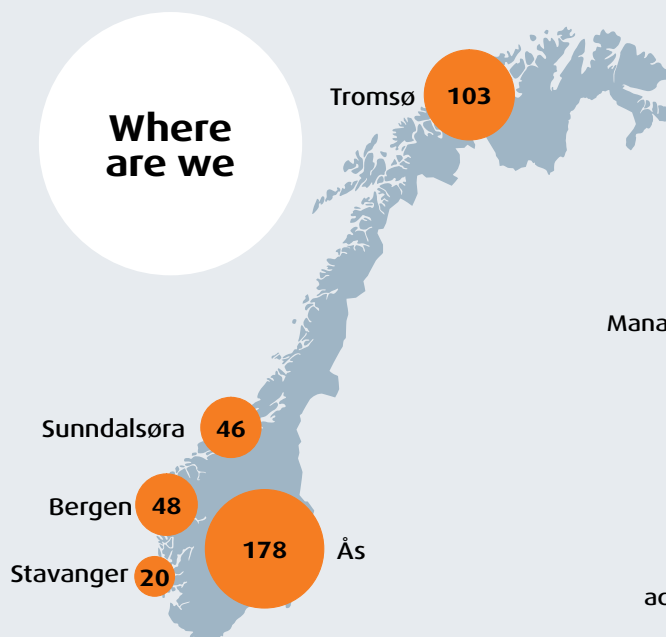
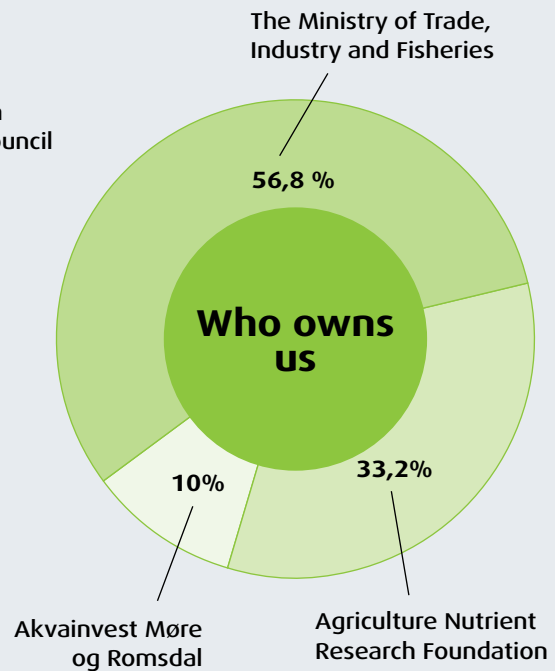
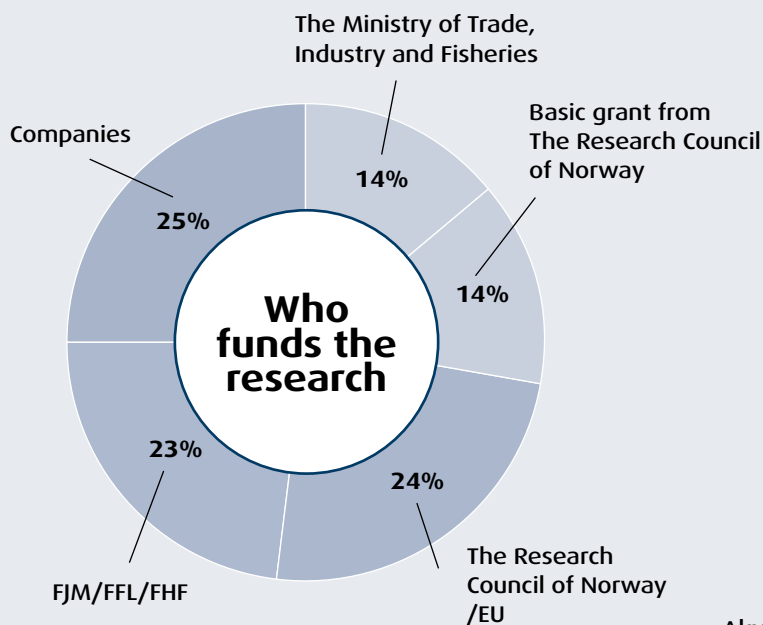


