

Creating value

Project year 2020



Aquafeed Technology Centre (ATC)

The aquaculture industry is growing, and it needs full flexibility in the choice of raw materials for fish feed. Our scientists are working with the feed industry to identify new raw materials that can increase the sustainability of the aquaculture industry and reduce its carbon footprint. This knowledge also provides the basis for better utilisation of the raw materials currently in use.



The Aquafeed Technology Centre is offering the industry competence and research infrastructure within:

- Bioprocessing
- Downstream process technology
- Extrusion and feed technology
- Analytical platforms

The Aquafeed Technology Centre’s new equipment allows us to study the impact which the processing of new raw materials has on the ingredients and the final product.

ATC is part of the Norwegian Roadmap for Research Infrastructure and is a collaboration between Nofima (project leader), University of Bergen and Norce.

<https://aquafeed.science/>



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EDITORIAL STAFF:
 Editor: Anne-May Johansen
 Editor-in-chief: Morgan Lillegård
 Contributors: Anne-May Johansen, Emil Bremnes, Jon-Are Berg-Jacobsen, Lidunn Mosaker Boge, Reidun Lilleholt Kraugerud, Wenche Aale Hægermark.

GRAPHIC DESIGN AND PRODUCTION
 Lay-out: Krysspress
 Printed by: Fagtrykk Idé AS
 Cover photo: Lars Åke Andersen
 Translation: Semantix

Published by Nofima AS/January 2021
 ISSN 1893-6652 (trykt)
 ISSN 1894-4744 (digitalt)

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 or call +47 77 62 90 00



PHOTO: JON-ARE BERG-JACOBSEN

Five reasons to focus on applied research

12 March 2020 is a date we will always remember. The coronavirus forced the Norwegian government to enforce a lockdown. Overnight, we all had to reinvent our daily lives. It was a demanding, yet also interesting and an educational exercise in driving innovation.

Proper measures to control the corona pandemic and a well-functioning health care system is paramount, but in the midst of the pandemic we must still consider how we continue to develop our food production sector. That is the reason why Nofima has further clarified our purpose: The Norwegian food production sector is evolving, and as an applied research institute, we will contribute to ensure continuous development of the sector based on evidence-based research and knowledge.

The food industry uses raw materials from aquaculture, agriculture, and fisheries to craft their final product. Around 90 per cent of companies in this sector have fewer than 50 employees and represent businesses that play a key role in employment and value creation across the country. These companies rarely have their own separate research and development departments

and depend on evidence-based research to grow and evolve. Climate change, reduction of greenhouse gas emissions, a circular economy and improved resource utilization are topics that form part of the backdrop which these businesses have to take into account in order to maintain their future competitiveness. Nofima wishes to contribute to this shift in line with our vision:

Sustainable food for everyone. Here are five points we believe are important for future-proofing Norwegian food production.

1. A green shift in the food industry

Many point out that the food industry is a significant contributor to global greenhouse emissions, and that the entire food value chain needs to implement a number of measures to reduce its carbon footprint. We can see that plant-based foods are a rapidly growing international trend, and this poses a challenge for traditional agricultural products. Increased research-based innovation is fundamental in meeting this challenge. The key to innovation and restructuring is industry-oriented and relevant applied research.

2. The Norwegian food industry is dependent on research in the face of tough competition

The pandemic has shown us the importance of food safety and securing the national supply chain. Many Norwegians wish to become less dependent on food products from other countries. The Norwegian food and beverage market is facing significant – and growing – competition, and food import rates are increasing. However, the narrow margins in the food industry challenges our ability to innovate. Applied research and innovation is the key for enabling the Norwegian food industry to compete against large food imports in the future.

3. National value creation in the seafood industry

The Norwegian seafood industry is export-oriented and a world-class competitor. Certification of Norwegian wild caught cod has played a key role in retaining existing markets and acquiring new ones, and further research into quality aspects throughout the value chain will help to consolidate the Norwegian position in the markets. Year-round access to wild-caught raw material through research on and development of new methods and technologies for freezing and storage will help secure year-round jobs in



PHOTO: LARS ÅKE ANDERSEN © NOFIMA

the long term, which will in turn provide a basis for advanced industrial developments in the sector.

4. Sustainability throughout the aquaculture value chain

Increasing the proportion of seafood in our diet is an effective measure for reducing our environmental impact. More seafood means increased utilization of marine resources, and aquaculture is part of the solution. Growth must be achieved in a sustainable way, which will require focused efforts at all levels of production. We must develop new raw materials for feed, and use our expertise to ensure good fish health

and animal welfare, whether the production takes place along the coast, at sea or in land-based or ocean-based closed-containment systems. At the same time, we must ensure that aquaculture and fisheries can coexist, which requires a basic understanding of local and broader social contexts.

5. Food research for rural areas

The many businesses that do not have their own research departments require an enhanced collective research effort for the transition to a more sustainable society. By ensuring that the Norwegian food industry is equipped for the future, we also help secure jobs, settlement and business in rural areas.

In this year's edition of *Næringsnytte*, we highlight some selected examples from our research to illustrate the broad approach which Nofima takes in addressing some of the challenges I mentioned above. This research is intended to provide actionable insights and solutions for the food industries.

Happy reading!

A handwritten signature in black ink, appearing to read 'Øyvind Fylling-Jensen'.

Øyvind Fylling-Jensen
Managing Director

How to succeed with local food

Sales of local food are increasing, but the number of producers remains relatively stable, with around 1500 local food producers currently.

The challenge of increasing the number of producers is not due to a lack of new players who want to try their hand, but rather that many of them find it difficult to professionalise their business.

Nofima Senior adviser Stine Alm Hersleth is looking into which factors are key to enabling more local food entrepreneurs to keep going, and what benefits a support network could bring.

Everyone must feel included

“Both newly established and experienced producers need to operate in a professional and supportive environment and maintain networks where they feel included and can stay updated on current know-how. The community should be able to operate in the long term and meet different needs, and so we need professional network managers who are responsive and have a strong, relevant expertise,” says Stine.

As a long-standing project manager for the professional support network for local food producers in Eastern Norway, she has a lot of experience in how networks operate.

Characteristics for a successful professional network includes a well-developed sharing culture, room for recognition and professionalism, and individual follow-ups for each participant.

Learn the basics from an expert

Ask Gård Foredling is one of the local food producers who have taken advantage of the opportunities available through this professional support network.

“Having a food research professional as a mentor from day one has helped us have the basics in place, avoiding years of trial and error”, says local food entrepreneur Kristoffer Evang from Ask Gård Foredling.

In the booklet Slik kan lokalmatprodusenter lykkes, he and four other successful local food producers share their best advice. You can also read more about the practices which ensure successful networks. You can download the booklet by scanning the QR code below.



FOTO: JON-ARE BERG-JACOBSEN

Project Manager Stine Alm Hersleth researches the role of competence networks and what factors are key for local food producers to succeed.



CONTACT:
Stine Alm Hersleth
Senior adviser and research fellow
+47 975 41 669
stine.alm.hersleth@nofima.no

FUNDED BY:
Lokalmatprogrammet and The Ministry
of Agriculture and Food through
Innovation Norway

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PHOTO: SARAH FJØRTOFT JACOBSEN

In her doctoral work, Marthe Jordbrekk Blikra has developed a tool that can be used to optimise heat treatment of cod.

A PhD in the baked cod

Baking fish can actually be science. Marthe Jordbrekk Blikra has achieved a PhD in the optimal heat treatment of cod.

“The overall goal was to develop a tool that can be used to optimise the heat treatment of cod. And we managed to achieve it”, says Nofima scientist Marthe Jordbrekk Blikra.

Long shelf life and great taste

While taste and mouthfeel are in focus when chefs prepare food, microbiologists prioritise food safety. Achieving a long shelf life is also an important factor. Marthe’s PhD deals with combining these aspects to create safe food with a long shelf life and great taste.

“While restaurant chefs optimize for juicy cod filets by heating until a core temperature of 48 degrees Celsius, the microbiologist prefer 72 degrees to ensure food safety. However, the high heat load can make the lean pieces of cod become overcooked, dry and chewy. This can lead to unnecessary food waste”, the scientist points out.

Therefore, her thesis developed a physics-based mathematical model for transporting heat and liquid during baking.

The equations take into account the size of the pieces of fish. It can tell you how many minutes of heat treatment each piece of fish needs.

To build the tool, the scientists mapped several parameters and variables relevant for heat treatment of cod.

“We also wanted to broaden our understanding of what was happening during heating”, Blikra explains.

An app

Although it includes advanced equations, the scientist believes that in the future, the developed model could be used by anyone cooking fish. This includes consumers buying raw fish to bake at home in their kitchens, and food manufacturers preparing large amounts of cod in their factories.

“We use the software COMSOL Multiphysics, where the relevant equations can run simultaneously and interdependently. To reach industrial- and home users, we can create an app based on the current model. Whether this will happen or not depends on interest from the industry.



CONTACT:
Marthe Jordbrekk Blikra
+47 454 50 641
marthe.blikra@nofima.no

FUNDED BY:
The Norconserv Foundation,
the Research Council of Norway,
and DTU

PARTNERS:
The Technical University of
Denmark (DTU), food industry
stakeholders (MatBørsen AS)

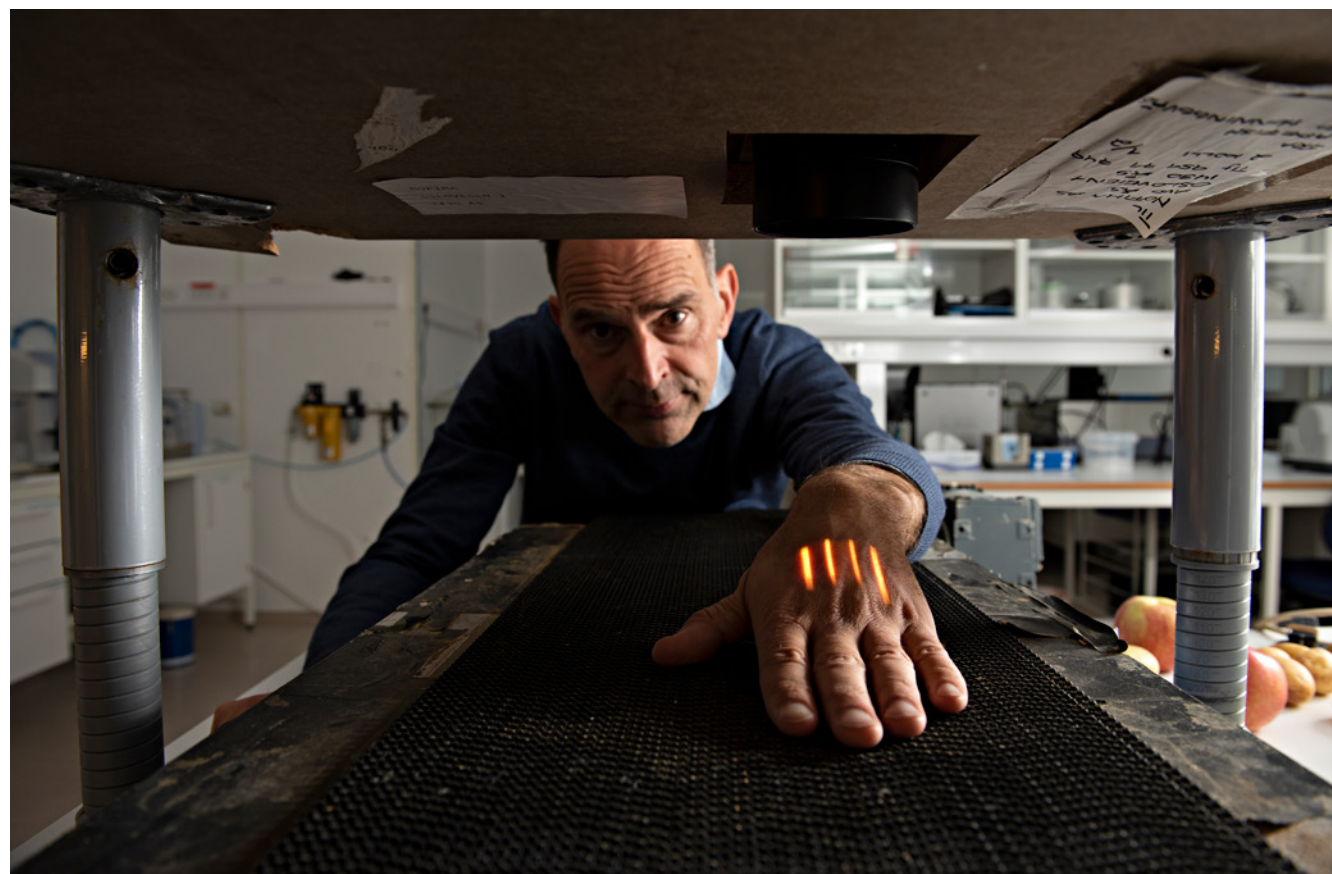


PHOTO: JENS PETTER WOLD © NOFIMA

Jens Petter Wold, leading the SFI Digital Food Quality project, has worked with sensor technology and spectroscopic methods for decades.



