ANNUAL REPORT
2020

FOODS OF NORWAY

FOODS OF NORWAY AIMS TO FEED FISH AND FARM ANIMALS USING SUSTAINABLE NEW INGREDIENTS.

Foods of Norway is funded by the Research Council of Norway (grant no. 237841/O30), our partners and our host institution - the Norwegian University of Life Sciences (NMBU).

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EXECUTIVE SUMMARY

The challenges of 2020 have offered an enhanced perspective on the importance of the work we do in Foods of Norway. Being at the forefront of how to use novel and sustainable resources to feed fish and livestock, and in that way ensuring food security and self-sufficiency, fortifies our role as knowledge providers in our field.

With the consequences of the Covid-19 pandemic having a major impact on both our research staff and our partners, there is no doubt that this year has been our most challenging so far. Still, we have been able to move forward with our trials and other scientific ventures in Foods of Norway and continue the ground-breaking work in our fields of expertise, due to the hard work and persistence of all involved in the centre.

Yeast from trees as a novel protein source is one of the main areas we work with in Foods of Norway. Our work at the Biorefinery Lab at NMBU (NorBioLab) makes it possible to produce 10 kilos of yeast a week, and the yeast production process is now ready for upscaling. Several trials with yeast in feed have been carried out during 2020, including trials with piglets, cows and salmon. Foods of Norway researchers have also examined the milk quality from cows fed yeast-based diets.

Seaweed is a natural resource we have in abundance along the Norwegian coastline. In 2020 we have developed and upscaled methods for biorefining seaweed, including extracting bioactive substances with beneficial health effects. Also, experiments with feeding sugar kelp to lambs show a positive effect on the nutritional value and product quality of the meat.

We have continued the work with developing methods for selecting feed-efficient salmon. The methods have been validated on rainbow trout and, based on experiments with lambs, we can now document that the method can be used for ruminants.

As we now have 2020 behind us, we are looking forward to an eventful 2021. Among many other exciting events, we will conduct important field trials with seaweed in diets for ruminants and with yeast in feed for Atlantic salmon and piglets. The coming year will most likely also present some challenges for us in Foods of Norway, but I know we will be able to meet them head-on and continue our good work.

Centre Director,
Professor Margareth Øverland

Margareth Øverland

"We have been able to move forward (...) due to the hard work and persistence of all involved in the centre.

Margareth Øverland, Centre Director Foods of Norway

VISION AND OBJECTIVES

The Foods of Norway vision

is to increase value creation in the Norwegian aquaculture, meat and dairy industries by developing novel feed ingredients from natural bioresources and by improving feed utilization.

The main objective

of Foods of Norway is to make Norwegian fish and animal farming industries more competitive and innovative by developing novel feed ingredients from bioresources and ensuring efficient feed resource utilization.

Secondary objectives

EXPLOIT modern biorefining technologies to develop high-value feed ingredients from lignocellulosic biomass.

USE innovative bioprocessing to develop novel feed ingredients from local natural bioresources such as macroalgae and animal and plant co-products.

IMPROVE efficiency of existing feed resources through innovative bioprocessing.

ALLOCATE feed resources across species (fish, pigs, broiler chickens and dairy cows) for optimal production economy and minimal environmental impact.

PROVIDE knowledge to ensure that the novel feed ingredients support production of high quality Norwegian food products.

IDENTIFY biomarkers for optimal utilization of novel feed resources for use in future fish and animal breeding programs.

RESEARCH PLAN

The Norwegian fish-farming and farm-animal industry rely largely on imported protein-rich feed ingredients, such as soy-based products. In addition, the use of human food resources as feed ingredients has been questioned, both for ethical and economic reasons.

The sustainability of future farmed animal and fish production will depend on an increased use of local and novel feed ingredients.

Novel feed ingredients should have a low environmental impact and be produced from resources not suitable for human consumption. At the same time, we need to use our feed resources more efficiently, for example by genetic improvement of animals and optimal feed resource allocation across species.

Norway has limited land area for cultivating food and feed crops, but possesses large natural bioresources such as trees, grass, macroalgae, and by-products from fish, animals and plants. These can provide a basis to produce novel feed ingredients.

Foods of Norway develops sustainable feed ingredients from renewable bioresources that are not suitable for direct human consumption and that have the potential to be produced in large quantities at a competitive cost.

