creatingvalue Project year 2021







Smart sensors - sustainable food

Sensor technology is a key area of research at Nofima that involves leading international scientists. In 2020, the Centre for Research-based Innovation, SFI Digital Food Quality (DigiFoods) was established. DigiFoods will develop smart sensor solutions to ensure the best possible use of raw materials of varying quality throughout the entire value chain. You can read more about the centre at digifoods.no



More info: DigiFoods annual report



25 examples of useful research

From value chain to food systems	2
Norwegian beans and cereals in burgers	4
Talk about benefits of the product	6
Tough for women in the fisheries	7
New side effect of PD vaccines	8
Optimisme for marine arter	9
Lots of opportunities with PEF	10
Temptation catches your eye	12
In the forefront of cultivating meat	13
This fatty acid promotes fillet quality	14
Pink salmon: A tasty fish	16
Automatic measurements	17
Green food from blue fields	18
Attractive residual raw material	20
A lot to save from targeted UV-light	22
Preparing for more species in aquaculture	23
New knowledge about ballan wrasse feed	24
Are cleaner fish edible?	26
Gave salmon feed to wild cod	27
Tailored food packaging	28
Creating value is challenging	30
Tools for increased bacterial control	32
Removing flavour from fish offcuts	33
Good data can help reveal risks	34
Challenging goal conflicts	35
Freeze vegetables quickly	
Unlocks genetic value of feed intake	
Behind the results	
Sustainable food for everyone	40



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From value chain to food systems

At Nofima, we talk less and less about value chains. Instead, we talk about the food systems, because simply viewing food production from a fragmented perspective is no longer enough. This is because everything related to production, distribution, consumption, and food waste is connected in an interdependent system. If we are to succeed in solving some of the major challenges associated with sustainable production and processing of food, we must think differently than we did before.

As CEO of Nofima, I know how important it is to keep an eye on what is happening. To follow the narrative of the UN, FAO and other international organisations present to the world is a prerequisite for Nofima as an applied research institute. For example, the UN has recently concluded its global Food Systems Summit, and we at Nofima have been following closely. The Food and Agriculture Organization (FAO) has defined the food systems that include all parts of food production. They draw the circle from primary production via cultivation, harvesting/slaughter, transport, processing, marketing, consumption and handling of residual materials.

There are several challenges that will affect food production in the future. Production must take place in a way that takes into account climate change and environmental challenges, without adversely affecting biodiversity. It is a fact that food production must take place within the limits of what nature can tolerate.

Two other major challenges are food security and food safety. We must ensure that enough healthy and safe food is produced for a growing population. Access to food with the right nutritional content is important in a society where food habits and demographics change. The pandemic has shown us that we are vulnerable, and more people than ever are unsure whether they have access to enough, nutritious food. All in all, we face major challenges that can only be solved through research, development and innovation.

Fortunately, Norway has a robust food industry that, despite the current challenges, has succeeded in maintaining production and security of supply. Investigations conducted by our scientists show that consumers have great confidence in the Norwegian food industry and want foods that are produced in Norway. We also see that less food is being thrown away and that consumers want a greater degree of food produced locally. This gives me great faith in the Norwegian food systems.

Challenges related to climate change, the environment, food and nutrition security will place new and more demands on companies. Through the EU's Green Deal and the authorities' expectations regarding a society with lower emissions and a production that requires less energy, all aspects of sustainability have been put on the map. In addition to environmental sustainability, we must also safeguard social and economic sustainability.

Nofima's vision is "Sustainable food for all". This vision is a guiding principle in all the research and innovation work we do. The vision places demands on our entire organisation in a new way, not least in terms of how we will contribute to a better and more sustainable food system.

As trade and industry's research partner, we must acquire new expertise and methods ranging from aquaculture and fisheries to agriculture and the food processing industry. We need to understand the major trends leading up to changes in dietary advice and increased consumption of plant-based foods. We need to understand technological changes such as the cultivation of meat and precision fermentation, but also how biology meets new technology. This is demanding, but it keeps us on our toes. As a supplier of research-based knowledge, we must ensure that the results we produce through our research benefit the food industry, the society, and are put into use and contribute to safe and secure workplaces.

In this year's edition of Creating Value, we showcase a small number of our research projects. They show both the breadth and depth in the activities of delivering relevant and applied research to the Norwegian and international food industry. There are examples taken from the diverse organisation that is Nofima, and they show how interdisciplinary research and innovation contribute to a more sustainable food system.

Enjoy the read!

Øyvind Fylling-Jensen Managing Director

mainim



Norwegian beans and cereals in burgers

Sales of vegetarian products are increasing, but few are based on Norwegian cereals and pulses. Nofima scientists are working to increase the use of Norwegian protein-rich raw materials.

"Broad beans or faba beans are a promising foodstuff. We have developed a step-by-step process model for production of protein-rich ingredients from broad beans. This is a technology that the industry can benefit from", says Senior Scientist Svein Halvor Knutsen.

Why broad beans?

Many of today's plant-based meat substitutes are produced from soybeans. Broad beans can be a good soybean substitute:

- Broad beans can be cultivated in Norway
- Broad beans are rich in protein
- Once the hull is removed, the kernel has a relatively neutral taste. Therefore, it is easier to add other flavours without the taste being negatively affected.

Good sources of protein are required

Plant-based meat substitutes used in meals should have a protein content of approximately 20 percent. Most of today's vegetarian products have a much lower protein content. It is important to emphasise protein content when assessing different processing stages and technologies.

"Broad beans have a protein content of ca 30 percent. We have developed a fractionation technique that doubles the protein content of the protein fraction. The protein fraction is only one of the ingredients in the finished meat substitutes, so the protein content should be as high as possible", says Senior Scientist Stefan Sahlström.

Optimal processing models

An important part of the scientists' work is to develop optimal step-by-step process models to produce ingredients. The following process steps are beneficial when processing broad beans:

- Stone milling technology is best suited for separating the hulls from the kernels. The hulls are removed because they contain a lot of tannins that produce a bitter taste
- 2. A so-called zig-zag air classifier is used to separate the hulls from the kernels
- 3. Hammer milling technology mill the kernels into smaller particles, then a pin mill is used to produce a fine powder made up of protein and starch particles
- 4. A final process involving an air classifier produces a protein fraction and a starch fraction
- Extrusion technology enables one to produce healthy snacks or ingredients that can be used as meat substitutes. The ingredients provide structure to the meat substitutes. There are many possibilities, and the recipes are adapted to the products one wants to develop

Different process steps for different raw materials

Nofima scientists have worked hard to find out which technologies are best suited for the various process steps. The relevant steps depend on the type of raw materials that are included in the products. Unlike legumes, oats contain quite a lot of fat. It is beneficial that this fat is separated out early in the process. This means that there is an additional process step; separating the fat. The scientists have found that this is best done using supercritical CO2 extraction technology – a sustainable technology that replaces the use of organic solvents such as hexane.

Supplying input to the industry

Several experiments have been carried out, including a good deal of trial and error. The technical processing equipment needed in the various process steps is available in Nofima's pilot plants and is part of the infrastructure project called Food Pilot Plant.

"We want to work in projects together with the industry where the process models we have developed and the equipment we have installed are used", Knutsen points out.

Nothing left to waste

Developing sustainable food involves utilising all the raw materials in the best possible way. To date, the scientists have developed ingredients from protein fractions. They are now trying to find suitable applications for starch.

"We envisage that side streams such as starch can be used as binding agents in meat substitutes and replace the use of imported tapioca- and corn starch", Sahlström concludes.



Senior Scientist Stefan Sahlström preparing beans and corn for further processing. He is about to test varieties both with and without their hulls.



Senior Scientist Svein Halvor Knutsen assessing dehulled broad beans, after they have been ground in a hammer mill.



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Partners: NMBU and Nibio

Talk about benefits of the product

Extensive consumer surveys provided insight into how people perceive food products made using new processing technologies.

When food is produced in new ways, it is normal for the consumer to be a little sceptical. Is the food safe, or am I taking a risk by eating it? Does it taste good, and is it healthy?

It is important for those selling the product to know what type of information the customer needs in order for them to buy it. Transparency creates confidence in the product, but what should one say?