PHOTO: WENICHE AALE HÆGERMARK © NOFIMA

The DigiFoods leader group: Pål From, Jens Petter Wold, Nils Kristian Afseth, Kristian Hovde Liland, Ingrid Måge and Marion O'Farrell.

Precise quality measurements

Digitisation offers new opportunities for Nofima scientists who have spent decades developing non-destructive sensor-based measuring methods

The ability to test for food quality quickly, objectively and in a non-destructive manner is very useful, whether in a lab setting or during industrial processes. However, food quality is a complex concept which is defined by a number of different chemical and physical characteristics. Using sensors to measure quality can therefore be quite challenging.

Nofima saw the potential in such quick measuring methods early on, and in the late 1980s they published their first articles on methods for measuring fat and protein content in meat by using near-infrared (NIR) spectroscopy. Since then, the development of such methods

has become a vast international field of research, where Nofima has been continuously providing key innovations in measurement methodology, useful applications and data analysis methods.

Developing measurement methods based on different techniques

"We started with NIR spectroscopy and later developed measurement methods based on other spectroscopic techniques, such as fluorescence, Raman and IR and hyperspectral imaging, which make it possible to create images of chemical properties", says Senior Scientist Jens Petter Wold.

The various measurement methods

have their own advantages and limitations, and are used for different purposes: To measure the total fat content, you use NIR; for more information about the composition of the fat, you use Raman or IR.

Industry-relevant utility value is key

"Our objective all along has been to develop methods which are useful for the food production industries. Over the past 15 years we have developed systems that can be applied directly in the process lines to measure the quality of every single product there", Jens Petter explains.

This allows products to be sorted into

different quality tiers, which can add value, or you can control the processes to achieve specific product qualities. We have developed effective solutions for use on key Norwegian products and raw materials such as salmon fillet, whole fish, crab, beef, chicken and residual biomass. Several of these solutions have been commercialized and are in use every day in Norway and around the world.

In order to develop well-functioning systems that are adopted by the industries, interdisciplinary collaboration is key. Food companies can define which quality characteristics are important to measure, and at which part of the process. Instrumentation experts can design tailor-made solutions for different applications.

Instrument suppliers can manufacture and market ready-made systems. Scientists have expertise in spectroscopy, food technology and data modelling.

Digitisation and systematized quality measurements provide great value

There are several examples where in-line measurement provides opportunities for useful quality classification. However, it may be just as useful for food producers to collect, digitize and systematize all the quality measurements that are carried out, use this data to monitor changes in quality over time and connect these variations to other parts of the value chain. These insights can in turn be used to learn more about what

types of production result in the best quality for chicken, salmon or protein hydrolytes.

These ideas and experiences form the basis for SFI Digital Food Quality (DigiFoods).

"DigiFoods is a centre for research-driven innovation where 27 partners with expertise in the food industry, sensor technology, robotics, IT, data analysis and R&D come together to develop new fast methods for measuring food quality. These methods must be applicable to in processes for measuring and digitising the fundamentals of food quality, which can be used to optimize processes and value chains. This will help us succeed with the digitisation of the Norwegian food industry," says Jens Petter.



CONTACTS:
Jens Petter Wold
Senior Scientist
+47 959 79 749
jens.petter.wold@nofima.no



Ingrid Måge
Senior Scientist
+47 900 84 041
ingrid.maage@nofima.no

FUNDED BY:
The Research Council of Norway and participating stakeholders

PARTNERS:
Sintef Digital, NMBU and 24 other partners

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Toolbox for better fish health

It is hard to tell how a fish is doing, so we need toolkits to do a proper health and welfare check.

Nofima scientists are assembling these toolkits. The research project HVI Toolbox is building upon the currently available welfare indicator toolboxes in order to enable everyone involved in salmon farming to assess both fish health and welfare.

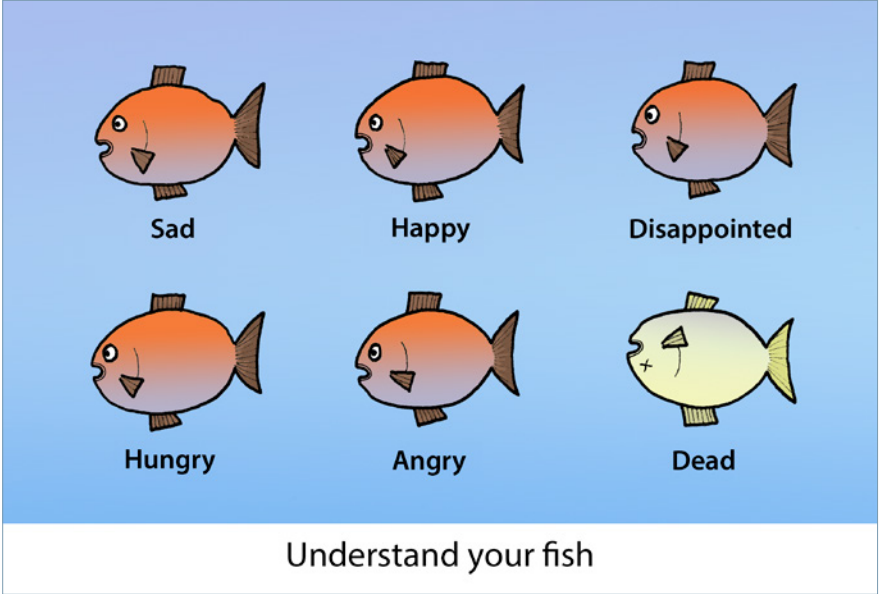
“Such toolkits provide methods for assessing the fish during handling operations such as fish transfers, de-licing operations and other potentially stressful situations, as well as the ability to assess their health and welfare status during day to day farming operations. The objective is to limit stress and poor welfare, which can in turn lead to even poorer health”, says one of the lead scientists in the project, Lill-Heidi Johansen.

Consolidating knowledge

There is a close link between health and welfare – even for fish.

But how can we know how the fish is really doing?

“Different species respond differently to stressful situations. Salmon flee from



Sad, happy, disappointed, hungry, angry? When an untrained eye has difficulties assessing fish health and welfare, a toolkit could be the answer.

ILLUSTRATION: SVERRE BJØRSTAD GRAFF © ABSURDGALLERIET

the perceived threat, while lumpfish attach themselves to the substrate and appear unconcerned – but may be just as stressed as the salmon”, says Lill-Heidi Johansen.

We can get some information by observing the fish, as ventilation rate and movement patterns can reveal a great deal about its wellbeing to a trained eye. Skin and fin damage are also visual indicators of problems. However, scientists also want to be able to detect injuries and infections that are not immediately visible, but where samples of the fish must be examined more closely in the laboratory for answers.

Many stakeholders care for the health and welfare of farmed fish, such as the individual farmers, fish health authorities and the Norwegian Food Safety Authority. However, they may have different evaluation systems, criteria and parameters for assessing fish welfare.

“We need to develop and refine our existing tools to get a better picture of the health and welfare status of the fish and ensure that the tools can be applied to all situations which the fish are subjected to”, says Johansen.



Lill-Heidi Johansen has spent her professional career focusing on fish health and will use the HVI toolbox for the benefit of farmed fish. Photo:

PHOTO: LARS ÅKE ANDERSEN © NOFIMA



Evaluation of the HVI Toolbox is taking place under commercial conditions. Research assistant Tina Thesslund & project manager Roy-Inge Hansen are prepared.

PHOTO: © NOFIMA

Assessing production fish

Nofima and its research partners have already developed species-specific toolkits with welfare indicators for salmon and rainbow trout as part of the Norwegian Seafood Research Fund (FHF) project FISHWELL, and during the FHF project RENSVEL they prepared fact sheets about operational welfare indicators for cleaner fish such as lumpfish and ballan wrasse. The HVI Toolbox utilises this work with a much greater emphasis on fish health indicators.

“The project is part of a larger Nofima initiative where we carry out several projects to increase our ability to develop more precise tools for assessing fish health and welfare.”, says Johansen.

What tools do we need? Which tools can be used on the fish farms, and which tools should only be used in the laboratory?

Evaluation of the HVI Toolbox is carried out in full scale cages at a commercial farm, and the tests are carried out in cooperation with the Aquaculture Research Station in Tromsø, which has an R&D licence operated by Salmar.

A broad approach

We need to understand, utilise and interpret the data we collect about de-licing operations, fish transfers, and so on. Can the fish tolerate the procedure? What if they are already injured? What does that indicate?

“We need to take a broad approach

and apply the tools in different situations. After testing them we can determine where they should ideally be applied and in which combinations,” says Johansen.

The HVI Toolbox concept is also applied in controlled studies under the FHF project CrowdMonitor, which is led by Nofima, and the FASTWELL project led by the Norwegian Institute of Marine Research and financed by the Research Council of Norway.

“What the final HVI Toolbox will eventually look like and how it will be used will be announced upon the completion of our current evaluations. We believe we will have more robust data in place by the end of 2021”, says Johansen.



CONTACTS:
Lill-Heidi Johansen
Scientist
+47 908 82 677
lill-heidi.johansen@nofima.no



Chris Noble
Senior Scientist
+47 909 65 133
chris.noble@nofima.no

FUNDED BY:
The Aquaculture Research
Station in Tromsø – R&D
license no. T-T-0035

PARTNERS:
The Aquaculture
Research Station
in Tromsø

Iron powder from salmon blood

A unique iron powder from salmon blood is more easily absorbed by the body than iron salts – good news for people with iron deficiency.



Blood powder made from salmon blood.

PHOTO: AUDUN IVERSEN © NOFIMA

When Norwegian salmon are shipped from the slaughterhouses to reach dinner plates all over the world, the slaughterhouses are left with colossal amounts of salmon blood. Approximately 36,000 metric tonnes of salmon blood – the only part of the salmon currently not utilised – is discarded annually.

Presently, anaemia is a global problem. According to the WHO, as many as 800 million women and children around the world are affected, making anaemia one of the most common deficiencies – but also one of the most difficult to treat.

The WHO estimates that around half of all anaemia cases are caused by iron deficiency, and iron supplements are recommended for a number of other patient groups. But even if iron can be found all around us, it's not necessarily easily replenished in our bodies.