The research plan consists of six integrated work packages with several sub-tasks, each led by an NMBU researcher and in close collaboration with our industry partners. The research is multidisciplinary and there are close synergies across the work packages.

Foods of Norway will continue to develop microbial ingredients, such as yeast, as protein sources in diets for animals and farmed fish.

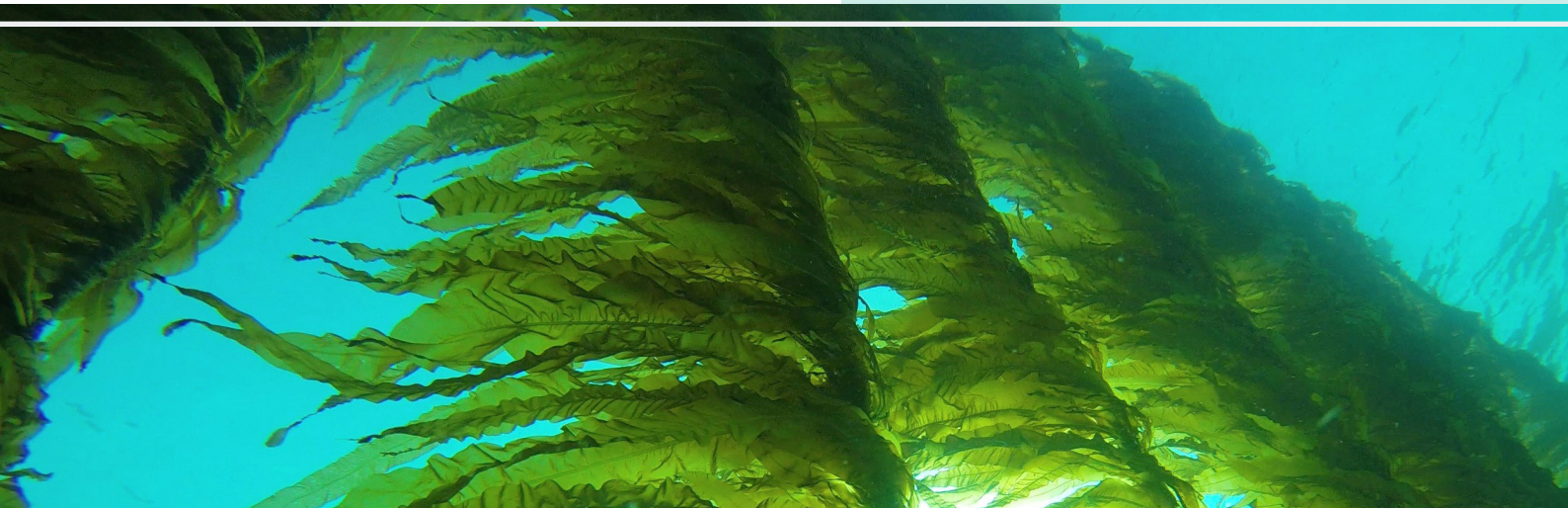
The research plan for the next three years will focus on optimizing a growth medium to achieve high yield at a low cost, and to optimize downstream processing conditions to ensure high nutritional value, functionality and cost-efficient yeast production.

Cultivation technologies for seaweed and downstream processing methods are being refined to develop novel seaweed-based feed resources. Emphasis will be on upgrading the nutrient value of the seaweed by a biorefinery process in order to make use of the entire biomass in the fermentation process to produce yeast and to isolate high-value bioactive components from the biomass.

Foods of Norway has a special focus on improving feed efficiency and robustness of farm animals and fish. Improvement in feed efficiency has a large impact on feed resource utilization, feed costs and the environment.

We have developed a method for direct selection of salmon with improved feed efficiency, based on stable isotopes in the feed. Over the next years we will evaluate whether this method can be used for other farm animals in large production systems.