Innovative technologies

The topic has been closely investigated as part of the iNOBox project, in which innovative food processing technologies are tested to see how they can improve both production and product.

Some of the technologies are partly in use in food production already, such as high pressure processing, pulsed electric fields, UV light and microwave processing. However, more experimental technologies are also being investigated, such as ultrasound and plasma-activated water.

Nofima's marketing researchers have created a decision support tool that can help manufacturers communicate with customers about food that has been processed in new ways.

Emphasise the benefits

More than 1800 Norwegians participated in consumer studies. They answered open-ended questions, regular questionnaires, and participated in experiments. Thoughts and feelings about different topics were assessed using different research methods. The work resulted in a tool that companies could use to create different product concepts. The process provided insights that are now ready to be used by companies in the real market to create successful products.

"Norwegian consumers are not particularly interested in food processing technologies. Therefore, one does not have to focus much on technology in marketing communication", says senior scientist Themis Altintzoglou, who is behind the new tool.

"Instead, talk about the benefits of the product. Information that the product makes cooking easier, for example, can be used to increase both willingness to pay and acceptance of the new technologies", he says.



Norwegian consumers, for example, want to know how products make cooking easier, says market researcher Themis Altintzoglou.



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Oda Solhaug Humstad is one of the few women who have chosen to work in the fishery industry. A Nofima report states that measures are needed to make the profession attractive to more women.

Tough for women in the fisheries

What does it take to make the fishing industry attractive to women? There has been a lot of debate in the industry since Nofima presented a report on the issue last summer.

The Norwegian parliament Stortinget asked the Government to develop a strategy for better gender equality in fisheries. Commissioned by the Ministry of Trade, Industry and Fisheries, Nofima has prepared the 'Better gender equality in fisheries' report.

Bullying and harassment

The report states that there are three clear reasons that result in low participation of female fishermen:

- A male-dominated and at times rough culture
- Greater challenges for women than men in combining the profession with responsibility for children
- Women's own career choices

"Parts of the fisheries are characterised by too much of a tough male culture, and this is something that makes retaining women difficult", says now retired scientist Edgar Henriksen, who together with colleague Thomas Nyrud prepared the report.

This is confirmed by the debate in both the media and fishery organisations after the report was presented. Female fishermen have reported bullying and harassment from male colleagues.

The researchers have not found formal barriers that prevent women from becoming fishermen or fishing boat

owners in the same way as men. This suggests that stereotypical attitudes and a 'macho culture' are keeping women away from the profession.

Several proposals for measures

Despite the fact that far more females currently choose Fishing and General Seamanship at upper secondary school compared to ten years ago, the proportion of girls in the fisheries is only 11.3 %. The proportion of female fishermen is 4.3 % in the open fisheries, while it is below 2.5 % in the closed fisheries.

The report provides several suggestions regarding specific improvements: The profession can be highlighted as an alternative for girls in upper secondary education, positive special treatment should be considered when allocating apprenticeship quotas, and more women should be encouraged and educated to take over the family fishing business. Financial support for running women's networks and promoting good role models should also be considered, both in terms of fishing companies with female fishermen and women in the fishing industry.

The report also points to the absence of female perspectives in relevant public documents.



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New side effect of PD vaccines

Cross-stitch vertebrae are a type of deformity in farmed salmon that is initiated by oil-based vaccines used to prevent pancreas disease (PD) in salmon. The vaccines cause a transient defect in the vertebral growth zone.



The X-ray at the top shows a normal salmon spine, while the picture below shows a salmon with cross-stitch deformities.

The COVID epidemic has been a reminder that vaccines have side effects, and that we must weigh the side effects against the protection they provide. Good vaccines have had a major impact on the salmon industry, and have helped control serious diseases and kept the use of antibiotics out of salmon production.

In the autumn and winter of 2016-17, there were reports of a new type of spinal deformity in slaughtered fish, and fish farmers suspected a relation to the use of a new vaccine against PD. The deformities were particularly severe, with a high number of abnormal vertebrae, reduced weight gain and reduced fillet quality. X-rays clearly showed that these deformities differed from other types of spinal defects, and they were called ' cross-stitch vertebrae'.

Analysis of production data from producers who were affected by the problem clearly showed that the vaccine was a risk factor. Scientists at Nofima also confirmed what the fish farmers already observed; that autumn smolts were much more susceptible than spring smolts. However, there was considerable variation between otherwise comparable groups, so it was obvious that something more than just the vaccine had influenced the reaction in the vertebrae.

We don't have any answers as to what it is about these vaccines that trigger the cross-stitch reaction

Ring-shaped vertebral weakness

The scientists gained access to sample material from slaughterhouses. It clearly showed that this was a specific problem that was similar from fish to fish and between different fish groups and fish farms.

"In vertebrae that had the typical appearance on X-rays, we found a ring-shaped weakness running symmetrically around the centre of the vertebrae, sometimes also with a fracture of the vertebral endplate", says senior scientist Grete Bæverfjord, who has led this research.

At Nofima's research station at Sunndalsøra, Bæverfjord and her colleagues set up a long-term trial in order to follow the development of this pathology, from vaccination and through to slaughter. They had four different vaccine groups: Unvaccinated fish, fish vaccinated with a standard vaccine without a PD component, and two groups that were vaccinated with the two oil-based PD vaccines that were on the market at the start of the trial.

The trial fish developed normally, showing good growth and low mortality rates. They were then slaughtered at an

average weight of 3.8 kilograms. No X-ray pathology was seen until the last sampling. A clear, albeit low, prevalence of cross-stitch vertebrae was found in the two PD-vaccinated groups, and not in the other two.

Growth zone defects after vaccination

In tissue studies (histology), the scientists found vertebral growth zone changes in the period after vaccination. There were increased deposits of the protein fibrin and irregularities in the bone-producing cells in the growth zone. As the fish grew, normal bone continued to form, while the weakness that were induced in the period after vaccination remained in the location where it had formed. After being slaughtered, the scientists found the typical cross-stitch changes using X-rays and histology. X-ray control measurements showed that the ring-shaped weakness that had formed was consistently located where the vertebral growth zone was at the time of vaccination.

Temperature during the post-smolt stage

A subgroup of fish was withheld at seawater transfer and placed in seawater tanks at 6 and 12 degrees, respectively. The scientists found several indications that the reaction to the vaccine was stronger at the higher temperature. This may indicate that temperature and growth patterns after transferring to sea are factors that have an impact on whether the pathology develops or not, but this is something that needs to be investigated further.

"We don't have any answers as to what it is about these vaccines that triggers the cross-stitch reaction", says Bæverfjord.



We found the key to understanding what went wrong in histology, says Senior Scientist Grete Bæverfjord.



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Partners: NMBU Veterinærhøgskolen,INAQ AS, Pharmaq AS, Pharmaq Analytiq AS





Nofima scientists Torstein Skåra and Tone Mari Rode strongly believe that PEF can become a valuable technology for Norwegian food producers.

Lots of opportunities with PEF

Nofima is investigating how electrical pulses can improve both food products and food production.

Pulsed electric field (PEF) processing is a relatively new technology that has many applications in food production. Currently, it is most commonly used on fruit and vegetable products, wine and olive oil in Europe and the United States.

"We believe that this technology can also be very useful in Norwegian food production", says senior scientist Torstein Skåra, who is about to investigate the technology in Nofima's research facilities.

This is how it works

In short, the raw material or product, such as a potato, is sent through a chamber where it is exposed to a strong, pulsating electric field that perforates the cell walls of the potato. Among other things, the holes in the cells make the potato more malleable so it can be adapted to machines that cut it into potato wedges, chips or thin slices.

The intensity of the electrical pulses varies and is determined by the type of raw material and the effect one wants to achieve. For potatoes, the strength will typically be around 20,000 Volts, and the processing is over in a matter of seconds. PEF has become a huge success in crisp production, and not only because it makes the potato more malleable, which creates less wear and tear on cutting machine blades. The technology also reduces water and energy consumption, provides greater yield, gives the potato a nice colour, and it speeds up the deep-frying process.

However, PEF can do more for the food industry.

Peeling, drying and extraction

Among other things, the holes in the cells can make peeling tomatoes easier, so it is faster to make ketchup and tomato sauces. The technology is used in winemaking to get as much liquid as possible out of the grapes, and a lot more oil or other desired components can be extracted from olives or firmer raw materials that require pressing.