"Humans prefer biologically available iron, i.e. in a form that the body can absorb", states Nofima scientist Runar Gjerp Solstad.

Iron adapted to the human body

The most common ferrous molecule in nature is haemoglobin. Haemoglobin used in iron supplements is usually extracted from pigs and livestock. Iron salts from plants are also used, but they

are not as easily absorbed by the body.

"We wanted to look at whether we could extract haemoglobin from the salmon blood in order to use it in iron supplements", says Research Director Ragnhild Dragøy at Nofima.

Along with colleagues from the Nofima Department of Marine Biotechnology, Norinova, Lerøy Aurora, and participants from the University of Tromsø, she has tested various methods for utilising the leftover blood.

The minister had a taste

And the researchers' experiments yielded results. The promising experiments from the laboratory were passed on to Biotep – Nofima's national pilot facility for marine bioprocessing – where the process was scaled up a small industrial production. An additional scale-up was performed at a pilot facility belonging to Catapult Life Science. Using these new methods, scientists



Nofima scientist Runar Gjerp Solstad & colleagues are excited to continue their efforts to produce iron supplements from salmon blood.

PHOTO: AUDUN IVERSEN © NOFIMA



Minister of Fisheries and Seafood, Odd Emil Ingebrigtsen, is briefed on salmon blood research by Nofima's Runar Gjerp Solstad and Ragnhild Dragøy.

PHOTO: EMIL BRENNES © NOFIMA

have managed to manufacture a unique iron powder.

"The blood powder has been tested on humans at a small scale with very promising results, and more comprehensive clinical testing is being set up for the future", says Dragøy.

An informal "test" was also carried out as the Minister of Fisheries and Seafood, Odd Emil Ingebrigtsen, visited Nofima's headquarters in Tromsø. The Minister was presented with the new and ongoing research – and even got a taste of the result.

"After all, there is a reason why we allocate money to Nofima and the Institute of Marine Research. Sustainable management of ocean resources is something the whole

world is concerned with. We have a highly skilled scientific community here in Norway which already has strong cooperation agreements in place with the aquaculture and fisheries communities", said Ingebrigtsen.

Sustainable alternative

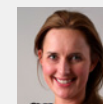
The main advantage of iron supplements from salmon blood is that it may be used by many different consumers. As some social groups do not wish to consume iron supplements containing haemoglobin from land animals, a salmon-based supplement might provide a better alternative.

This creates opportunities to increase income and reduce costs for salmon producers.

"Today, the slaughterhouses have to bear the cost of disinfecting and disposing of the blood, which can contaminate the ocean", says Ragnhild Dragøy.

However, some challenges remain before the salmon industry can start serious production of iron powder. The blood must be properly collected, and both taste properties and recipes require further work. It will also be important to consider the results from the more extensive clinical trials.

Researcher Runar Gjerp Solstad and his colleagues at Nofima are looking forward to the next steps.



CONTACTS:
Ragnhild Dragøy
Research director
+47 977 49 562
ragnhild.whitaker@nofima.no



Runar Gjerp Solstad
Scientist
+47 907 34 498
runar.gjerp.solstad@nofima.no

FUNDED BY:
The Research Council of Norway (NFR), Lerøy Aurora AS and MABIT.

PARTNERS:
Norinova, UiT – The Arctic University of Norway and Lerøy Aurora AS

Gene technology improves shrimp health

By using genomic selection, Nofima have demonstrated that we can rapidly increase the level of disease resistance in whiteleg shrimp.



Healthy whiteleg shrimp.
PHOTO: MARCELA SALAZAR, BENCHMARK COLOMBIA.

White spot syndrome virus disease causes mass mortality and large economic losses for shrimp farmers all around the world. The disease spreads quickly and preventative measures for contagion have proven ineffective.

DNA sequencing technologies

Genomic selection is a recent methodology originally developed for livestock improvement employing the latest in DNA sequencing technologies.

“Genomic selection is more efficient than traditional selective breeding because we can assess the genetic value of candidate breeders more precisely, both within and between families, without exposing them to the disease”, says Nick Robinson, senior researcher at Nofima.

More shrimp survive

Nofima Scientists have collaborated with scientists at Benchmark Genetics in Colombia and Norway to show that genomic selection can be used to boost the ability of shrimp

to resist the highly lethal and contagious WSSV disease. The results demonstrated that the average survival of shrimp families increased from 38 % to 51 % after only one generation of genomic selection for high resistance against the virus. In the best genomically selected families, more than 80% of individuals survived when challenged with the disease.

“Like vaccinating a population against disease, having animals with this level of resistance in the shrimp population would likely be sufficient to provide a herd effect”, says Robinson.

The work has demonstrated that one can rapidly increase the level of disease resistance in whiteleg shrimp. Benchmark Genetics now use this tool to offer growers shrimp populations that can survive and produce in the presence of WSSV.

Genomic selection also holds great promise for the improvement of other economically important traits in shrimp and other aquaculture species. The research shows that genomic selection could go some way towards solving this multibillion US\$ problem for the shrimp industry in the future.



The extruder can be used for both wet and dry extrusion. Scientist Catia Saldanha do Carmo has mapped the effects from both processes
PHOTO: JOE URRUTIA © NOFIMA

Database for plant-based food

Food producers need more knowledge to be able to use Norwegian raw materials for developing healthy and appealing plant-based alternatives.

Nofima scientists gather and develop data about:

- Which raw materials and raw material mixtures are best suited to different products based on their desired properties (functional, nutritional and sensory)
- Which processing methods and parameters are best suited for different products, raw materials and raw material mixtures.

Little use of Norwegian raw materials

The aim is to obtain data that the food producers may utilize in order to save time on trial and error in their own experiments.

“There is little current use of Norwegian raw materials in plant-based meat substitutes on the market. We believe the data we gather can help producers catch up with foreign products”, says Nofima Senior Scientist Svein Halvor Knutsen.

He adds that they have also worked to develop several other plant-based products and ingredients, such as healthy protein-rich snacks.

Detailed and accurate knowledge

Nofima scientist Catia Saldanha do Carmo plays a key part in the mapping of suitable combinations of raw materials and processing methods. An important part of this work has been to obtain detailed data about the functionality and possible combinations of applicable machinery, as well as their effects on products.

“The technology I have mainly worked with is called extrusion, which makes it possible to process raw materials into the desired shape and texture. To determine optimum conditions I have studied the effects of the various extruder settings such as temperature, water content, input speed and rotational speed”, says Catia.

- Among other things, she has developed prototypes for:
- Healthy pea- and oat-based snack products rich in fibre and protein
 - Protein-rich meat substitutes based on fava beans

The research has been carried out as part of the project FoodProFuture and at the FoodPilotPlantNorway. Scan the QR code below to learn more.



CONTACTS:
Nick Robinson
Senior Scientist
+61 448 984 002
nicholas.robinson@nofima.no



Marie Lillehammer
Scientist
+47 64 97 04 05
marie.lillehammer@nofima.no

FUNDED BY :
Research Council of Norway

PARTNERS:
Benchmark Genetics

READ MORE:





CONTACTS:
Svein Halvor Knutsen
Senior Scientist
+47 482 99 594 svein.knutsen@nofima.no



Catia Saldanha do Carmo
Scientist
+47 907 47 497
catia.carmo@nofima.no

FUNDED BY:
The Research Council of Norway

PARTNERS:
A number of partners from the scientific community, as well as a reference group with many industry players

Ripple effects from the seafood sector

The value creation from the seafood sector was 127 billion NOK in 2019. It has increased sixfold over the past 15 years.

This is according to a report on ripple effects prepared by Menon, Nofima and Norce.

The ripple effects can be felt across Norway. Value creation is perhaps the most telling key figure for an industry, as it highlights the returns on efforts made: salaries to employees, financial returns to the owners and taxes to the authorities.

The total employment effects from the activities of the seafood sector amounted to over 90,000 jobs in 2019 (or 78,000 jobs measured in work years). These activities contributed to 32 billion NOK in taxes in 2019, which corresponds to almost 3 per cent of the government's total tax revenues last year.

Growth boosts value creation

"Hardly any sector has grown more than the seafood sector in recent years. This growth plays a key role

for Norwegian value creation and social welfare. The sector's average for value creation per employed person is almost twice that of Norwegian onshore industries," says Nofima's project coordinator Roy Robertsen.

The growth in the seafood sector has been driven by increased salmon production, higher prices for fish and a weakened Norwegian currency.

The report shows how important the seafood sector is to all coastal regions. In direct value creation, Møre og Romsdal scores highest with 15 billion NOK in 2019. In second place comes Vestland with 13.5 billion NOK in value creation.

However, it is in Northern Norway that the seafood sector has the strongest relative importance. In Troms and Finnmark, the seafood sector accounts for almost 12 per cent of all private sector jobs, followed by



Over half of private jobs in certain Norwegian municipalities can be linked to the seafood sector and its ripple effects.

Nordland with 11.5 per cent and Møre and Romsdal with just over 11 per cent.

Ripple effects from the fishing fleet

In addition to the ripple effects analysis for the entire seafood sector, a separate report on the fishing fleet was also published in late 2020.

The report on the fishing fleet shows that the fleet is profitable, that it creates great value for the owners and good remuneration of the crew, and that this value creation takes place along the entire coast.

- The ripple effects, on the other

hand, are not as evenly distributed along the coast. The supplier industries are concentrated in the counties of Vestland and Møre og Romsdal, as well as Oslo and the other large cities, says researcher Audun Iversen.

New methods provide better analyses

The ripple effects are calculated based on a selection of the seafood

companies' actual purchases of goods and services, before further ripple effects are calculated through Menon's ripple effect model - ITEM.

Compared with previous analyses, this analysis goes further in calculating the geographical distribution of the ripple effects, and this analysis also captures more of the ripple effects from

investments in the seafood industry, by including specialized suppliers in the population.

- The supplier industries are becoming an increasingly important part of the industry. They also grow through the export of both aquaculture and vessel technology. In 2021, there will be a separate report on the suppliers to the industry, Roy Robertsen concludes.

Facts about the reports:

- The analyses presented is part of an annual exercise commissioned by the Norwegian Seafood Research Fund (FHF).
- The first national report was published in September 2020. In addition, 11 regional reports were published.
- All reports are available for download via the QR code at the bottom of the next page (in Norwegian).



CONTACTS:
Roy Robertsen
Senior Scientist
+47 906 80 275
roy.robertsen@nofima.no



Audun Iversen
Scientist
+47 900 40 615
audun.iversen@nofima.no

FUNDED BY:
Norwegian
Seafood
Research Fund
(FHF)

PARTNERS:
Menon Economics
and NORCE

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Breeding climate robust salmon

Breeding salmon for growth or resistance to sea lice in cold waters may have little effect if the offspring grow up in warmer waters.

“With climate change and more frequent heatwaves in the ocean I think this is useful information for breeding companies who are breeding for growth or resistance to sea lice”, says Nofima scientist Celeste Jacq.

The individual characteristics of both salmon and sea lice can determine whether the sea lice attaches to and feeds on a salmon. The fact that resistance to sea lice is hereditary in salmon is known from previous breeding and genetics research by Nofima. By drawing in expertise from fish health, production biology and chemistry, Nofima was able to answer a broader question: How to increase robustness in salmon and lumpfish in the face of climate change. This resulted in the establishment of the strategic initiative FutureFish.