Photos: Foods of Norway



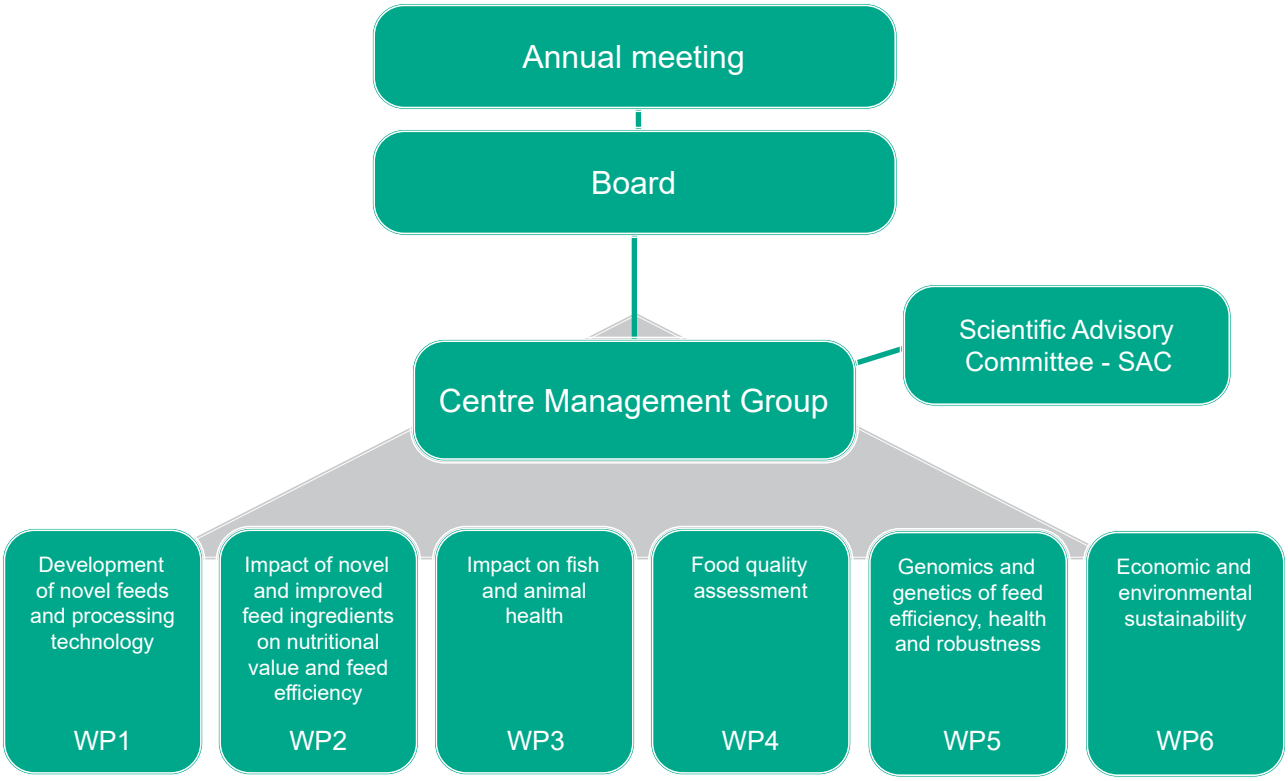
ORGANISATION

The Annual Meeting convenes once a year to discuss the centre's activities, present result highlights from the past year and discuss further plans.

The Board is the ultimate decision making body of the Consortium. The board's main responsibility is to ensure that the intentions and plans underlying the contract for the establishment of the Centre are fulfilled. The Centre Director is in charge of the operation of the centre, assisted by the Centre management group that consists of the Centre Director, the work package leaders, Centre coordinator and administrator.

The Scientific Advisory Committee (SAC) are leading international experts who can provide the centre quality assurance, inspiration and support in scientific matters. The members of the SAC are appointed for a period of two years to accommodate the need for different competences throughout the life of the center. The current SAC has three members:

- Birte Svensson, Professor at the Technical University of Denmark,
- Rune Waagbø, Program Director of Fish Nutrition Research at the Institute of Marine Research (IMR), Bergen, Professor II at University of Bergen (UiB), Department of Biological Sciences
- Georg Kau, former Vice President of DSM Nutritional Products Ltd



THE BOARD

Knut Røflo
Chair

Felleskjøpet Fôrutvikling (FKF)