When the cells are perforated, fluid escapes more easily. Nofima has recently tested this in two trials with kelp: a relatively new type of food produce.

"It was quicker to dry kelp that was treated with PEF. But we also wanted to see if the treatment could remove or reduce unwanted substances. We are now waiting anxiously for the analysis results", says Skåra.

Destroys bacteria

The cells of vegetables, fruits and other raw foodstuffs are quite large. In order to make holes in the cell wall, electric fields of relatively low strength are used. But if the strength is increased, the pulse can be directed towards bacteria.

"Bacterial cells are much smaller than the cells in e.g vegetables. But iff we increase the energy of the electrical pulses, we can also perforate bacterial cells, causing the bacteria to die and thereby extending the product shelf life", explains Skåra.

The PEF-inactivation process can be suitable for use on liquid products such as juices, smoothies or soups. Nofima is in the process of conducting trials on milk.

Possibilities for food producers

The electrical pulses must be adapted to both the product and the effect one wants to achieve. Tailoring setups for individual productions is something that Nofima scientists are working on. They also document the shelf life of products that are treated using different intensity and duration.

Food producers are now invited to discuss opportunities and run test trials using PEF. Nofima has PEF facilities both in Stavanger and Ås.

"It is well documented that PEF has an effect on the yield and shelf life of a number of food products. However, we are not able to document the effect on all raw materials and processes, and we therefore want to investigate whether PEF could be a good solution to various problems facing the food industries", says Torstein Skåra.

"A technology that can save costs and reduce energy consumption makes food production more sustainable. It is also our concern with this research – to contribute to more sustainable food for everyone.



PEF treatment also makes it possible to create brand new products no one has seen before. How about tying a knot in a strip of sweet potato? The holes in the cells make the potato more malleable so it can be adapted to machines that cut it into potato wedges, chips or thin slices



When the electrical pulses hit the cell, holes are made in the cell wall. This gives the raw material new characteristics that can improve factors such as yield and production.



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Temptation catches your eye

Eye tracking tests show that packaging affects how a product is perceived; expected and actual experience may vary.

What is it that arouses interest and what expectations arise when children aged 9-10 assess chocolate milk cartons? Biometric methods such as eye tracking and facial decoding have been used to find the answers.

"Biometic methods help us to understand children's perceptions, without having to ask them. Combining different methods can provide a more holistic understanding of how children perceive food and beverages. Food manufacturers can benefit from this when developing healthy foods that children actively choose and like", says Nofima senior scientist Paula Varela. She and doctoral research fellow Martina Galler are responsible for the studies.

The children associate the Litago cow with good taste

In the eye tracking study, the children were shown eight different varieties of chocolate milk cartons. Four of them had an illustration of the Litago cow. The other four had cocoa beans.

"The children think they will like the chocolate milk with the Litago cow the best, while they think the carton with cocoa beans on is healthier", says Martina Galler.

The 'Mysterious Taste' star always attracts interest

Eye tracking shows that children mainly emphasise different elements based on what they are asked about, but the 'Mysterious Taste' star attracts a lot of interest both when deciding how much they like the drink and how healthy they think it is.

Differences between expectations and actual experiences

The scientists used both traditional questionnaires and biometric facial decoding to map how the children experience different tastes. There is a correlation between the answers the children give and the emotions the facial decoding measures.

In addition, there are several differences between the expected and the actual taste experience. For example, the children expected to like the chocolate milk with added sugar the best when looking at the cartons, but they liked both just as much when tasting them blind. Furthermore, they expected to like the chocolate milk with the mysterious better, but they preferred the taste of the original products rather than chocolate milk with added liquorice or mint.



Paula Varela and Martina Galler showing different varieties of the chocolate milk packaging that the children in the study assessed.



Photo:

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Partners: 17 partnere i syv land





At Nofima, a sustainable approach to the cultivation of meat cells has been important; making the growth-serum based on by-products and residual raw materials.



Scientist Sissel Rønning and doctoral research fellow Christel Andreassen are at the forefront of Norwegian meat cultivation. The picture illustrates the meat of the future.

In the forefront of cultivating meat

A muscle cell sample from a living cow, a bioreactor, some cell-food and within few weeks we might have produced kilograms of cultivated meat.

Nofima scientist Sissel Rønning is Norway's leading scientist in cultivated meat. She thinks this could be a method of producing meat in the future. Therefore, she is delighted that Nofima, as the first institute in Norway with public funding, initiated this research in a somewhat controversial field of science.

In the GrowPro research project, the goal was to develop new technology to produce tomorrow's food.

Sustainable

The scientists wanted to cultivate muscle cells from cattle using bioreactors, utilise by-products from the food industry during this process, and map the properties of the proteins found in foods.

After four years of research, we have come a long way:

"The biggest technological challenge is the cell food. Currently, it is common to use serum from calf fetuses, but it goes without saying that cannot be used to produce food for many people", says Sissel Rønning. Nofima believes that using by-products as cell food may be the solution.

"Doctoral research fellow Christel Andreassen has produced several different types of hydrolysates from industry byproducts, such as blood plasma from pigs, chicken offcuts and egg whites. It turns out that much of this is excellent material that the cells really like, and it can be included as tailored, sustainable food for the cells", says Rønning.

Interdisciplinary

She and her colleagues are now hoping to build on this knowledge through a larger, interdisciplinary project that combines technology with sensory science and ethics, involving major industry actors.

"It is really important to be at the forefront. In Norway, we have both the expertise and the money needed to develop new technical solutions for food production", says Sissel Rønning.



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Nofima researchers have obtained many useful results regarding the role of fatty acids in salmon fillet colour. From left, Turid Mørkøre, Tone-Kari Østbye, Esmail Lutfi Royo, Bente Ruyter og Marta Bou Mira.

This fatty acid promotes fillet quality

Scientists have now shown that the omega-3 fatty acid DHA inhibits the synthesis of the pigment melanin, which produces unwanted dark spots in farmed salmon.

Therefore, another piece of the puzzle is in place regarding the understanding of why marine fatty acids are so important in the diet of salmon. Nofima scientists have found that a high content of DHA contributes to a redder fillet and fewer unwanted dark spots, so-called melanin spots. These spots have to be cut away on the filleting line, and the fillet achieves a lower price. This is the largest and most costly quality problem for the salmon farming industry.

Why omega-3 is important to research

The diet of farmed salmon has changed over several years. Around 70 percent of the ingredients in the feed come from the plant kingdom, whereas the feed used to be dominated by fish meal and fish oil. Therefore, the content of marine omega-3 has decreased over time.

To minimize negative effects of high plant content in the feed, scientists have investigated benefits of increasing the proportion of the marine fatty acids EPA and DHA. This is a joint effort in a number of projects led by Nofima, involving national and international research partners and industry. In short, the research projects show that there are good reasons to assure sufficient marine fat in the feed.

"We have known for a long time that omega-3 has an effect on colour. But which omega-3 fatty acid has an effect and how, this is new", says Nofima's omega-3 scientist Bente Ruyter.

The latest findings from Nofima indicate that the fatty acid DHA actually enters the cells and regulates the synthesis of melanin.

When salmon get an inflammation of the muscle, immune cells called macrophages are attracted. These cells produce melanin, which causes dark spots in the fillet. Scientists have conducted cell experiments in which they gave DHA to macrophages isolated from the salmon, and initial trials show reduced melanin production in the cells.

Reduced dark spots

The effect of DHA is also evident in a trial in which salmon were fed a low (1–1.3 %), medium (1.6 %) and high (3.5 %) content of marine fatty acids. The salmon that received



a high content of marine fat had better fillet quality in terms of colour and a lower occurrence of dark spots.

In this trial, dark spots were significantly reduced with a high content of marine fatty acids. While only 8.6 percent of farmed salmon that received a lot of marine fat in their feed had dark spots, the corresponding figure was around 20 percent and higher for fish that received low and medium-high content.

Senior scientist at Nofima Turid Mørkøre has been researching dark spots for a long time:

"We have now pointed out which fatty acid has the greatest inhibiting effect on dark spots. This is the long marine fatty acid DHA that reduces the occurrence of dark spots and gives a good red fillet colour", says Mørkøre.