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Funded by: The Ministry of Trade, Industry and Fisheries

Behind the research



The following are our largest funding providers:

THE MINISTRY OF INDUSTRY AND FISHERIES (NFD)

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

THE FISHERY AND AQUACULTURE RESEARCH FUND (FHF)

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

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

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

THE RESEARCH COUNCIL OF NORWAY (NFR) is a research policy adviser for the government and the ministries which allocates NOK 10 Bn. annually for research and innovation. The Research Council's mission is ensure 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.

This is Nofima

Nofima has some 400 employees, and a turnover of NOK 677 million i 2021. 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
Bente E. Torstensen

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

Competition for research funding from policy instruments and industries is tough. The economic prospects for the world and our area are uncertain and, in the short term, they are tighter with higher cost increases than in the past. This will place even higher demands on us in that we must deliver efficiently and provide relevant knowledge, so that we make our contribution to tackling the major societal challenges we face.

In 2022, we have won many projects and made good use of our R&D capacity and infrastructure. Nofima has a solid economy, even though the high increase in costs is expected to affect this year's financial result. Going forward, there is a need for an even stronger focus on costs and for us to use our capacity and infrastructure smartly and efficiently so that we continue to have a well balanced economy.

Grete Sollesnes Winther
Chief Financial Officer





Sustainable food for everyone

Nofima's vision

Research is at the core of knowledge-based innovation. Nofima's social mission is to produce new knowledge that brings Norwegian food industries forward.

Nofima has close ties to Norwegian food production. We are Norway's leading food research institute and conduct research and development for the aquaculture, fisheries and food industries. Our research is industry-oriented and relevant, and the knowledge we generate is actively applied by our clients.

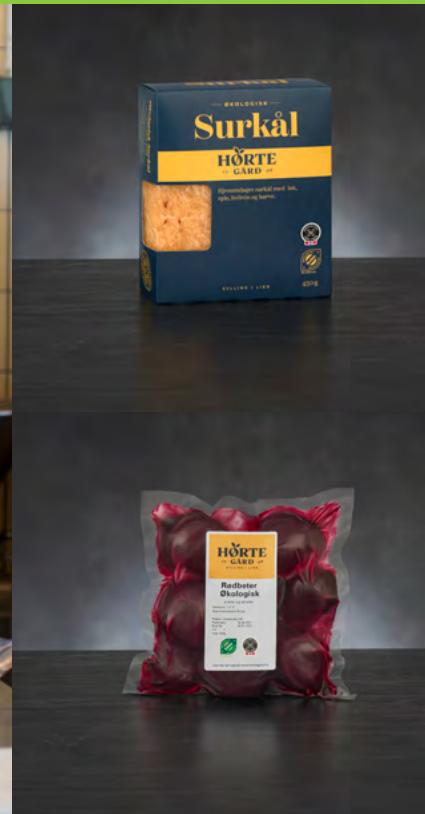
That is why you often find our scientists onsite in various businesses. They work closely with staff who manage net-pens, at fish reception stations and salmon processing facilities, in meat halls, bakeries and other food production facilities.

Research-based innovation increases value creation and improves competitiveness. For small and medium-sized enterprises, it is we who in many cases make research and development possible.

This is how we contribute to sustainable food for everyone.



If organic products are your focus,
we can help you



Through the Ecology Programme, which is funded by the Norwegian Agriculture Agency, we can offer:

- professional assistance and guidance regarding product and process development
- the visit scheme with up to 15-20 hours of free professional food guidance
- courses and networks

One of the companies we have helped is **Smaksriket**. They are famous for their organic lettuces and, with the help of the Ecology Programme, have developed a series of ready-to-eat organic vegetables.

Two of these have received the 'Unique Taste' specialty label. They are Beetroot sous vide and Sauerkraut. Nofima has helped with both recipe and process development.

"We are very pleased with the help we have received from the Nofima experts, and not least that the products have been a hit with the customers", says vegetable farmer Anders Hørthe.



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