Ragnhild Solheim
Deputy chair

NMBU, Research Department

Kari Kolstad
Member

NMBU / Faculty of Biosciences

Ågot Aakra
Member

NMBU / Faculty of Chemistry, Biotechnology and Food Science

Eirik Selmer-Olsen
Member

TINE

Christine Tørklep
Member *(until June)*

Denofa

Hege Rivedal Ødegaard
Member *(from June)*

Denofa

Eli Grindflek
Member *(from June)*

Norsvin

Nina Santi
Member *(until June)*

AquaGen

Cecilie Hultmann
Member *(from June)*

Nortura

Morten Sollerud
Member *(until June)*

Norilia

CENTRE MANAGEMENT GROUP

Margareth Øverland
Centre Director

Professor, NMBU
Faculty of Biosciences

Svein Jarle Horn
Leader WP1

Professor, NMBU
Faculty of Chemistry, Biotechnology and Food Science

Liv Torunn Mydland
Leader WP2

Researcher, NMBU
Faculty of Biosciences

Charles McLean Press
Leader WP3

Professor, NMBU
Faculty of Veterinary Medicine

Siv Borghild Skeie
Leader WP4

Professor, NMBU
Faculty of Chemistry, Biotechnology and Food Science

Gunnar Klemetsdal
Leader WP5

Professor, NMBU
Faculty of Biosciences

Gro Steine
Leader WP6

Centre Coordinator, NMBU
Faculty of Biosciences

PARTNERS

The Foods of Norway consortium comprises three faculties at NMBU and 19 partners in industry and innovation. We also work closely with several international partners and collaborators.

Academic partners

- NMBU`s faculties of
  - Biosciences
  - Chemistry, Biology and Food Science
  - Veterinary Medicine
- University of Copenhagen

International collaboration

- Aarhus University
- Swedish University of Agricultural Sciences
- University of Minnesota
- University of Western Australia
- University of Chile
- US Department of Agriculture (USDA - ARS)

Industrial partners

- Animalia
- AquaGen
- BioMar
- Borregaard
- Denofa
- Felleskjøpet Fôrutvikling
- Geno
- Lallemand
- Norilia
- Norske Felleskjøp
- Norsvin
- Nortura
- TINE
- Viken Skog
- Seaweed Solutions

Supporting partners

- Innovation Norway
- NHO Mat og Drikke
- The Federation of Norwegian Agricultural Cooperatives
- The Norwegian Farmers' Union

Photo: Shutterstock

COOPERATION BETWEEN PARTNERS

As a Centre for research-based innovation (CRI), cooperation between the partners in the centre is very important. The industry partners represent three sectors – agriculture, aquaculture and forestry.

The aim is to promote discussions and close collaboration, leading to new research ideas and innovation potential across sectors.

In 2020 two partner meetings were held, both digitally. The main topic of the April meeting was the results on yeast production from woody biomass and a techno-economic analysis on the topic, as well as a workshop to discuss the next steps going forward. The meeting in September focused on using seaweed as a feed resource.

In a bid to strengthen cooperation in the centre even further, a task force was established early 2019. This is a meeting platform for the industry partners, enabling them to address topics relevant across Foods of Norway such as sustainability, economy and the centre's business plan.

Several trials with yeast in diets for salmon have been carried out in 2020 in collaboration with several partners, including Lallemand, Borregaard, Denofa and BioMar. A new method for selecting salmon with higher feed efficiency has been developed by scientists from NMBU and AquaGen. Together with AquaGen and BioMar, researchers at NMBU conducted experiments with rainbow trout to adapt the method to a large-scale experiment in saltwater.

NMBU and Seaweed Solutions have collaborated on a method to extract bioactive components such as laminarin and fucoidan from cultivated sugar kelp in the biorefinery laboratory at NMBU.