Several new sources may be the solution

Nofima has reported in previous research that if the proportion of marine fat is around 1.6 percent of the feed, it is considered safe for the fish. So far, little has been known about the benefits of including more than 2 percent in the feed. However, the scientists can now answer this question.

Salmon that received 3.5 percent marine fatty acids in their feed throughout the entire sea phase in net-pens had significantly better growth, welfare, robustness and fillet quality compared to salmon that received 1–1.6 percent in their feed.

"Our findings underline the importance of marine fats in maintaining good growth, robustness, welfare and fillet quality in salmon farmed in net-pens", says Ruyter.

Does this mean that more DHA should be added to salmon feed?

"Yes. There are so many trials that show the positive effect of going higher than 1.6 percent, so we are reasonably confident that this is a good recommendation. The aquaculture industry has understood this, and as far as I know, the level of marine omega-3 is already well above 2 percent in commercial feed", says Ruyter.

Ruyter emphasises that marine fatty acids must not necessarily originate from fish oil. There are currently alternative sources of DHA that are suitable, and more are being developed by industry and researchers. Examples of such sources are microalgae, krill or genetically modified plants.



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Pink salmon: A tasty fish

Nofima has investigated the quality of the despised fish that is invading the Norwegian coast. Conclusion: pink salmon is definitely suitable for human consumption.

In the summer of 2021, huge numbers of pink salmon flowed into Norwegian rivers. Many fear that it will affect the wild Atlantic salmon population, and the authorities allocated funds to catch as many pink salmon as possible before they had a chance to spawn.

But not everyone saw this as a problem. Can pink salmon become a useful resource?

Investigating a new species

Nofimascientists have investigated the food quality of pink salmon, and assessed characteristics such as odour, texture, fat content and colour.

Some fillets were used in storage trials, others were smoked. The scientists used their vast experience of other fish species and compared the results.

"Pink salmon is more like wild Atlantic salmon, Arctic charr and trout compared to farmed salmon, as it has less fat and is redder in colour. Smoked pink salmon is dry and firm, and has a nice red colour", says scientist Torbjørn Tobiassen, adding:

"The quality of pink salmon also depends on gentle catch methods, rapid refrigeration and bleeding out after slaughter.

Senior Scientist Sten Siikavuopio emphasises the potential of utilising the roe of pink salmon, which is an internationally sought-after product.

"It is important to establish effective and selective fishing gear that doesn't harm the pink salmon. This should be initiated in 2022 so that things are ready for 2023, when we next expect a large influx of pink salmon", he says.



Pink salmon or humpback salmon – this fish has several names. Here are three specimens ready for inspection at Nofima.

Could it be profitable?

Many fisheries come to a standstill during the summer months. Pink salmon fishing could create new activity.

The scientists are reminded of another invasive species that was considered a threat but is now managed as a resource and an important fishery in Finnmark – the red king crab.

"Pink salmon is an uncertain resource because we do not know how many will arrive along our shores from year to year. However, pink salmon are simply too good to ignore. If they continue to come, they can generate income for young people, fishermen and processing facilities", says Tobiassen.

Pink salmon is more like wild Atlantic salmon, Arctic charr and trout compared to farmed salmon, as it has less fat and is redder in colour



Torbjørn Tobiassen and his research colleagues use different methods to assess the fish's food quality characteristics.



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A bunch of Nofima's spectroscopy scientists, from left, Petter Vejle Andersen, Tiril Aurora Lintvedt, Jens Petter Wold and Nils Kristian Afseth.

Automatic measurements

There are several different spectroscopic methods of measurement. They are suitable for different raw materials and analysis needs.

"The goal of the methods we are developing is to give food producers the opportunity to measure the quality of their food, all the way from net-pen, sea, soil or barn to table, and thereby use it in the best possible way", says senior scientist Jens Petter Wold. He heads SFI DigiFoods.

Down to the smallest detail

Raman spectroscopy is an analysis technique used for detailed and accurate measurements of the chemical composition of materials. The measurements can be made all the way down to the molecular level. This means it is possible to measure not only the amount of fat, protein and water in raw materials, but also the types of fat and proteins - and how much of each type of fat and protein is present.

"Raman technology is developing rapidly, becoming more affordable and is therefore also interesting regarding industrial analysis of food. We are now investigating how we can use Raman to measure important quality properties of food so as to increase raw material utilisation, ensure consistent product quality or develop differentiated products", explains Jens Petter. Doctoral research fellow Tiril Aurora Lintvedt is investigating how she can use Raman to measure fatty acid composition in salmon and the amount of bone residue in residual raw materials from chicken.

"The laboratory trials have been successful, but it must also work for the industry. These are the adaptations I am working on right now", says Tiril.

Smart sensors

Other food quality measurement technologies are also being developed in DigiFoods, and these are based on methods such as near-infrared spectroscopy (NIR), IR and new applications of hyperspectral imaging. The goal is for the industries to adopt these technologies.

"We combine robotics with smart optical sensors. For example, a robot can control the sensor in a complex manufacturing process where it would otherwise be impossible to make good measurements. We equip mobile agricultural robots with sensors so that they are better at 'seeing' the quality of fruit and from there making good decisions.



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Funded by: The Research Council of Norway and participating partners Partners: There are 27 partners in the centre



Green food from blue fields

New producers are starting up all the time. Kelp is beginning to play a larger role in the Norwegian seafood industry, and scientists are in a hurry to acquire new knowledge.

"Yes, this industry is environmentally friendly, green and organic, and will grow! Currently, there are around 20 kelp producers in Norway. We are going to see a lot more in just a few years' time", says kelp scientist Dagbjørn Skipnes.

Nofima's senior scientist has played a central role in the food research institute's focus on kelp research since it was intensified six years ago.

One hundred percent organic

Seaweed and kelp are macroalgae and are one of the world's largest renewable biomasses. They are found in huge quantities and many different species along the entire length of the Norwegian coast. According to the scientist, producing a food that is environmentally greener than kelp is a very hard thing to achieve.

"Kelp cultivation is just about as green as it gets. Photosynthesis takes place in the kelp. It binds CO2 and absorbs nitrogen and nitrates, so it has a purifying effect on the environment. It is a form of cultivation that does not require fertilizer or food. Cultivated kelp is one hundred percent organic and is also suitable for vegans", says Dagbjørn Skipnes.

Results

Large and well-known food producers such as Orkla, Lofoten and Lerøy actively use kelp in their product development. Today, for example, kelp is used as a seasoning on snacks and seafood, and as a component in liver pâté, fish cakes, mackerel in tomato sauce and ketchup.

So far, Nofima's kelp research findings can be summed up as follows:

- More than 20 research articles and reports on cultivation, harvesting, pretreatment, processing, use in the food industry, marketing and consumer behaviour.
- New knowledge and tools for creating healthy products
- Recognition that production must be further developed to be more efficient with greater volume and less energy use
- The choice of location and type of kelp for cultivation is crucial in terms of both growth and content
- Kelp that grows in nutrient-rich water is more resistant to pests
- Kelp that grows closer to the surface contains less iodine than kelp growing at greater depths
- Mechanical pressing, PEF and fermentation are all promising processing methods
- Enzymatic extraction of alginate and fucoidan can replace current processes

And not least: Nofima helps spread knowledge about kelp. "So far, we can count three bachelor's degrees, four master's students, an ongoing PhD and two postdoctoral fellows,

Seaweed and kelp are one of the world's largest renewable biomasses, they are found in huge quantities and many different species along the entire length of the Norwegian coast.

Photo: © divedog - stock.adobe.com

and more are on the way. This gives the industries access to personnel who have a great deal of expertise in kelp", says Dagbjørn Skipnes.

Iodine problem

Nofima also plays a key role in the Norwegian Seaweed Association. An arena cluster that, according to the scientist, provides better coordination throughout the entire kelp industry. "Previously, there were several small groups, but everyone is now gathered and works as a team in a different way than before. Therefore, the industry is rapiudly developing. And because several research institutions are on board, we also avoid researching the same thing in several places at the same time", says Skipnes.

Kelp contains minerals, vitamins and fibre, which are all positive for humans. However, there are some challenges. Kelp contains a lot of iodine. And consuming too much of it is not the best thing to do. According to the scientist, the entire industry is taking the problem very seriously.