Growth and lice activity are temperature dependent

Let's look back to the start of the trials in the winter of 2017, when fifty salmon families from the fish farming company Mowi were distributed across different tanks at the Aquaculture Research Station in Tromsø. At the start of the trial the salmon weighed 100 grams, and were reared in seawater of 5, 10 and 17°C. A few weeks into the experiment, the researchers added young sea lice to the tanks and measured the effect on the salmon. They counted the number of sea lice, took samples of mucus and skin and measured the size of the fish. They analysed the DNA for 45,000 genetic markers and examined the relationship between the lice load (i.e. how much lice attach to the salmon) and salmon growth at the different temperatures.



Nofima scientists suspect that some of the compounds in salmon mucus attract lice.

The genetic analysis revealed that neither growth nor the lice load are single traits, but rather that they vary with water temperature. There is only a weak to moderate genetic correlation between salmon growth in seawater at 5°C and 17°C.

“The good news is that it is possible to breed for reduced temperature sensitivity to ensure increased salmon growth and resistance to sea lice even in fluctuating temperatures”, says Jacq.

The project had several interesting results that indicate why different salmon characteristics are associated with sea lice resistance at both high and low temperatures.

The salmon's smell and lice infestation are linked

Nofima scientists John-Erik Haugen and Gareth Difford combined their

respective knowledge about aroma compounds and genetics and found some volatile organic compounds in the salmon skin mucus that seem to attract sea lice in much the same way that human odours attract mosquitoes.

“We also found that the salmon families that are resistant to lice produce less of these compounds, and vice versa”, says Difford.

The scientists will investigate this further in a new project that aims to utilise species-independent variation to improve sea lice resistance and is funded by the Norwegian Seafood Research Fund.

The fish health researchers also found structural differences in the skin of the salmon. The outermost barrier of the skin, the epidermis, was thinner in fish that had been reared at 17°C and had markedly smaller mucus cells. The combined results may indicate that the fish skin barrier weakens over time when the fish lives in warmer water. In addition, the researchers found chemical differences in the mucus between fish from high and low temperature tanks. How these mucosal properties impact fish health will be investigated further.

Breeding lumpfish to eat more lice

Finally, the scientists used genomic information to examine the heritability of sea lice eating ability in lumpfish. The heritability for this trait was low, but there were significant differences between families. This means that it is possible to use genetic selection to increase lice eating ability through breeding programs, which can reduce the reliance on wild-caught cleaner fish and chemical delousing agents.



Gareth Difford has examined the genetics behind mucus cells.

PHOTO: JON-ARE BERG-JACOBSEN © NOFIMA

PHOTO: TERJE AAMODT © NOFIMA



CONTACT:
Celeste Jacq
Scientist
+47 482 54 804
celeste.jacq@nofima.no

FUNDED BY:
The Research
Council of Norway

PARTNERS:
Mowi Genetics AS
& the Aquaculture
Research Station at
Tromsø

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From lab to industrial scale

Nofima scientists have developed methods for better utilising residual biomass, which will now be adopted by the industry.



PHOTO: JON-ARE BERG/JACOBSEN

Our project goal is to understand the relationship between biomass variations and product quality to ensure a consistent final product.

At Nortura in Hærland, chicken and turkey carcasses are transported in a pipe from the cut-up line directly to a process line. Biomega outside Bergen already processes salmon heads, skin and bones. Enzymatic hydrolysis process lines have been installed at both of these facilities. It is in this hydrolysis process where Nofima's research proves useful.

Large chemical variations

The biomass used in these processes contains a great variety of chemical components with large chemical variations.

"In the laboratory we know a little about which parameters we can use to achieve the desired quality of the products, and the next step is to investigate what needs to be done in order for this to work on an industrial scale. We will use spectroscopy and other analysis methods to understand what is actually happening", says Nofima scientist Nils Kristian Afseth.

Biomega has already developed a hydrolysis process which is currently used on salmon off-cuts. "The goal is now to develop tools to further improve production control, which will result in a more standardised process", says Biomega's Director of Research and Development, Bjørn Liaset.

Pioneering research is taking place at Hærland. The process of continuous enzymatic protein hydrolysis of chicken and turkey carcasses to develop them into valued products and ingredients has never been tested on an industrial scale before.

Consistent product quality is key

It is important to ensure stable quality of residual biomass.

"We are developing new spectroscopic analysis methods. The aim is to use sensor technology, such as NIR (Near-Infrared) spectroscopy, to make it possible to control the process, the quality of the residual biomass and the final product," says Afseth.

This research is being conducted as part of the Smartbio project. Scan the QR code below to learn more about the research.



CONTACT:
Nils Kristian Afseth
Senior Scientist
+47 958 40 641
nils.kristian.afseth@nofima.no

FUNDED BY:
Research Funding for Agriculture
and the Food Industry (FJM) and
participating companies

PARTNERS:
BIOCO, Norilia
and Biomega

READ MORE:



CONTACTS:
Kevin Torben Stiller
Scientist
Phone: +47 480 92 838
kevin.stiller@nofima.no



Carlo C. Lazado
Scientist
Phone: +47 930 27 905
carlo.lazado@nofima.no

FUNDED BY:
Research
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Norway

PARTNERS:
CtrlAQUA – the
Centre for
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PHOTO: TERJE AAMODT @ NOFIMA



PHOTO: KEVIN STILLER @ NOFIMA

Color of the water in the tank during the ozone trial shows the turbidity with (left) and without (right) ozone addition.

Kevin Stiller and colleagues have defined the threshold of ozone in brackish water. Here he is at the machine room of Nofima's RAS facility at Sunndalsøra

Have found safe ozone level in closed facilities

Salmon post-smolts tolerate similar level of ozone in brackish water as they do in freshwater.

Ozone is a strong oxidant commonly used for improving water quality and disinfection in freshwater fish farms. When ozone reacts with certain constituents of seawater, however, toxic byproducts can severely impact the health of fish.

As brackish water is increasingly introduced in farming post-smolt salmon, thresholds for the safe use of ozone need to be established. Suppliers of recirculating aquaculture systems (RAS) are looking for safe, cost-efficient and reliable ways to maintain optimal water quality in brackish water RAS, and with this research they are now a step closer.

Scientists from Nofima and The Conservation Fund Freshwater Institute (TCFFI, USA), carried out a trial determining the ozone limit in a flow-through system in brackish water for post-smolts. Atlantic salmon at 100 grams were reared for 12 days in brackish water treated with different ozone doses.

The scientists identified ozone levels up to 350 mV (millivolts) as potentially safe and 300 mV as safe for the health of post-smolts in flow-through brackish water. In a follow-up study led by Nofima fish health scientist

Carlo C. Lazado, it was confirmed that the identified threshold is safe for salmon post-smolts in brackish water RAS.

"The recommendation of being below 350 mV for 100 gram post-smolt salmon in brackish water is consistent with ozone thresholds for other farmed fish species, and for salmon post-smolt in freshwater", says Kevin Stiller, RAS-scientist in Nofima.

However, optimal dosage depends on the quality of water being treated. In the experience of the TCFFI scientist Chris Good, a lower ozone level of 290 mV still resulted in significant improvements to water quality.

Too much ozone is hard on the gills

The scientists registered mortality and changes in the gills, as well as indicators of fish welfare, such as genes important for antioxidant defense and quality of skin and gills.

"What surprised us, was that ozone is much more aggressive on the gills compared to the skin. It means that gills are a good indicator tissue to check out the sensitivity to ozone", says Lazado

Dehydrated food improvements

Packet soup for dinner? There's no need to feel bad about that.

Dehydrated foods largely retain the taste and nutrients found in the fresh raw materials they are made from. The Innøtørk research project, aimed at finding innovative and sustainable methods for dehydrating food, develops new, optimised drying methods to make meals more nutritious and tasty.

Excited Minister of Food

A longer shelf-life means that dehydrated food contributes to less food waste. Additionally, dehydrated food results in a reduced environmental impact from its transportation as it is lightweight and has low space requirements.

"Not to play down fresh food by any means, but dehydrated food can be a great supplement to fresh food as part of a balanced diet", says Nofima Senior Scientist Jan Thomas Rosnes.

The Norwegian Minister of Agriculture and Food, Olaug V. Bollestad, is enthusiastic about the project.

"Research and innovation are important to developments in Norwegian food production, and new, improved drying methods are a great example of how we can take even better care of Norwegian raw materials," says the Minister.

New methods

"Through the testing of drying methods for both vegetables and new marine raw materials, we aim to identify new products and drying methods that can form part of a healthy and nutritious everyday diet for the future," says Jan Thomas Rosnes.

The sale of dehydrated foods has declined in recent years. According to the scientists, dehydrated food has become stigmatised and labelled as nutrient-poor and full of additives. This, however, is a myth.

Today, the most common drying methods for food are either warm air or the complete opposite: freeze drying. Scientists now intend to explore methods that are gentler on the food.

Drying at low temperatures can preserve some nutrients even better. This can be done in several different ways, from room temperature and all the way down to -90°C , says Rosnes.



Jan Thomas Rosnes (right) with fellow scientist Dagbjørn Skipnes. New drying methods are being tested out on tomatoes, peas and kelp.



No need to feel bad about packet soup. Dehydrated foods retain the taste and nutrients found in the raw materials they are made from.

PHOTO: ANNE-MAY JOHANSEN © NOFIMA

PHOTO: AUDUN IVERSEN © NOFIMA

Documenting effect of light on Atlantic salmon performance

Nofima scientists studied the effect of LED light on salmon performance in closed-containment recirculated aquaculture systems.

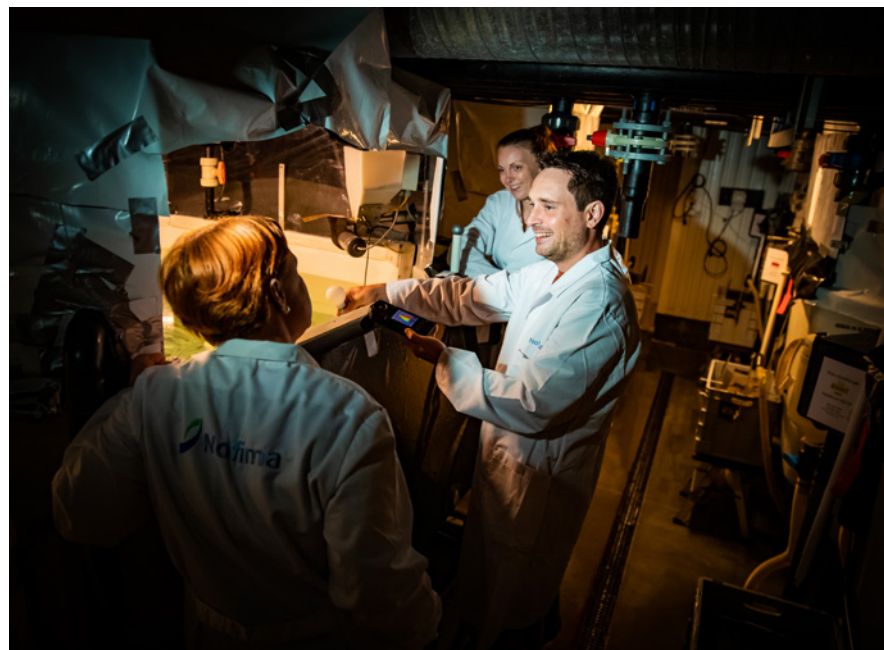
So far, the existing lighting conditions for salmon in recirculating aquaculture systems (RAS) appear to be safe in terms of growth and mortality rates.

"However, we still know little about how the light affects salmon physiology and how they cope with the change in lighting condition after transfer to sea water", says Jelena Kolarevic, Nofima Senior Scientist and project leader for CtrlAQUA's research into light.