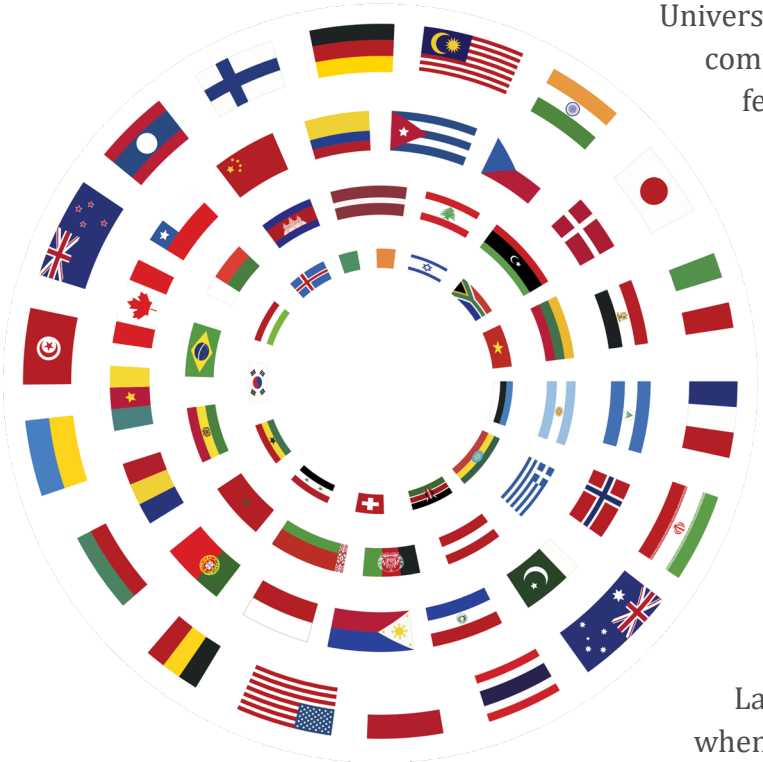
Felleskjøpet Fôrutvikling was granted a project to carry out a techno-economic analysis (TEA) of yeast, funded by Innovation Norway. The analyses were undertaken by Biocentrum AS, with contributions from Felleskjøpet, Borregaard, NMBU, Norilia, BioMar and Viken Skog. The results are important for further prioritisations in the centre.

INTERNATIONAL COOPERATION

Foods of Norway continued to work closely with several of our international collaborators in 2020

Researchers from NMBU in close collaboration with Seaweed Solutions and Nortura have continued their cooperation with the Institute of Agrifood Research and Technology (IRTA) in Spain. In 2020 this collaboration included mapping chemical properties in cured legs of lamb (fenalår) from animals which have been fed seaweed.

Postdoctoral fellow Byron Maximiliano Morales Lange from Pontificia Universidad Católica de Valparaíso in Chile has spent 2020 as a guest researcher in Foods of Norway. In cooperation with other researchers in the centre he is evaluating the health effects of yeast in feed for salmon.



Foods of Norway has two international partners, the University of Copenhagen and the Canadian company Lallemand, specializing in fermentation of yeast. During 2020 Foods of Norway has collaborated closely with the University of Copenhagen in planning experiments investigating yeast as a novel and functional feed ingredient for broiler chickens.

The centre's collaboration with Lallemand in 2020 includes planning of experiments, as well as evaluating and publishing results on yeast as a functional feed ingredient for Atlantic salmon.

Lallemand has also been a central partner when planning the upscaling of yeast production based on Bali sugars for field trials with salmon and piglets.

The University of Minnesota is a partner in the centre's work to upgrade the nutritional value of fibre-rich plant ingredients, such as rapeseed meal, by solid-state fermentation technology. The outcome of this research will be important for future work in the centre and will further strengthen this collaboration.

Meetings in 2020 were mostly digital, due to travelling restrictions and social distancing regulations because of the Covid-19 pandemic.

Photo: Shutterstock

International ongoing spin-off projects

Researchers in the centre are participating in an ERA-NET network (Sustainability of pig production through improved feed efficiency). The aim of the network is to share insights and results from research on local feed resources for pigs, and to study how best to assess how these results will affect the economy, society and environment.

RESEARCH HIGHLIGHTS IN 2020

1 Biomass processing and production of yeast

Foods of Norway has been studying the potential of underutilized unused biomass from the fish and meat industries in the production of yeast.

Development of yeast from trees and documentation of how we can use the yeast as a novel protein source is one of the main goals in Foods of Norway. At NMBU's Biorefinery Lab (NorBioLab) it is now possible to produce 10 kilos of yeast in a week - based on a repeatable and robust process developed in the centre. The yeast production process is ready for upscaling.

To get a better overview of the market for yeast-based single-cell protein, Menon Economics conducted a market analysis on behalf of the centre. The report shows that an increased focus on sustainability, restrictions on the use of antibiotic growth promotors and the development of new technology suggest that the market for yeast will grow, and that the price of this type of protein will rise.

Find the full report here: https://www.menon.no/wp-content/uploads/2019-110-Markedsanalyse-gj%C3%A6rbasert-encelleprotein.pdf

Spray drying yeast in the biorefinery lab at NMBU.