Processing can solve the challenges regarding heavy metals and iodine. "The industry has been aware for some time that blanching at a moderate temperature or boiling for a few minutes greatly reduces the iodine content. We are now working to find methods for extracting iodine and heavy metals without having to resort to boiling or other processes

that result in high energy consumption, changes in quality and loss of nutrients."

Nofima is continuing its kelp research through several different projects that involve increasing interdisciplinarity. "As Nofima food scientists, we are working to ensure that everyone has access to sustainable food. This is why we are also researching how to cultivate and process kelp so that it can be a safe and beneficial part of the range of food products on offer", says Dagbjørn Skipnes.



Dagbjørn Skipnes and colleagues were involved in both the extrusion of the kelp and the composition of the seasoning in Sjy Seaweed's kelp crisps.



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Insight into consumer attitudes towards residual raw materials is necessary in order to succeed with new, innovative ingredients, says Nils Kr. Afseth and Mari Øvrum Gaarde.

Attractive residual raw material

Health, environment and economy are important reasons why consumers may consider eating or drinking products enriched with proteins from residual raw materials.

Insight into consumer attitudes towards residual raw materials is necessary in order to succeed with new, innovative ingredients. That is why Nofima scientists have investigated whether young people, elderly and avid exercisers would consider consuming protein-enriched foods based on residual raw materials from chicken.

"This is a sensible way of utilising the nutrients in the raw material, but we must be sure that consumers are positive about using this type of protein enrichment", says scientist Mari Øvrum Gaarder. She is responsible for the research in the HydroProt project.

In the project, Nofima scientists have also investigated and seen that the protein powder has the potential to reduce blood pressure and increase growth in muscle and bone cells.

Information about the origin

Three consumer groups participated in the study; avid exercisers, young people and elderly. The avid exercisers are most interested in the protein content, but at the same time most sceptical about residual raw materials. The scepticism is due to the fact that they are unsure whether it is safe, they do not want to eat processed food and they are not convinced it is good for their health.

It is worth noting that information and knowledge about the product reduce this scepticism. All three consumer groups become more positive the more they know.

All the consumer groups are concerned about sustainability, but their interpretation of the term varies. Sustainability can be viewed from three different aspects; environmentally, socially and economically.

"In our study, we saw that the young people and the elderly were more concerned about sustainability than the avid exercisers. This is an important reason why they are also more positive to residual raw material products, but young people and the elderly have different views on what sustainability entails. The environmental aspect is the main reason why young people are positive about this form of protein enrichment. For the elderly, the economic aspect and their own health is more important", Mari points out.



The elderly would also like to see cold cuts, meat patties and protein-enriched bread, while protein-enriched sausages appeal to young people.

Cold cuts

The scientists investigated which food products consumers would like to see on the market in relation to protein enrichment based on residual raw material from chicken. Cold cuts were at the top of the list, followed by meat patties. The elderly would also like to see protein-enriched bread, white cheese and fish cakes, while protein-enriched sausages appeal to young people.

The elderly said that the food must be easy to digest and must provide enough nutrition, and they were more concerned about the dietary fibre content than the proteins. The young people emphasised satiety and the avid exercisers were interested in nutritional content.

Effective methods

Residual raw materials from chicken and cod contain minerals, fats and sought-after proteins. In the Notably project, the scientists are working on developing effective methods for the extraction and separation of various valuable components found in the residual raw materials. The aim is to develop multi-step processes based on enzymatic hydrolysis. These multi-step processes will enable more of the raw material components find their way to new products.

The proteins from residual raw materials can be divided into two main groups; muscle and connective tissue proteins. Connective tissue, for example, is very rich in collagen proteins, but these proteins are often not optimally utilised at present, despite being sought after. With new multi-step processes, the degree of utilisation can be significantly increased.

"Different enzymes can break down proteins in different ways, and this makes it possible to create protein products where the protein has s pre-defines compositions of components such as muscle proteins and collagen", explains Nofima senior scientist Nils Kristian Afseth. He is head of research in the Notably project.



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A lot to save from targeted UV

UV disinfection can kill 99.9 percent of bacteria and viruses found in the inlet water of aquaculture facilities. But how high should the doses be?

Recent Nofima research in the CtrlAQUA Intake project "Strategies for water treatment in closed-containment aquaculture" shows that there is a lot of gain from adapting the dose to the pathogen one is dealing with.

Expensive

The technology is known. The knowledge the scientists generate through trials is fresh.

"Because UV treatment of intake water is so energetically costly, it will be more economically sustainable to use the exact dose that is necessary to eliminate a specific pathogen. Neither more nor less. We test different doses to find out which dose leads to a 99.9 percent reduction of various pathogens. We do not require particularly high doses for most pathogens", says Nofima scientist Vasco Mota.

Six pathogens investigated

Two master students, Kari Justad (The Arctic University of Norway) and Miguel Guerreiro (University of Algarve, Portugal), conducted their work at Nofima Tromsø laboratories. Together with Nofima technicians and researchers they used two UV Collimated Beam Apparatus to investigate six different pathogens:

- Two viruses: IPNV and ISAV
- Three bacteria: Yersinia ruckeri, Moritella viscosa and Tenacibaculum spp.
- One copepodite: salmon sealice

Two different UVC technologies of distinct wavelength lengths (λ) were used; a low-pressure (254 nm), and a medium pressure (220–300 nm).

"The IPNV is the only one of the five viruses and bacteria we have tested that required a very high dose, luckily there is a vaccine against it. All the other pathogens were eliminated using UV doses typically below 10 mj/cm²", says Vasco Mota.

And what about the challenging salmon lice?

"Lice is hard to kill with UV. At least without using absurdly high UV doses (> 100 mj/cm²)", says Vasco Mota.



Miguel Guerreiro is one of two master's students having conducted UV measurements showing that 99.9 percent of pathogens are eliminated at low doses.



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Partners: Norce, Atlantium, FiiZK





Cod scales can be further cultivated in cell cultures.

Preparing for more species in aquaculture

Nofima is developing a methodology for following up health challenges that may result from climate change and growth in the farming of new species.

There are still less than 2 million cod being farmed in Norway, but the number is increasing. In addition, the industry is also interested in farming other relevant species.

Elisabeth Ytteborg is a fish health scientist and has led a project in which she and her colleagues have developed tools to compare how stressful environments affect the external immune system of cod, salmon and lumpfish. The tools they have developed are so-called 'in vitro models', which involve the cultivation of cells from various fish organs such as skin and nose.

Using these tools, the fish can indirectly tell the scientists how they tackle the challenges they face in a net-pen, such as changes in temperature or chemical agents.

Disease may increase

The prevalence of bacterial diseases may increase as a result of higher water temperatures caused by climate change. At the same time, the majority of farmed species in Norway do not thrive at high temperatures. "We need more knowledge about temperature and fish resilience. We can make real progress by using cell models", says Ytteborg.

We need to develop good tools

Nofima has been running the national cod breeding programme for 20 years, and the knowledge created should be transferred to other relevant species in Norwegian aquaculture.

"Climate change brings along new challenges related to fish health. This is a field that has so far been given little priority", says Lill-Heidi Johansen, head of fish health in the national cod breeding programme.

"We need to improve our toolbox so that we are prepared to meet health challenges that may arise, including species other than cod and salmon", says Johansen.

Nofima's models will be used in research for the industryand will be further developed. Through the use of cell models, scientists can gain valuable information without using more animals in trials. In 2021, the Nofima scientists received Norecopa's 3R animal research prize for this work on developing alternatives to animals in experiments.



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New knowledge about ballan wrasse feed

The ballan wrasse is the best lice eater, but in order to stay healthy and in good condition, it must be given a feed that meets its nutritional needs and also has a taste that it likes.



A healthy and nice ballan wrasse (Labrus bergylta) in good condition.

We now have new knowledge about what is required to succeed.

There are many challenges when producing ballan wrasse with good health and welfare, and which can do well in a challenging environment together with salmon in net-pens.

Unlike salmon, the ballan wrasse lacks stomach and pyloric caeca and has a short, simple intestine. This affects feed utilisation. In the CleanFeed project, scientists from Nofima, the Norwegian University of Life Sciences (NMBU) and the Institute of Marine Research (IMR) have conducted many nutritional trials on ballan wrasse.