Different conditions in RAS and netpens

There is little existing research on what the optimum light intensity and quality in RAS should be. Nevertheless, white LED lighting has become widespread in closed containment systems on land. Very often RAS are managed without in-loop disinfection which means that more particles and organic substances are present in the water preventing the light from penetrating the water column. In sea-based netpen systems, daylight and clearer water represent the natural conditions where blue light penetrates the deepest, while red and yellow light is more common in recirculated water due to the accumulation of substances like humic and fulvic acids. The insights from netpen farming are therefore not directly applicable for the conditions in RAS.

The CtrlAQUA scientists have looked into how the use of white and full-spectrum LED light affects salmon post-smolt in RAS and how the water quality affects light penetration. Light is



Jelena Kolarevic observes trial fish along with scientist Andre Meriac and research technician May Britt Mørkedal at Nofima in Sunndalsøra.

traditionally used in salmon farming to regulate the timing for smoltification.

Challenging in big deep tanks

Based on experience from commercial RAS facilities, the scientists selected two light intensities ($0,25$ and $1,9 \mu\text{mol}/\text{m}^2/\text{s}$) and two light qualities (white LED and full-spectrum LED). Post-smolt, i.e. salmon that have passed the smolt stage, were illuminated for 90 days, after which the scientists measured the water quality and salmon growth and mortality.

The results showed that a light intensity higher than $0,25 \mu\text{mol}/\text{m}^2/\text{s}$

does not affect the fish's growth and survival in the RAS facility.

The industry is looking into the minimum light intensity required for optimum growing conditions in order to cut costs. However, challenges still exist such as understanding the effect of light intensity below $0,25 \mu\text{mol}/\text{m}^2/\text{s}$. Further research is needed:

"In the current large tanks with a depth of up to five metres, it will be difficult for the fish farmer to be able to distribute the light evenly without major investments. It's a challenge the industry has begun to look into," says Kolarevic.

PHOTO: TERJE AAMODT © NOFIMA



CONTACT:
Jan Thomas Rosnes
Senior Scientist
+47 901 72 816
thomas.rosnes@nofima.no

FUNDED BY:
Norwegian Research Council,
Orkla Foods Norge AS and
Algetun AS.

PARTNERS:
Orkla Foods Norge AS, Algetun AS,
the Norwegian Institute of Marine
Research and the Belgian research
institute ILVO.



CONTACTS:
Jelena Kolarevic
Senior scientist
+47 900 97 335
jelena.kolarevic@nofima.no



Åsa Maria O. Espmark
Senior scientist
+47 991 60 039
asa.espmark@nofima.no

FUNDED BY:
The Research
Council of
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PARTNERS:
CtrlAQUA – the
Centre for
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Healthy seniors may have a better sense of taste than previously thought, which is useful knowledge for product development.

New nutrition for seniors

Could fibre and protein-rich shots be the solution for older people who are struggling to get enough of these nutrients?

It might be a good idea to include seniors when developing products adapted to suit this group, but this involves two challenges that it is important to be aware of. One, is that elderly participants tend to give overly positive feedback when interviewed. The second is that our vision and our sense of smell and taste may deteriorate with age.

The sense of taste

“Research on elderly people with impaired general health shows that they have a significantly poorer sense of taste, but not many studies have been conducted on the sensory abilities of healthy elderly people. We wanted to take a closer look at this,” says Paula Varela-Tomasco, a senior researcher at Nofima.

Nofima’s professional sensory trained panel and 38 healthy, active elderly people were served the same 8 varieties of raspberry shots. As expected, the professional judges went into far more detail in their descriptions. Nevertheless, the groups were relatively in agreement.

“This is good news, because it suggests that healthy older people have a better sense of taste than previously thought. This knowledge is also useful in the development of food and drink products intended for the elderly,” Paula points out.

Shots as energy refills and snacks

The fact that older people often respond more effusively presents challenges in respect of participating in product development testing. Nofima researchers have resolved this by using a “holistic”, undirected method, where participants group products rather than rating them, and describe the products based on their objective characteristics.

“Our findings show that older people are happy to drink shots on suitable occasions. They prefer shots with a fresh, fruity taste, and dislike shots that are bitter or give them a feeling of dryness in the mouth”, concludes Paula.

This research is being conducted under the Matlyst project. Scan the QR code below to find out more about the research results.



CONTACT:
Paula Varela-Tomasco
Senior Scientist
+47 454 26 026
paula.varela.tomasco@nofima.no

FUNDED BY:
The Research Council
of Norway and
participating companies

PARTNERS:
Tine, Fjordland,
Norgesjøllene,
Nortura, SESAM,
Nofima and NMBU

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Size matters for coastal fleet

Individual vessel quotas in the coastal fleet were originally determined by vessel length. But new vessels and quota purchases claim a new approach.

The fishing fleet is constantly evolving – old fishing vessels are scrapped, and new ones contracted. Nofima is currently investigating these developments.

A traditional dichotomy in the Norwegian fishing fleet distinguish between the ocean fishing fleet, with large offshore vessels, and the coastal fleet, with smaller vessels fishing along the coast. Norwegian catch quotas have been divided between the two groups.

New dilemmas

In the last few decades, coastal fleet development makes politicians confused. The total allowed catch for the coastal fleet has been allocated among vessel groups based on the length of the vessels: less than 11 meters, 11–15 meters, 15–21 meters, or 21–28 meters. The idea was that the longer the vessel, the greater catch potential, so the quotas were determined accordingly.

However, since then many quotas have been sold or assigned to vessels that are larger than the original provision accommodated for, and the structure of the coastal fleet has

radically changed. Many combine several quotas on a single vessel after scrapping older vessels – known as “structural quotas”.

Nofima’s review shows that not only are there fewer vessels in the coastal fleet than before, but the vessels in all categories are larger. A quarter of the coastal vessel’s quota is now caught by vessels longer than 28 metres, while the number of vessels of less than 11 meters has decreased sharply.

System update needed

In 2020, the Parliament determined how fishing quotas should be allocated in the future. However, some key issues remain unresolved. Structural quotas are valid for 20 years, and the first ones will expire in 2026. Then what? Should they then be allocated to the vessel groups currently using them, or rather be reallocated to the group which they were originally issued to?

Nofima’s review shows that we need a quota system adapted the reality in the coastal fleet.



PHOTO: TRUDE ANDERSEN

Old and new “Seingen”, both under 21 m. Increasingly large coastal fleet vessels makes it challenging to distribute quotas for the future.



CONTACTS:
John R. Isaksen
Scientist
+47 992 59 717
john.isaksen@nofima.no



Bent Dreyer
Research manager
+47 992 76 715
bent.dreyer@nofima.no

FUNDED BY:
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Storing fish under “normal” conditions is not cold enough. Lower storage temperatures could make a big improvement, says Svein Kristian Stormo.

PHOTO: LARS ÅKE ANDERSEN © NOFIMA

Colder frozen fish, please

Research on freezing and thawing shows that regular frozen storage at -18°C is inadequate. Lower storage temperatures could make a big improvement.

“The secret of a perfect fish meal lies in preserving the quality of the fish through all processing stages until it lands on your plate. One weak link is enough to impact the quality. If we can take good care of it all the way, fish can maintain its fantastic quality – even after being frozen”, says scientist Svein Kristian Stormo.

Over the past few years, he has led Nofima’s research initiative on the subjects of freezing, frozen storage and thawing, dubbed “Fresk”. He and his colleagues have studied what happens to fish when frozen and thawed at different temperatures and with different methods, in several combinations.

18 below zero is not enough

Freezing might lower the quality of fish because ice crystals that are formed can damage the fish muscle. Yet, now scientists know more about how to constrain the formation of damaging ice crystals and limit its negative effect.

It’s common to keep frozen food at -18 – -20 degrees below zero, both in the industry and at home. Judging from

experiments where storage temperature -20°C was compared to -40°C , storing fish under “normal” conditions is not cold enough.

While regular frozen fish saw a significant drop in quality after only 6 months, fish that was deep-frozen at minus 40°C maintained its high quality, even after two years.

How is that the case?

Large and small ice crystals

The answer is found by monitoring the water content of the fish after it has thawed. Scientists often use the liquid loss following thawing as a measure for quality. Fish that has released a lot of water will be dry and fibrous after cooking.

“Fish will release water as it thaws, but it’s not only freezing and thawing that determines how much water is lost. Frozen storage also has an impact since the ice crystals that are formed during the freezing process can grow in size, especially if temperature is high. Bigger ice crystals increasingly damages the cellular structure of the fish, resulting in a greater loss of water”, says Stormo.

“When a fish is kept at minus 20°C , not all the water in the fish muscle is frozen. Some of the water remains in an unfrozen state between the ice crystals, helping the ice crystals to expand. The larger the ice crystals, the more damage they do, and the more water is released during the thawing process”, he says.

Fast freezing results in smaller crystals which cause less damage. Scientists therefore recommend freezing the product as fast as possible to temperatures that freezes all the water.

The fish which was kept at minus 20°C had a liquid loss between 4–9% after only 6 months. The fish kept at minus 40°C had a liquid loss less than 4% through a 26-month period.

In the fishing industry, it is not uncommon to process thawed fish before freezing it once more – known as double freezing. After undergoing double freezing, the fish kept at minus 20°C had liquid loss exceeding 9% after 9 months, while the fish kept at minus 40°C again resulted in liquid loss less than 4%.

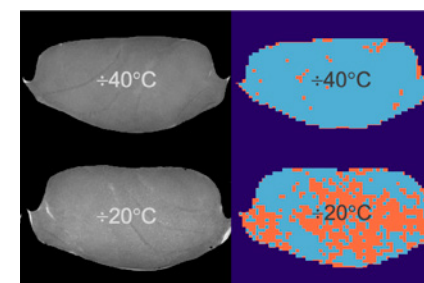
Quality in – quality out

The benefits of using lower temperatures during frozen storage is not only relevant for fish products, but for all foods. However, since fish is more fragile than meat, the impact on fish is more apparent.

“A low-quality fish cannot be salvaged no matter how perfectly you freeze and thaw it. It never gets better than it was in the first place. That’s why it’s so important to keep quality in mind during the catch situation as well – fishing quality before quantity”, says Stormo.

He now hopes to apply this research to experiments in industrial contexts. Several industry players have shown great interest as they see opportunities to create better products and achieve a more consistent production process.

“Preserving the high quality of the fish caught during fishing season will potentially improve the quality of the fish products, ensure a stable raw material supply, and ultimately secure jobs in several local communities along our coast”, says Stormo.



MRI images of fish samples frozen at minus 40°C (top) and minus 20°C (bottom). Analyzes of the images mark damaged tissue in orange.

PHOTO: KATHRYN ANDERSEN © NOFIMA



CONTACT:
Svein Kristian Stormo
Scientist
+47 971 64 669
svein.stormo@nofima.no

FUNDED BY:
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Big kelp potential in the North

The cold north Norwegian waters are ideally suited for production of a relatively new seafood product in Norway: kelp.

“The growth period in the north is 2–3 months longer than in the south, which is a major advantage”, says Xinxin Wang.

She is a postdoctoral researcher at Nofima, funded by the SUREAQUA research project, a Nordic Centre of Excellence with 40+ Nordic partners providing research and innovation insights for sustainable production and management of marine resources.

Short and intense season

One of the project topics is macroalgae; a relatively new field within the aquaculture industry where extensive development work is currently underway. Nofima’s kelp research focuses on sustainable value creation from kelp production in northern Norway.

Kelp cultivation is associated with large volumes of biomass that must be harvested and processed during a short and intense season to retain its quality and yield.