Photo: Foods of Norway

A Life Cycle Assessment (LCA) analysis for yeast based on second-generation sugar (Borregaards BALI sugar) has been done, showing that:

◊ Yeast produced from second-generation sugar had a significantly lower climate footprint than yeast produced from first-generation sugar
◊ Use of by-products from chicken instead of inorganic nitrogen reduces the climate footprint

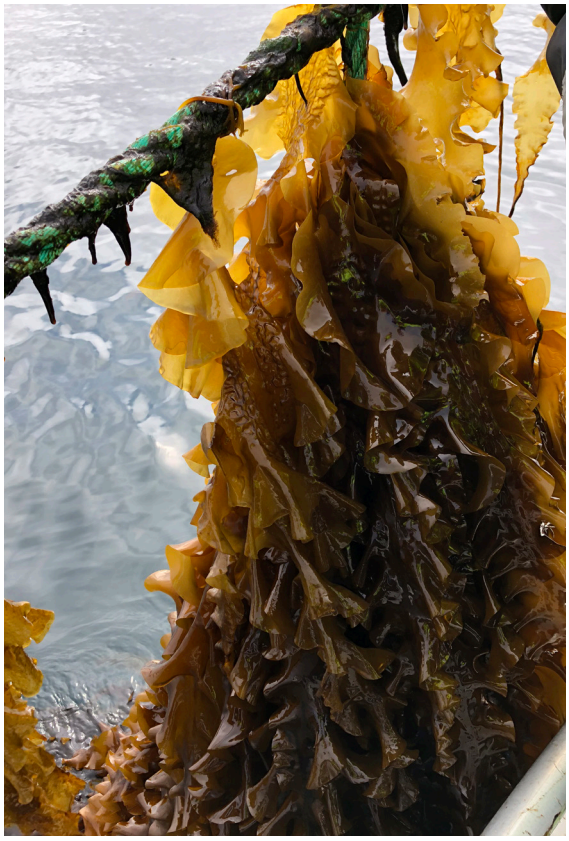
To further develop profitable production of yeast, costs also need to be evaluated.

Felleskjøpet Fôrutvikling received funding from Innovation Norway to carry out a techno-economic analysis (TEA) of yeast. The results show that second-generation sugar is the largest cost in the production of yeast. These results are important for further prioritisations in the centre.

Seaweed as a feed ingredient

The centre has developed and upscaled methods for biorefining seaweed, including extracting bioactive substances with beneficial health effects. This work has been performed at NorBioLab at NMBU. The bioactive substances will be used in functional feeds for salmon, chicken and pigs to improve animal health and welfare, and to increase the quality of meat products.

Experiments have also been carried out with sugar kelp in total mixed rations for lambs during the last five weeks before slaughter. The results show that lambs fed 2.5 or 5 per cent semi-dried, unprocessed seaweed have similar feed intake, growth rate, feed utilization and carcass quality to lambs fed grass and concentrate. The seaweed-based feed also had a positive effect on the nutritional value and product quality of the meat.



Saccharina latissima - or sugar kelp

Photo: Foods of Norway

2 **Testing the impact of novel feed ingredients**

Foods of Norway is evaluating the effect of novel feed ingredients on nutrient digestibility, growth performance and the health of farm animals and fish as well as the product quality of the meat and milk from farm animals and fish.

Several trials with yeast in feed have been carried out in 2020, including trials with piglets, cows and salmon. Experiments with up to 15 per cent yeast in pig feed showed good results for feed intake, growth rate and feed utilization. The feed had a positive impact on the intestinal health of the pigs, causing less diarrhoea and a favourable effect on the microbiome.

To document how processing affects the nutritional value and health effect of yeast, trials were performed with both whole yeast cells and yeast cells processed by autolysis from three different yeast species (*C. jadinii*, *W. anomalus*, *B. adenovorans*). Feed containing 40 per cent soybean meal and up to 40 per cent protein from yeast was given to salmon in fresh water.

Results so far have shown:

- Feed with a high level of soybean meal caused mild inflammation in the distal intestine of salmon.
- The effect of yeast on the intestinal health of salmon depends on the type of yeast and downstream processing method used.
- The *W. anomalus* and *C. jadinii* yeasts provided the best protection against intestinal inflammation.

Processing by autolysis increased the health effect of the yeast by changing the amount and properties of the cell wall components, β-glucans and mannoproteins.