These have provided a lot of useful knowledge, primarily in three areas: feed technology, nutrients, and raw materials for feed.

(Heat) Extruded feed must be avoided

Nofima recently reported that farmed ballan wrasse that receive usual (heat) extruded feed at early stages develop

skeletal deformities. The industry is paying attention to these consequences:

"It is great news that producers of ballan wrasse feed are already using these results, and are producing ballan wrasse feed using "cold-extrusion" says senior scientist Ingrid Lein.

The scientists believe that ballan wrasse are not able to tolerate extruded feeds because high extrusion temperatures make feed nutrients harder to access for ballan wrasse that lacks stomach and acid digestion.

The trial results show that the correct use of technology during feed processing is key to good ballan wrasse health:

"We have now shown that technical feed quality is very important for the welfare of fish", says Katerina Kousoulaki, feed scientist at Nofima.

Positive effects of marine phospholipids in the feed

The scientists also investigated how the amount of fat in the feed affected the performance of Ballan wrasse, and what it







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Feed scientist Katerina Kousoulaki (centre) has composed feed for ballan wrasse in the trials at the Aquafeed Technology Centre in Bergen.

means for the fish whether phospholipids in the feed originate from marine or vegetable sources. Phospholipids are types of fat that are the main components of cell membranes.

The scientists found that using marine phospholipids in the feed gives positive results, especially when the total fat content in the feed is increased.

"When marine phospholipids accounted for half of the fat, growth increased and intestinal health improved", says senior scientists Gerd Marit Berge.

Continues to like an expensive diet

Compared to many other species, ballan wrasse is very fussy about its feed, and if it does not like the taste, it will not eat it even if the nutritional content is good.

The feed that ballan wrasse prefers contains expensive raw materials such as cod muscle and shrimp meal. In a trial, the scientists investigated whether it is possible to replace these raw materials with more affordable options such as poultry meal and krill meal, but again, all new ingredient combinations resulted in lower growth.

The scientists are yet unable to say whether this is due to taste and feed intake, or lower digestibility and utilisation of the feed. Nevertheless, it may be possible to partially replace the more expensive raw materials in order to get a more affordable feed. The scientists would like to take a closer look at this.

"If we manage to find a more affordable feed that the ballan wrasse likes, and that contains enough available nutrients, we will be able to offer an important contribution to the production of good quality cleaner fish", says Lein.

The trial results show that the correct use of technology during feed processing is key to good ballan wrasse health

Funded by: The Norwegian Seafood Research Fund (FHF)

Partners: Institute of Marine Research, Norwegian University of Life Sciences (NMBU) More info: See Nofima: website



Are cleaner fish edible?

Can cleaner fish such as lumpfish and Ballan wrasse be used for human consumption after completing their job as a lice eaters? So far, the answer is uncertain.

Two Nofima projects have been looking at the sustainable after-use of cleaner fish. The objective is human consumption. This will be the most sustainable solution.

South Korea

Market researcher Gøril Voldnes put Norwegian chefs on the case. They made good dishes, but stated that lumpfish was very difficult to work with. It is rather tasteless and has a special texture.

An interdisciplinary research project has looked into the collection, nutritional content, processing, regulations, residual raw materials, profitability and market possibilities of these cleaner fish. Nutritional content tests show that the fish have a good fatty acid composition and are a good source of vitamins B and D.

"The first test market was South Korea. Whole, frozen cleaner fish were sent to Seoul and distributed to chefs and industrial buyers. The task was to make dishes that complemented the fish and Korean food culture", says Voldnes.

The respondents were then interviewed about appearance, taste, texture, the fact that they have eaten lice and the potential for use in their food culture. "They made many exciting dishes. Fish in a spicy pepper sauce and in soy sauce, they deep fried it, shallow fried it and took some great pictures", says Gøril Voldnes.

Scary

But what do they actually think of it?

"They did not like the appearance of the fish at all. They thought it was rather scary looking and very unappetising".

The respondents perceived that the fish didn't have much taste, the texture was too soft, there was little filet, and the story about them eating lice was unpleasant.

"The results of the market test in South Korea show that the sale of whole cleaner fish for human consumption can be a bit challenging", the researcher states.

The respondents proposed processing before export. Dried or semi-dried fish is a very popular product in South Korea.

"The most important thing to reveal a suitable solution for after-use sothat cleaner fish do not lose their value when they are finished as lice eaters", says Gøril Voldnes.



Lumpfish for dinner do not tempt South Koreans. The scientists are now testing new uses for cleaner fish when it has finished eating lice.



Illustration: Oddvar Dahl, Nofima

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Partners: Akvaplan-niva, Nha Trang University, Lerøy Aurora AS, Ryfylke Rensefisk AS, Nordøy Sea AS

creatingvalue 2021



Five weeks of salmon feed on the menu didn't affect cod fillets.

Gave salmon feed to wild cod

A short-term cod feeding trial suggests that the quality of wild fish around fish farms is not harmed through intake of salmon feed.

Every now and then, one comes across rather heated debates where both recreational and commercial fishermen are shocked at the amount of pellets that pour out of the stomachs of the fish they gut. It both looks and smells unappetizing, and many believe that these fish are not fit for human consumption.

But do we really know if this diet affects fish fillets?

Little knowledge about the problem

As part of the 'Coexistence' project, in which we acquire knowledge about how marine industries are able to positively coexist, scientists initially conducted a survey among Norwegians to find out what they think of so-called 'pellet-saithe' – i.e. coley that eat feed around fish farms.

Most people did not know anything about this. Only men over the age of 60 from Northern Norway had an opinion on the issue – maybe because these are the people who have experienced catching pellet-coley. In a new survey, northern Norwegian fishermen said that especially the smell, texture and appearance of the fish are affected by a pellet diet.

Nothing wrong with fillet quality

In order to assess the quality, the scientists fed a small group of wild-caught cod with pellets over a period of five weeks before slaughter. They then assessed the fish using a modified quality index method (QIM), where the main focus was on smell, texture and appearance.

"We were unable to find many significant differences between wild fish that had eaten pellets and other wild fish", says postdoctoral researcher Ragnhild Aven Svalheim.

"The fish had the same texture, smell and appearance as other fish, but the fillet gaping was different. Wild-caught fish fed with herring and prawns had more filet gaping than those that had eaten pellets, but those that had eaten pellets had more filet gaping than wild fish."

The difference between the groups depended on how much food there was in the gastrointestinal system of the fish. The results suggest that it is not what the fish eats, but rather how much it eats that determines the quality.



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Tailored food packaging

Nanomaterials will be important in green food packaging of the future, but they must be used correctly – and some are better suited than others.

Nofima scientists have studied which nanomaterials are suitable for encapsulating natural antimicrobial agents for use in food packaging.

Natural plant oils need protection

"We are working on the possibility of combining active packaging solutions based on naturally active components with more environmentally friendly packaging solutions. These natural components are found in natural plant oils that have antimicrobial properties, thus inhibiting bacterial growth so that food has increased shelf life", explains Nofima scientist Jawad Sarfraz.

One challenge is that the plant oils, or more precisely the active components of the plant oils, are very volatile. That means that they 'disappear' after a certain amount of time. The components are also sensitive to oxygen, heat and light, which make it difficult to process them in their natural state. This is where nanomaterials come in. They can form a protective environment around the sensitive plant oil components.

Nanocarrier = nanomaterial with encapsulation abilities

The Nofima scientists have investigated nanomaterials that are able to encapsulate things such as organically active components, and then adjust the effect so that the components are released after a certain amount of time. These nanomaterials are called nanocarriers.

"We have investigated and compared different nanocarriers to take a closer look at which ones can work best in a food packaging application" says Tina Gulin-Sarfraz. She is a postdoctoral researcher at Nofima and works on the PackTech project.

Tailoring silica particles

"Interest is now growing in so-called synthetically produced porous silica particles for use in food packaging. This is a harmless mineral found naturally in large quantities. It is a common food additive called E 551 and we believe this nanocarrier is the most relevant with regard to food contact" says Jawad Sarfraz.

The Nofima scientists' studies of silica particles are very promising. These particles offer great design possibilities, and the scientists can tailor the particles so that they protect a specific active component.