The growth season in southern Norway ends in May, and all crops must be harvested before June to prevent “biological growth” – other organisms growing on the kelp fronds, making them unsuitable for human consumption.

“It dramatically reduces the value of the crop and may even render it useless”, says Nofima senior scientist Philip James.

Big differences

In the north the biological growth sets in later, so the harvesting season can be stretched from May until August.

“It appears that the quality may also be better in the north. Photosynthesis is

key in the cultivation of kelp, and in the north kelp is exposed to sunlight around the clock. The growth rates for kelp in the north are amazing, with huge potential to develop a kelp industry”, says James.

Results from Nofima trials also reveal large variations in the kelp

growth even within the northern region.

“The variations in size and quality are enormous”, says Xinxin Wang after assessing the 2020 production of sugar kelp at Kraknes in Tromsø and in Rotsund in Lyngen.

New trials will be carried out at the same locations in 2021.



Postdoctoral researcher Xinxin Wang says the growth conditions for sugar kelp are very good in the cold northern Norwegian waters.

PHOTO: © NOFIMA



PHOTO: JON-ARE BERG-JACOBSEN © NOFIMA

Marit Kvalvåg Pettersen with a tray of the monomaterial HDPE, which in the study was compared to the composite material of APET/PE.

Sustainable food packaging

The goal for Nofima packaging scientists is to develop new environmentally-friendly and recyclable packaging solutions.

The main function of food packaging is to protect and preserve food. The challenge for researchers is to develop materials that are both recyclable and offer optimal protection.

“We have studied packaging solutions for chicken breast fillet, and the results using recyclable plastic are promising,” says senior scientist Marit Kvalvåg Pettersen.

The difference between complex and mono materials

complex materials are comprised of several types of plastic and are difficult to recycle. They are often used in food packaging as they provide a relatively

simple way of delivering a protective barrier, i.e. minimizing the amount of oxygen transmission through the packaging.

mono-materials consist of only a single type of plastic, and are far easier to recycle, but often have poorer barrier properties. This may have an adverse impact on shelf life, particularly for perishable foods such as fresh chicken fillet, which is often packaged in a modified atmosphere with a carbon dioxide/nitrogen gas mixture.

“When we choose a material with a relatively poor oxygen barrier, we also wanted to test whether further ‘assistance’ was required, such as adding

an oxygen absorber. However, the absorber turned out not to prolong the shelf life”, says Marit.

Same quality after 19 days of storage

The bacterial growth in chicken breast fillets in the various packaging solutions was measured during 24 days of storage. Both solutions were packaged in a modified atmosphere. In the first 19 days, there were no significant differences in smell, bacterial growth or fluid loss.

This research has been carried out in the FuturePack project and the strategic programme FoodMicroPack.



CONTACTS:
Philip James
Senior Scientist
+47 481 68 263
philip.james@nofima.no



Xinxin Wang
Postdoctoral researcher
+47 980 13 862
Xinxin.wang@nofima.no

FUNDED BY:
NordForsk
and Nofima

PARTNERS:
Norce, Akvaplan NIVA,
Lyngen Seaweed AS,
Ocean Forest



CONTACT:
Marit Kvalvåg Pettersen
Senior Scientist
+47 928 07 951
marit.kvalvag.pettersen@nofima.no

FUNDED BY:
The Research Council of Norway
& participating businesses and
the Foundation for Research Levy
on Agricultural Products (FFL)

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Business ideas for food safety

40 percent of all food poisonings occur at home. Nofima researchers are leading the way to find the best solutions for reducing this number.

We are aware of what leads to food poisonings at home, and we know which groups are most at risk; but it's only now that we have studied in depth how these groups shop, store and prepare food at home," says microbiologist Solveig Langsrud, leader of SafeConsume – a large interdisciplinary European research project where microbiologists, sociologists, statisticians, innovators, designers and economists work together.

Microorganisms – the microbiologist’s field of study

“When people get sick from home cooking it’s usually because they eat high-risk food types, such as oysters,

expired food, food that has been stored at too high temperatures or has been made by someone who is sick. We have also seen other risk factors such as insufficient heat treatment, inadequate hand washing, insufficient washing of fruits and vegetables and using dirty sponges, cooking utensils and chopping boards”, says Solveig.

The microbiologists’ expertise in microorganisms – their behaviour, where can be found, how long they survive and relevant risk factors – formed the basis for the sociologists’ work as they studied people’s habits.

Researchers from Norway, Portugal, France, the UK and Romania accompanied their research subjects – young

men living alone, those with small children and the elderly – on shopping trips and when they were cooking. We know from previous experience that babies/toddlers and the elderly are the least resilient, while young men take the greatest risks. The researchers collected samples from food and kitchen counters, refrigerators, taps and cutting boards both before and after the food was prepared.

Packed fridges and old food

The result is new data about how people in different countries and at different stages of life handle food, which has provided new insights. Young



Translating research into solutions requires a holistic approach, interdisciplinary insights and expertise in facilitation processes.



How about an ‘innovation picnic’ on the washing cloths and dishwashing brushes being analysed? Solveig and Antje are ready to test them.

men who live alone no longer seem to be the worst offenders when it comes to hygiene in the kitchen.

A more problematic issue is that the elderly seem to be exposed to the greatest risk, as they are the ones who most often eat foods that are past their expiry date and have the warmest and most packed refrigerators.

“In all the surveyed countries it seems like the older you are, the more refrigerators you have and the more food you keep in them”, says Solveig.

Insights create business opportunities

The researchers have now moved on to study what needs to be true to make people change their habits. The various insights are plotted in an ‘opportunity map’ to visualise which parts of the user

journey offer good business opportunities.

“Insights such as the observation that the temperature of many refrigerators is too high, so the food spoils faster, or that many don’t really know what’s in their fridge, opens the door to new and important innovations”, says innovation scientist Antje Gonera.

She is responsible for mapping and further developing opportunities for innovation, and explains that their main task in the project is to translate research findings into innovation and facilitate a process that takes into account both consumer needs, technological opportunities and business potential.

“By systematically combining scientific results with a specialised design and innovation process and

close interdisciplinary cooperation with stakeholders and industry partners, we have come up with over 300 ideas, 23 specific concepts and 5 patent applications,” says Antje, adding that this way of working is quite new in research projects.

The researchers have worked closely with the design agency Designit, which is also gaining new insights from the project.

“Working closely on the same issue with researchers and multiple industry partners in parallel has been very informative, different and fun. In this innovation process we have been able to take a broad approach to find opportunities and consider problems from different angles,” says Siri Yran, Lead Product Designer at Designit.



CONTACTS:
Solveig Langsrud
Senior Scientist
solveig.langsrud@nofima.no
+47 905 67 218



Antje Gonera
Senior Scientist
antje.gonera@nofima.no
+47 400 75 077

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of large and smaller
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Breeding cod for faster growth

Patience and maintenance of genetic diversity are two key reasons why farmed cod grow significantly faster than wild cod in net-pens.

Ever since the start of the national breeding programme in 2002, rapid growth and maintenance of genetic diversity has been prioritized. Several generations later, the result is a farmed cod that grows significantly faster than wild cod in net-pens.

Good news for the industry

“This is good news for the industry. We are now working with the fifth generation of farmed cod, and can show that selective breeding has produced additional growth of up to one kilogram”, says Nofima scientist Anne Helena Kettunen.

2.5 years after hatching, farmed cod will achieve a slaughter weight of 4 kilograms, while under the same conditions wild cod will only weigh 3 kilograms.

Maintenance of genetic diversity

Farmed cod is selected for body weight, but maintenance of the genetic diversity in the breeding population is even more important. High-quality genetic material with adequate genetic



Anne Kettunen is one of the researchers behind the cod breeding programme, and is very pleased with the results.

variation ensures that we can select for more robust and disease-resistant cod than what we currently have.

“We have selected carefully not only based on body size but also aiming at low relationships between selected individuals in order to conserve the genetic variation and avoid inbreeding. We have not been looking for quick solutions, but rather worked systematically, with great precision and with a long-term perspective. That makes it extra satisfying when we succeed with our efforts”, says Kettunen.

Cod from all along the coastline

To ensure the broadest possible genetic base, genetic material for farmed cod is gathered from northern and southern coastal cod as well as migrating Northeast Arctic cod, “skrei”.

The success is a result of collaboration across departments in Nofima. The departments for breeding and genetics, production biology, fish health and the breeding station for cod have made a collective effort to find solutions that now result in fast-growing cod well suited for aquaculture.

PHOTO: JON-ARE BERG-JAKOBSEN © NOFIMA

Snow crab: a seafood adventure?

The “SnowMap” research project investigates how to achieve optimum resource utilization of the snow crab through the entire value chain.

Snow crab is a cold-loving species that has started to appear in the Barents Sea in recent years. Norway started fishing for the crab in 2013. In 2019, we caught 4037 tonnes and exported 1109 tonnes of frozen snow crab. In 2020, 8 Norwegian vessels are actively fishing for the crab.

“Our research focus is the value chain and how to optimise catch, processing, residual biomass and bioeconomy until the crab reaches the market. The goal is a sustainable industry that ensures the highest possible value with the lowest possible environmental footprint,” says Head of Research Ragnhild Dragøy in Nofima.

Live storage

In order to optimize catching processes, several crab trap designs and methods for attracting crabs have been tried out.



PHOTO: JON-ARE BERG-JAKOBSEN © NOFIMA

Nofima scientists believe the snow crab will become a profitable Norwegian industry in the future.



Gøril Voldnes and fellow Nofima scientists believe the snow crab can become a profitable Norwegian industry in the future.

PHOTO: JON-ARE BERG-JAKOBSEN © NOFIMA

Live storage and crab welfare have also been key topics for research. The snow crab is very sturdy and can be kept in live storage without feeding for at least two months at temperatures of 1–5°C.

The scientists have also tested boiling, freezing, freezing times, thawing and storage impacts the quality. A method for objectively assessing discolouration, or «bluing», have been developed.

Residual biomass and the market

To ensure a sustainable production of snow crab, achieving a value increase of the residual biomass is key.

“We have worked to optimize

a process to completely exploit commercially interesting components in the residual biomass”, says Dragøy.

Snow crab is a new product for Norwegian stakeholders, so SnowMap also focused on marketing research in USA and China, among others.

The project further examined how the authorities, in cooperation with research, industry and those countries affected, have worked to ensure the sustainable management of snow crab fishing.

“Still, much exciting research remains. “Nofima has several projects on the go and we strongly believe that this crab could be a profitable industry in the future”, says Dragøy.



CONTACT:
Anne Kettunen
Scientist
+47 977 80 903
anne.kettunen@nofima.no

FUNDED BY:
The Ministry of Trade,
Industry and Fisheries

READ MORE:



CONTACTS:
Ragnhild Dragøy
Research director
+47 977 49 562
ragnhild.dragoy@nofima.no



Gøril Voldnes
Scientist
+47 926 40 722
goril.voldnes@nofima.no

FUNDED BY:
The Research
Council of Norway

PARTNERS:
Industry stakeholders,
organisations and academia
in Norway, Scotland, USA

New ingredients fit for feed?

In the search for new, sustainable fish feed ingredients, researchers are working to see if the ingredients can be used in feed technically.

Tor Andreas Samuelsen and colleagues at Nofima in Bergen have a number of advanced techniques in store. Samuelsen says it is underestimated how important it is that new ingredients being introduced to fish feed actually have the correct technical quality. Some ingredients require too much water, others require too high a temperature, while others disrupt the structural properties of the pellet – a bit like when you end up with a failed dough in your kitchen at home.

“If you cannot produce feed with high physical quality, it will crush into pieces before it reaches the fish, and the fish will not be able to eat it”, says Samuelsen.