"We can tailor the pore structure, the surface area and the surface chemistry, and adapt to the components we are going to encapsulate. In addition, we see that the encapsulation of the volatile components is effective" says Tina Gulin-Sarfraz.



Equipment for the characterisation of nanoparticles

Synthesis and characterisation of nanomaterials is a relatively new field of research at Nofima, and the infrastructure is gradually being built up.

A Zetasizer, which is used for the characterisation of nanoparticles, is in place. This makes it possible to study the size and surface charge of the nanoparticles.

Gas chromatography - mass spectrometry (GC-MS) and spectroscopic techniques are available in house. These methods are used to study the encapsulation and release of active components. Other characterisation methods are used in collaboration with UiO and NMBU.



Tina Gulin-Sarfraz investigating the size and surface functionalisation of the nanocarriers.

About nanotechnology and nanomaterials

A nanometre is one-billionth of a metre. When the dimensions of a material enter the nanoscale, major changes occur in the reactivity of the material. Nanomaterials have a much greater surface area per unit mass compared to larger objects. Porous nanomaterials can have a surface area greater than 1000 m²/g. A result of the high surface-to-volume ratio

is that the optical, electrical, physical, mechanical and magnetic properties can be changed.

These unique nano-effects are the basis for the new and fascinating applications of nanomaterials. Nanomaterials can potentially be used in the field of food packaging to improve the barrier properties of the packaging material, and to develop new active and intelligent packaging systems.



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Creating value is challenging

Good will and a lot of research notwithstanding: Complicated and sometimes inadequate regulations make it difficult to create value from marine by-products.

"It has nothing to do with the will of industry actors. A jungle of regulations, certifications and cumbersome systems and legislation, both overlapping and inadequate, can stand in the way of value creation in practice", says scientist Birthe Vang at Nofima.

A useful tool

Together with colleagues at Nofima and partners from the Institute of Marine Research, SINTEF Ocean and the Norwegian Seafood Council, Vang has compiled an overview of relevant regulations, possible certifications, threshold values for foreign substances, knowledge communities and much more, gathered and presented clearly in a language that is easily understood.

The report is intended as a resource for all companies that wish to explore possibilities regarding the use of residual raw materials and new species, and also for authorities that follow up the regulations.

Great uncertainty

Norwegian companies that want to export residual raw material products face challenges, especially when it comes to classification and unclear customs regulations. If the product is to be exported, it must be stated what kind of product it is. Different national and international definitions, and different rules for different parts of production, mean that the manufacturer often has to choose which properties to emphasise in the classification.

Some requirements are also perceived as inconsistent. For example, dry protein products can enter the EU as duty free goods, while a similar liquid product receives an import duty. It is complicated and time-consuming to make changes to customs tariffs and market access, and the uncertainty surrounding this may prevent companies from investing.

"If Norway is to exploit marine by-products and new species such as algae, it is important that regulations and customs tariffs are updated", says Vang.

"Better organisation and corporate support would facilitate the work of getting products approved", she says.

The ambition is to update the report regularly.



Birthe Vang and Kjersti Lian are working to gain an overview of public regulations that may stand in the way of value creation regarding residual raw materials.





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Tools for increased bacterial control

New technologies that can be applied directly to food can provide increased control regarding problematic bacteria and thus ensure that food is safe and keeps well.

Unwanted bacteria that manage to survive or grow in foods can make us seriously ill and reduce the shelf life and quality of products. The challenges do not diminish as the demand for mildly processed products increases.

Listeria is the biggest challenge

The biggest challenge is often Listeria monocytogenes that can be found in raw foodstuffs and on production equipment and can grow in many products, even during cold storage. It is difficult to control and can cause serious foodborne infections.

"We have been working for a number of years investigating how technologies can be used to help food producers gain increased control over unwanted microorganisms in their foods. The challenge is to find technologies that provide effective control of problematic bacteria and give products with optimal guality, and that are also acceptable to the industry and consumers", says Even Heir, senior scientist at Nofima.

Salts of organic acids provide promising results

Salts of organic acids are natural compounds with antibacterial effect. These include so-called fermentates that are 'clean label'. Clean label is important for both industry and consumers.

Recent results show that such fermentates can be used to inhibit growth of spoilage bacteria and thus increase the shelf life and sensory quality of fresh chicken.

Trials conducted on cold-smoked salmon show that the use of 1% fermentate is sufficient to completely inhibit the growth of Listeria throughout the entire shelf life period without adversely affecting the taste. The fermentates also inhibit Listeria when used in liquid form on raw salmon.

"We are working with a number of other bacteria-inhibiting technologies such as UV light, bacteriophages and antimicrobial enzymes. The latest technological addition is pulsating electric field that has a wide range of applications for killing microorganisms", concludes senior scientist Askild Holck.



Salts of organic acids have a natural antibacterial effect. These include fermentates that can be used to increase the shelf life of fresh chicken.







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Scientist Silje Steinsholm wants to put protein-rich fish offcuts on our plates.

Removing flavour from fish offcuts

A magnetic tongue provides knowledge about flavours that can make fish offcuts suitable for human consumption. This is useful for industry that wants to create food from offcuts.

Large amounts of offcuts are left over from fillet production, much of which goes to waste. Researcher Silje Steinsholm used a method called enzymatic protein hydrolysis in her PhD so that we can eat a larger percentage of offcuts.

Can be used in food

By using this method on offcuts, one is left with a protein-rich powder, which, for example, can be mixed into food products to increase their nutritional content. However, it is a challenge that these nutritious powders have an unappealing and bitter taste.

The flavour and nutritional content are important factors in terms of consumer choice, while the functional properties, such as the ability to form and stabilise emulsions of water and oil, can be important production factors when changing the texture of a product.

Identified substances that produce different flavours

Steinsholm assessed how enzymes, raw materials and membrane filtration affect the properties of the powder. She has used the magnetic tongue (NMR spectroscopy) to find out which chemical substances produce flavour. She has linked these substances to objective measurements provided by the taste judges on Nofima's sensory panel, and has got a good overview of the substances that produce different flavours.

In the study, Steinsholm found that it is possible to remove the smallest substances through nanofiltration, thereby removing some of the flavours. The study confirmed that small peptides (parts of proteins) determine how intense the bitter taste becomes, which depends on the choice of enzyme and degree of hydrolysis. Knowledge about the production of powders (hydrolysates) with low flavour intensity will benefit the industry in the production of protein powders for human consumption.

NMR spectroscopy has been used in trials to define flavour in tomatoes, coffee beans and olive oil, but this is probably the first study that has been conducted on protein hydrolysates. The technology is not quite there yet, but NMR spectroscopy may help simplify the interpretation of flavour in the future.



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Good data can help reveal risks

A new PhD shows that there are many reasons for reduced quality and mortality in salmon farming.

In his PhD, scientist René Alvestad analysed large sets of production data from commercial salmon farming between 2010 and 2018. The data were collected from several net pen facilities and a slaughtering facility in Northern Norway.

The purpose was to identify risk factors related to mortality, reduced performance in net pen facilities at sea, and a downgrade in quality at slaughter.

Identified many associations

In the data, the scientists found a link between the seawater transfer of larger smolt (average weight up to 200 grams) and increased mortality due to the HSMI and CMS heart diseases, as well as mouth rot. There was a higher percentage of salmon that died of mouth rot when the smolts were transferred to the sea during low and falling seawater temperatures than otherwise.

The historical data also suggested that mechanical delousing contributed to increased overall mortality and to more fish dying that had the HSMI and CMS heart diseases. Winter ulcers were the main reason why the salmon were

downgraded at slaughter. Winter ulcers were also a persistent cause of mortality during the sea phase.

Melanin spots were the second most important reason why salmon were downgraded at slaughter. There was also a higher occurrence of melanin spots in the fillets of certain fish groups at slaughter. This applied to fish groups that had a higher percentage of fish that died from heart-related diseases.

Need for digitalisation

The research illustrates that collecting and analysing production data can be a valuable tool for identifying risk factors related to reduced welfare and quality of salmon in commercial salmon farming.

The basis for the PhD is access to a large amount of daily measurements of parameters such as water temperature, feeding, the number of dead fish and cause of death.

Alvestad believes there is a need to improve the infrastructure for the collection, processing and sharing of data, so that it is easier to identify risk factors and implement measures.



René Alvestad has found that it is possible to demonstrate a connection between production strategy and reduced quality when one has good access to data.



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Challenging goal conflicts

Efficiency, low fuel consumption and high quality are important goals in the fisheries. However, achieving one goal often conflicts with another.



The goals of both catch efficiency, high fish quality and energy efficient catch creates conflicts in Norwegian fisheries.

If increased catch efficiency and low energy consumption are emphasised too strongly, this may lead to reduced quality and market value.

"Catch regulations affect catch patterns and thus goal achievement. Prioritising between goals is therefore important before the framework conditions are formulated", says Nofima Research Director Bent Dreyer.

Framework

The main goals of the fishing industry have been in place for a long time; sustainable resource utilisation, value creation and profitability, and contributing to settlement and employment along the coast.

The 'Economic and environmental consequences of catch regulations' project has mapped the environmental and economic consequences of the institutional framework. Whether or not regulation leads to the squandering of resources has been a key question.

"Our findings show that there are conflicts between the goal of catch efficiency, the goal of high fish quality and the

goal of energy-efficient catches. Our findings also show that reduced catch intensity can contribute to better quality. The desire for increased raw material quality will inevitably affect catch efficiency and energy consumption", says Bent Dreyer.

Selected aspects

The project report states: "There is a big difference between different vessel groups and modes of operation, both in terms of energy consumption and fish quality. The authorities can influence these. First and foremost by establishing realistic fuel prices for industry actors and differentiating between the markets when it comes to quality".

Bent Dreyer emphasises that the results presented by the researchers in the project report do not show the full picture.

"The analyses in the report we have prepared are far from being complete, as the complexity found in both industry and management is too great. But they shed light on key priorities that the authorities must make when formulating catch regulations", says Bent Dreyer.



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More info: See Nofimas website





Among other things, scientist Sidsel Fiskaa Hagen has investigated the nutritional content of frozen carrot and yellow beetroot.

Freeze vegetables quickly

Nofima scientists have investigated differences in nutritional content between frozen and fresh vegetables. There are little or no differences.

"Our results show that heat treatment has the greatest impact on the nutrient content, and affects especially the vitamin C content", says scientist Sidsel Fiskaa Hagen. She has led the studies on health-related and sensory quality of vegetables in the NORFRYG project.

Texture analyses showed that frozen vegetables became softer than fresh ones after boiling, but the texture can also be affected by the cooking method. For example, boiled carrot was significantly softer than carrot that was pan-fried, steamed or heated in a microwave.

Frozen vegetables last long

Freezing is a good way to extend the shelf life of vegetables. If frozen industrially, they usually have a shelf life of up to 1.5 years. In order to preserve as much of the nutrients as possible, the vegetables should be frozen as quickly as possible.

"Rapid freezing gives the best results because vegetables contain a lot of water will expand and form ice crystals during

freezing. The larger the ice crystals are allowed to grow, the more damage they do to the cells – and the greater the leakage of nutrients and the loss of texture", explains Sidsel.

Vegetables should also be given a short heat treatment prior to freezing so as to inactivate enzymes that can cause poor taste and loss of nutrients during freezer storage.

Tested new freezing technology

The scientists have also tested a new technology; freezing under strong magnetic fields. They compared this technology with freezing in a factory tunnel freezer and in a regular freezer. The latter simulated the type of freezing that takes place in the homes of consumers.

"In our trials, freezing at the factory produced the best end results. 'Home freezing' came out worst. This is probably because freezing occurs much quicker in a factory tunnel freezer than in a regular freezer", says Sidsel. The scientists found no effect of adding magnetic fields during freezing.



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Partners: Findus Norway AS, Brødrene Freberg DA,

Hoppestad Gard and UCT Prague



X-ray with radio opaque beads (like stars) in the stomach of a salmon.

Unlocks genetic value of feed intake

By genetically selecting fish that grow well but require less feed, feed conversion ratio may be improved by 10 percent in Norwegian salmon farming.

That means saving 1,5-2 billion NOK per annum, and a decrease of carbon footprint of 7 percent.

Feed is the single largest operational cost in a salmon farming, counting for more than half the cost. It also counts for 85 percent of the carbon footprint. The benefit of reducing these numbers is great, and it can be done by selecting feed efficient fish. However, a bottleneck is that feed intake for individual fish in water, is very difficult to measure in practice, unlike livestock on land.

Can measure individual feed intake

But with the explosion in machine learning and deep learning algorithms, it's now trivial to segment out objects in an image. For example using x-ray to identify radio opaque markers. Nofima has given a technological facelift to the old x-ray method imaging beads in the feed to measure intake.

- Colleagues have successfully produced extruded feed with radio opaque markers, and they have live-x-rayed

thousands of salmon from our partner Mowi's breeding nucleus, says scientist in breeding and genetics, Gareth Difford at Nofima.

First breeding value for feed intake

– I'm very proud to say that for the first time we have produced reliable genomic breeding values for feed intake in Atlantic salmon, says Difford.

The scientists can therefore calculate what would happen if we selected fish that grow well but require less feed. And after three generations, a conservative estimate is that feed conversion ratio can be improved by 10 percent, as mentioned.

But there is a catch. We've done this in land based facilities with fresh water parr up to sea water post smolt. For this technology to be ready and relevant, the Nofima scientist will seek opportunities to do experiments in sea.

The research has been carried out in the projects PrecisionVision, NewTechAqua and AquaImpact.







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Behind the results



The following are our largest funding providers:

THE MINISTRY OF INDUSTRY AND FISHERIES (NFD)

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

THE FISHERY AND AQUACULTURE RESEARCH FUND (FHF)

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

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

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

THE RESEARCH COUNCIL OF NORWAY (NFR) is a research policy adviser for the government and the ministries which allocates NOK 10 Bn. annually for research and innovation. The Research Council's mission is ensure that this funding goes to the best research and innovation projects. The organization is at the forefront in developing research of the highest quality and relevance. Nofima carries out research and innovation projects in close collaboration with industry actors within the fields of aquaculture, fisheries, land-based and ocean-based food industries.

In 2021, Nofima has been awarded a number of projects that have an extensive content of research and development (R&D) in collaboration with trade and industry. The projects are funded by the industries, but they also receive solid financial support from policy instruments such as the Norwegian Seafood Research Fund, and the Research Council of Norway. Approximately 70 percent of Nofima's income is won in competition with other research communities.

There is fierce competition for research funding provided by research funders. And in 2021, some research activities have been postponed and cancelled and activity in laboratories and trial facilities have been somewhat lower due to measures related to the COVID-19 pandemic. Despite this, we have managed to maintain and develop research strength and increase the support and digitization of application processes.

Over time, Nofima has built up good financial solidity and we continue to strengthen our academic and research-related position by investing in targeted areas. This gives us a solid foundation for meeting future research needs and society's need for restructuring.

Grete Sollesnes Winther Økonomidirektør



This is Nofima

Nofima has some 390 employees, and a turnover of NOK 661 million in 2020. The research in Nofima is organized into three divisions, each organized in research departments:

Division Aquaculture

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

Director Bente E. Torstensen

Division Seafood

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

Director Magnar Pedersen

Division Food Science

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

Director Camilla Røsjø



Sustainable food for everyone

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

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

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

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

This is how we contribute to sustainable food for everyone.





Norway's first research station in aquaculture - 50 years

In 1971, the Research Station for Sustainable Aquaculture was established at Sunndalsøra. This is where much of the foundation for today's large aquaculture industry has been laid, and the station continues to be important for development in the industry. In recent years, significant investments have been made in upgrading the station so that our scientists and technicians can deliver new, valuable knowledge and innovations for the ever-growing industry. Good infrastructure is essential for delivering research of the highest quality. The station at Sunndalsøra was the first of its kind. Now, 50 years later, it is a station that is equipped for future aquaculture.



In November, member of the Storting Jenny Klinge opened a new pilot plant that houses 20 single-RAS units. We can now increase the scope and precision of research in closed facilities that recirculate water.





We also celebrated our 50th anniversary with three of the pioneers present: Terje Refstie who specialised in genetics, Arne Kittelsen who was the first station master and Torbjørn Åsgård who worked with fish nutrition.



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Sunndalsøra

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