He has a bag of tunicate meal in front of him on the table. Tunicate meal consists of dried and ground tunicates; a kind of sea squirt which feeds on microalgae in the sea. As part of the EU projects AQUABIOPRO-FIT and FutureEUAqua as well as the Swedish VINNOVA-funded project Marine Feed, the researchers have found that tunicate meal meets the nutritional requirements for ingredients that can

replace some of the fish and soybean meal commonly used in feed. Tunicate meal is rich in the essential amino acids that fish need to build protein, but there’s still a work to be done to reduce its salt content. Samuelsen has tested the technical quality of tunicate meal and how much can be used in the feed.

Feed analysis with a CT scanner

Trial feeds were produced at the feed technology centre in Bergen. First, feed mixtures with different levels of tunicate meal were fed into an extruder, where the mixtures were cooked, kneaded, expanded and dried into pellets with a porous structure. The pores were then filled with rapeseed oil and then subjected to an oil leakage test.

Samuelsen used a CT scanner to examine the microstructure inside the pellet. A CT scanner is an advanced X-ray device which makes it possible to see the 3D structure without slicing the pellet.

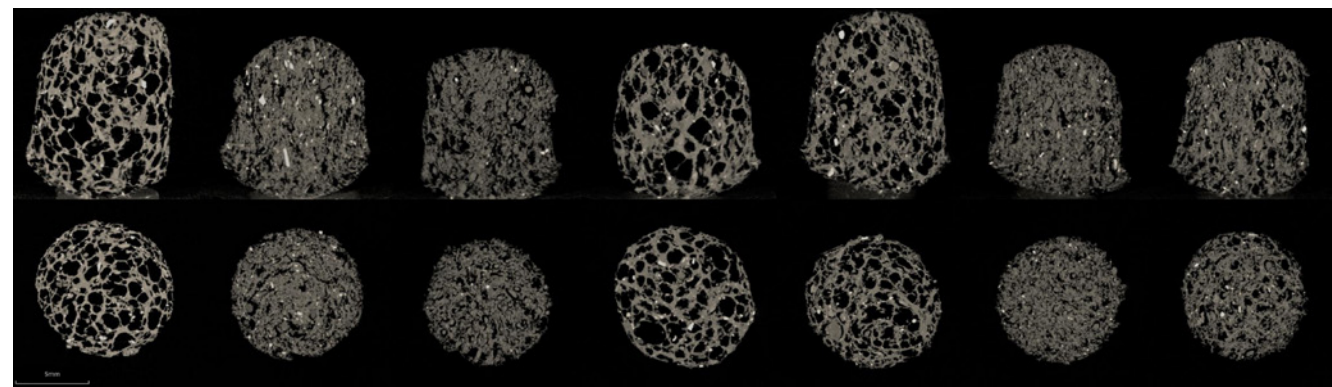
“By studying the pellet’s inner structure, we gain a detailed understanding for example on how various

ingredients affect the pore structure”, says Samuelsen.

The scan showed that feed pellets with a large percentage of tunicate meal had large pores. The pellet with the largest pores adsorbed the highest amount of oil, but also resulted in highest oil leakage.



Tor Andreas Samuelsen measure the feed pellets’ fracture strength (hardness).



The CT scan showed a large range in pore structure for pellets containing different amounts of tunicate meal.

Determining the maximum amount of tunicate meal

By running a mixture design experiment in the statistics program, he has set some quality requirements for the pellet when he adds tunicate meal to the feed:

“I want as much tunicate meal as possible in the feed mixture, but the pellet still needs to be of high physical quality and as porous as possible to make it adsorb the necessary quantities of oil. It also needs to have a high water stability.”

He found that 50% of the fish meal could be replaced by tunicate meal

without compromising the physical quality of the feed.

Advanced tools

New ingredients that may be interesting to use in fish feed are constantly emerging. The work on tunicate meal is a nice example of how important it is to have advanced tools for studying ingredients and feed, says Samuelsen.

“We need to understand why ingredients differ from each other to be able to model the production process and physical properties of the feed before we start.”

Such new tools are now available

through the Aquafeed Technology Centre (ATC) which is hosted by Nofima. This is part of the Norwegian roadmap for research infrastructure which is carried out in cooperation with Norce and the University of Bergen. ATC provides the industry with access to state-of-the-art laboratories and pilot-scale facilities to be able to meet the future needs of research, process and product development.

“ATC gives Nofima a unique opportunity to help the industry develop and characterize new, sustainable ingredients”, says Samuelsen.



CONTACT:
Tor Andreas Samuelsen
Senior Scientist
+47 950 35 304
tor.a.samuelsen@nofima.no

FUNDED BY:
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PARTNERS:
Partners in AQUABIOPRO-FIT

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PHOTO: JON-ARE BERG-JACOBSEN

Øydis Ueland with the persona "Manfred". He has a lot in common with the consumer segment the Carnivores.

Plant-based food for everyone?

Although many people want to eat more plant-based food, some consumer segments are less keen. How can we convince them as well?

"We have gained more insight into which consumer groups seem the most receptive to increasing their intake of legumes and other plant-based foods, which is useful knowledge for the development of new products in this category," says Øydis Ueland.

Consumers grouped by attitudes

Øydis and her colleague Antje Gønera have supervised Malin Hatlebakk for her master's thesis work on consumer attitudes to plant-based food, meat consumption, animal welfare and sustainability. The data has been sourced from a quantitative consumer survey which forms the basis of the SIFO report *Meat free eating habits – what do consumers think?*

Malin identified seven distinct consumer segments based on how

consumers eat, shop and think about food. There were clear correlations between these segments and demographic variables such as gender, age and place of residence. The segments are also compared to Norwegian consumer types, or personas, which present values and attitudes in future consumer groups.

"There are clear similarities between some of our personas and the consumer segments. The fact that they complement each other can be used to gain a better understanding of customer groups and introduce targeted and more accurate approaches for each segment", says Antje. She leads the consumer and innovation research in the FoodProFuture project, where the personas and the SIFO report have been developed.

Do people put their money where their mouth is?

The participants' diets were analysed, and the data was used to calculate the carbon footprint of the various consumer groups in collaboration with NORSUS. The results show that there is not always a correlation between a person's environmental awareness and the level of the greenhouse gas emissions from their diet.

For example, the group named *The Conservatives* are not particularly concerned about the climate. Nevertheless, their meals are associated with lower than average greenhouse gas emissions. The opposite is the case for the so-called *Open-Minded*, who show significant environmental awareness, yet also have average greenhouse gas emissions from their diets.

Who wants to eat a more plant-based diet?

One barrier to adopting a more plant-based diet is scepticism about whether one is getting enough protein. Although legumes can solve this problem, it is only among the *Flexitarians* and the *Open-Minded* that peas, beans, and lentils are a natural part of the diet.

The Flexitarians are the only ones who have a positive attitude towards plant-based ready-to-eat meals. Having this group further increase their consumption of plant-based food will not have much impact – they mainly eat this way already.

The Carnivores segment would have the greatest health benefits if they turned to a more plant-based diet, but they are also the most difficult to convince. They are not interested in reducing their meat intake, eating legumes, or trying new dishes; they prefer a traditional diet.

"*The Processed food eaters* are more likely to change. They don't currently eat much plant-based food but are interested in increasing their intake. They already eat a lot of processed food and are used to these types of meals. The main hurdle for bringing this group on board is probably price. Their income is lower than average, and ready-to-eat vegetarian dishes are often more expensive than other options", says Øydis.

Antje says they are also optimistic about the *Open-Minded*.

"This group is motivated to have a more plant-based diet. Their attitudes are similar to that of the *Flexitarians*, but their actual diet is completely different. They prefer to cook from scratch and are sceptical towards processed food, which is a barrier for choosing plant-based ready-to-eat dishes. At the same time, they find it difficult to prepare healthy, protein-rich and tasty dinners only from plant-based raw materials."

Hatlebakk's master thesis is linked to FoodProFuture and the strategic programmes InnoFood and FoodSMaCK.

Facts about the consumer segments:

Meat is traditionally associated with masculinity, while vegetarian diet is more associated with feminine values. This is reflected in consumers' preferences – far more women than men are positive towards a primarily plant-based diet.

The seven identified consumer segments:

Group #1 – constitutes 5 percent: The Flexitarians

Rarely eat meat or fish, and often eat plant-based foods. They are very interested in plant-based foods, and find such food to be healthy, tasty, and satisfying. They are concerned with the relationship between food, the environment and animal welfare.

Group #2 – constitutes 15 percent The Open-Minded (with regards to plant-based food)

The group that is the second-most interested in plant-based food; concerned with the relationship between food, the environment and animal welfare. They believe plant-based food is healthy, tastes good and is satisfying, but has relatively high meat consumption. They dislike processed food.

Group #3 – constitutes 12 percent: The Pescatarians

They eat fish and seafood often, dislike and rarely eat processed food and are concerned with nutritional content. After *Flexitarians* they eat least meat. They are concerned with the relationship between food, the environment and animal welfare.

Group #4 – constitutes 18 percent: The Processed Food Eaters

This group eats few vegetables and a lot of processed food but are relatively interested in plant-based foods. They are somewhat concerned with the relationship between food, the environment and animal welfare.

Group #5 – constitutes 18 percent: The Omnivores

This group has the greatest meat consumption, but also eat vegetables and fish more often than average. They are of the opinion that a meal for dinner should contain fish or meat.

Group #6 – constitutes 19 percent: The Conservatives

This group prefers traditional food and want fish- or meat-based meals. They are not interested in plant-based food or with the relationship between food, the environment and animal welfare. They eat fish relatively often. The greenhouse gas emissions from their diet are lower than average.

Group #7 – constitutes 14 per cent: The Carnivores

This group rarely eats plant-based food, fish, or seafood. They are the least concerned about the nutrient content, and often eat processed food. They often eat beef and pork. They are not interested in plant-based food or with the relationship between food, the environment and animal welfare.



CONTACTS:
Øydis Ueland
Senior Scientist
+47 996 07 621
oydis.ueland@nofima.no



Antje Gønera
Senior Scientist
+47 400 75 077
antje.gonera@nofima.no

FUNDED BY:
The Research Council of Norway and the Foundation for Research Levy on Agricultural Products

PARTNERS:
NMBU, OsloMet, NORSUS, NIBIO and industry partners

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Top tech is key

Nofima scientists need first-class research- and industry-standard equipment to drive development and innovation for the food industries.



Torstein Skåra and his colleagues at Nofima are looking into how benefits from heating food with radio waves can improve quality.

We call this research infrastructure, and we invest 25 million NOK annually to stay up to date with equipment and technical innovations.

“Our research should and must be at the forefront to be able to create new knowledge. In order to do so and continue to be a respected and leading research institute, we must be able to utilise new technology and the latest equipment at all times. And that costs money”, states Nofima’s Head of Business Development, Arne Mikal Arnesen.

Nofima’s social mission as an applied research institute is to ensure relevant and industry-oriented research-based

results which can be applied by our clients in the food industry.

“If we fail to stay at the forefront, we are not fulfilling our social mission”, says Arnesen.

There are plenty of examples of new research infrastructure which helps drive the research at Nofima forward.

Radio wave technology

Nofima has worked for several years on applying radio wave technology to thaw and heat frozen products and has equipment to run experiments on a pilot scale.

Now scientists will examine what quality advantages can be achieved

with rapid heating using radio wave technology.

A new radio wave heater with built-in temperature measuring functionality plays a key part in ongoing EU projects and nationally funded projects.

As products are heated from within with radio waves, the heating becomes much more energy efficient – and, in most cases, much faster than with traditional heating methods.

RAS – Recirculating Aquaculture Systems

Norwegian smolt production has undergone a paradigm shift where

recirculation facilities (RAS) have replaced traditional flow-through hatcheries. This has raised new questions about the management of disease in such facilities.

In order to generate new knowledge about how disease-causing organisms such as viruses and bacteria should be dealt with in RAS facilities, Nofima has established 9 mini-RAS at the fish health laboratory at the Tromsø Aquaculture Research Station. Although small, the plant is state-of-the-art in terms of quality and technology.

In addition to the mini-RAS facility, Nofima has a fullscale RAS station at Sunndalsøra, and a new RAS facility at the Tromsø Aquaculture Research Station under planning.

Food Pilot Plant Norway (Matpiloten)

Nofima (in cooperation with NMBU) is home to Norway’s largest food research facility.

It contains facilities for research, education and product development of food and residual biomass.

The Food Pilot Plant has a number of pilot facilities where students,



Upgraded equipment such as sensors for measuring food quality offers new possibilities with Senior Scientist Jens Petter Wold in the Meat Hall at the Food Pilot Plant.

scientists and businesses can test new technologies, packaging solutions and combinations of raw materials.

Funding from the Research Council of Norway (RCN) has enabled new investments in the latest and best technology in several areas, such as supercritical CO2 extraction, instruments

for using light in quality measurements, a FlowPack packaging machine and PEF (pulsed electric fields).

Feed technology

The Aquafeed Technology Centre (ATC) is part of the Norwegian Roadmap for Research Infrastructure financed by RCN. ATC’s new equipment allows us to study how process conditions affect properties of novel ingredients and application of these in formulated products.

Eye-tracking

Eye-tracking will be used in conjunction with finger sensors in consumer surveys where people are shown pictures, websites and more, allowing researchers to measure test participants’ reactions and which items catch their attention. Such observations are useful in cases such as supplementary information for consumer surveys.

“These are just a few examples illustrating why we as an institute for applied research are committed to investing in the continued training of our researchers and the development of the Norwegian food production industry,” says Arne Mikal Arnesen.



New knowledge is needed to manage disease-causing organisms in RAS facilities. Vasco Mota & his colleagues are prepared with new equipment.



CONTACT:
Arne Mikal Arnesen
Special adviser/Leader of Business Development
+47 995 30 304
arne-mikal.arnesen@nofima.no

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Behind the results

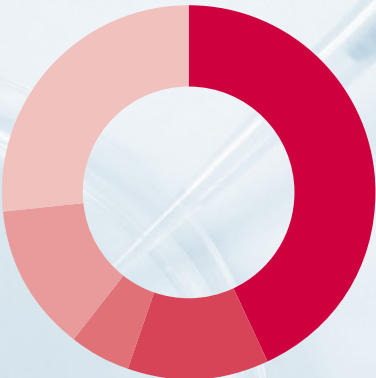
Who owns us

The Ministry of Trade, Industry and Fisheries (NFD)	56,8 %
Agriculture Nutrient Research Foundation	33,2 %
Akvainvest Møre og Romsdal	10,0 %



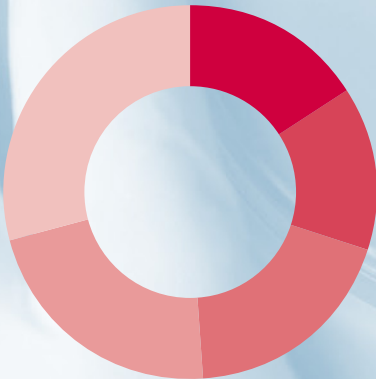
Where are we

Ås	168
Bergen	48
Stavanger	21
Sunndalsøra	50
Tromsø	103



Who funds the research

NFD	16 %
Basic grant from NFR	14 %
NFR/EU	19 %
FJM/FFL/FHF	22 %
Companies	29 %



What are we doing

Scientists and advisers	191
Laboratory engineers/research technicians	76
Technical and administrative staff	99
Managers	24



Nofima conducts research projects in close cooperation with clients from aquaculture, fisheries, land and ocean-based food industries.

The projects are directly funded by the industries, but are also largely dependent on input from the public funding system. About 70 per cent of Nofima's revenues are exposed to competition.

2020 has progressed somewhat differently from our budgeted revenues and costs, and we expect that Covid-19 will continue to make its mark on 2021. There is particular uncertainty as to how customers, clients and partners will be affected by the extensive measures for keeping the pandemic in check.

It is unclear how this will impact our access to research commissions and industry participation, as well as increased competition. Nofima must stay relevant and deliver high-quality research, and we expect that we will need to work even harder to stay ahead in order to achieve this.

Nofima has over time established a strong financially solvent position, which has allowed us to strengthen our relevance and utility to the various industries by focusing on several key research initiatives. This gives us a solid foundation for meeting future research needs and society's need for adapting to the new normal.

Grete Sollesnes Winther
CFO



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 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 390 employees, and a turnover of NOK 676 million in 2019. The research in Nofima is organized into three divisions, each organized in research departments:

Division Aquaculture	Division Seafood	Division Food Science
- Breeding and genetics - Nutrition and feed technology - Fish health - Production biology	- Marine biotechnology - Marketing research - Industrial economics - Processing technology - Seafood industry	- Food and health - Raw materials and process optimization - Consumer and sensory sciences - Food safety and quality
Director Bente E. Torstensen	Director Magnar Pedersen	Director Camilla Røsjø

Nofima – researching what matters most



PHOTO: JON-ARE BERG-JACOBSEN

Food is important in so many ways. It is of course, fundamental to life. But food is also business. Food is about jobs and where people live. Food is culture.

Nofima has close ties to Norwegian food production. We are Norway's leading food research institute and engage in applied research and development within the fields of aquaculture, fisheries and the food industry.

Our research is industry-oriented and relevant, and the knowledge we generate is actively applied by our clients. That's why you often find our scientists onsite in various businesses working closely with the 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 businesses, we often play the role of their research and development department. Research is at the core of knowledge-based innovation.

We at Nofima are proud of our contributions to creating a future-oriented and sustainable food industry in Norway.



Sustainable food for everyone



PHOTO: MARTINA GALLER

A healthier diet for the youth

Digital measurements such as eye tracking and facial decoding have been tested on children aged 9-10.

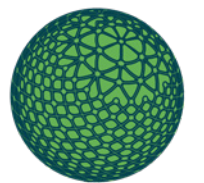
The aim of the European education and research network Edulia is to promote a healthier diet among children and adolescents.

Edulia is led by Nofima researcher Paula Varela-Tomasco and educates young scientists across borders and fields of research. Just over two years of research has yielded many promising results,

such as:

- newly developed methods that can give us insights about real consumer perceptions in children aged 9 to 10
- data on the development of taste, smell and sensitivities among children and adolescents in their choice of food
- how children aged 9-13 years perceive different emojis

These results can help food producers develop healthy products for young people with a greater impact among the target group.



EDULIA

Contact: :
Paula Varela-Tomasco
Senior Scientist
+47 454 26 026
paula.varela.tomasco@nofima.no





Øyvind Fylling-Jensen
Managing Director
oyvind.fylling-jensen@nofima.no
+47 917 48 211



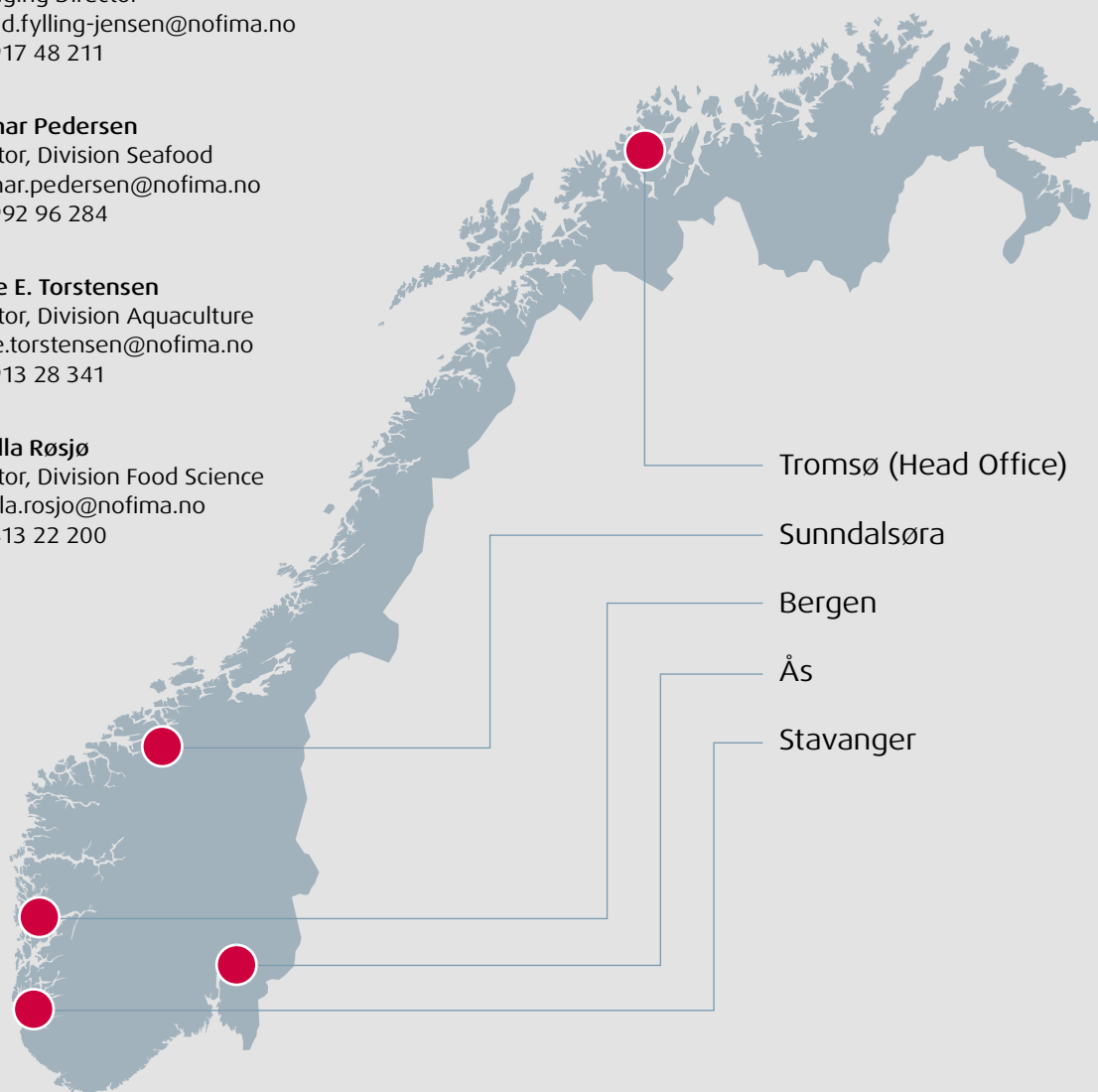
Magnar Pedersen
Director, Division Seafood
magnar.pedersen@nofima.no
+47 992 96 284



Bente E. Torstensen
Director, Division Aquaculture
bente.torstensen@nofima.no
+47 913 28 341



Camilla Røsjø
Director, Division Food Science
camilla.rosjo@nofima.no
+47 413 22 200



Tromsø (Head Office)

Sunndalsøra

Bergen

Ås

Stavanger

Follow us on:



Muninbakken 9–13 Breivika, P.O.Box 6122 Langnes, NO-9291 Tromsø, Norway
Telephone +47 77 62 90 00 | E-mail: post@nofima.no | nofima.no