Foods of Norway researchers have also examined the milk quality from cows fed yeast-based diets, proving that the yeast did not affect the product quality of milk. The cheese yield was equally high compared to soy in the feed and even higher compared to barley.

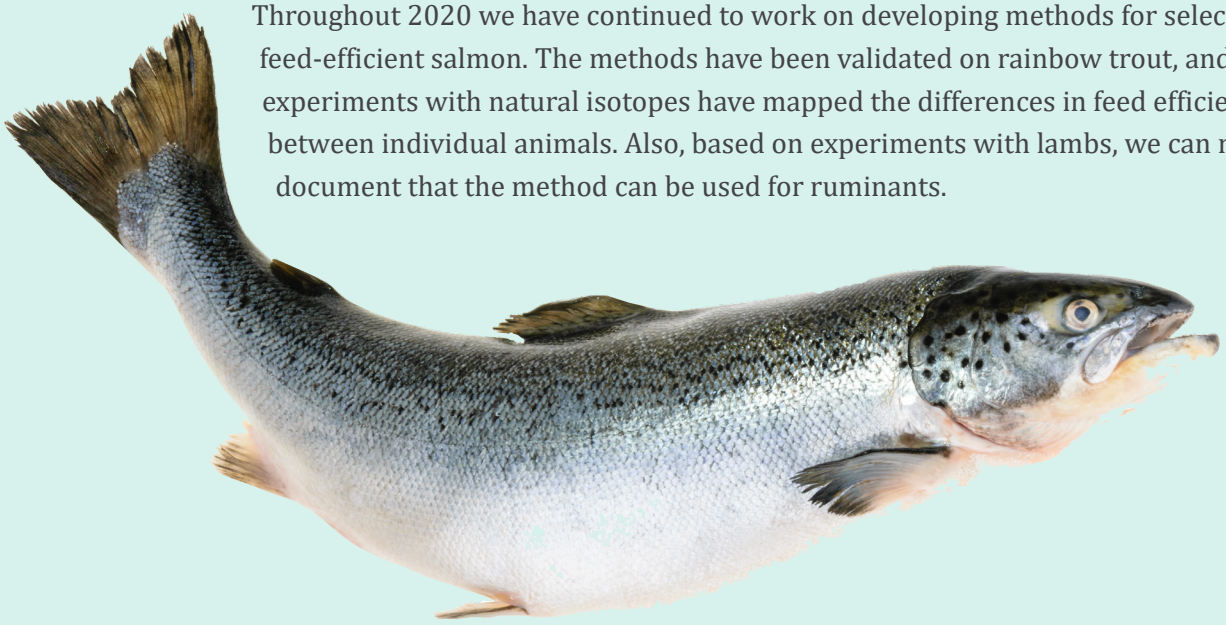
Feed containing protein from yeast from trees was given salmon in fresh water.

Photo: AquaGen

3 Genomics and genetics

Methods for direct selection for improved feed efficiency based on individual metabolic efficiency have been developed in Foods of Norway.

Throughout 2020 we have continued to work on developing methods for selecting feed-efficient salmon. The methods have been validated on rainbow trout, and further experiments with natural isotopes have mapped the differences in feed efficiency between individual animals. Also, based on experiments with lambs, we can now document that the method can be used for ruminants.



SPIN-OFF PROJECTS IN 2020

Two spin-off projects were granted funding in 2020.

NORDICFEED - Making fish feed from local waste streams

A new spin-off project, NORDICFEED, aims to enhance the performance, health and robustness of rainbow trout and Atlantic salmon at various life stages and environmental conditions fed optimized feed formulations based on sustainable microbial feed ingredients from locally available waste streams. The project will also investigate the economic aspects, regulatory constraints and environmental footprint of introducing by-products into the human food chain by bioconversion of waste streams into microbial ingredients.

The project will be a cooperation between three academic collaborators: Swedish University of Agricultural Sciences (SLU), Norwegian University of Life Sciences (NMBU) and Natural Resources Institute Finland (LUKE). In addition, each country also has an important industrial partner in the project: Vattenbrukscentrum Norr AB (Sweden), BioMar (Norway) and eniferBio Oy Ltd, a biotech startup created under VTT (Finland). The four-year project will start during spring 2021 and is led by professor Torbjörn Lundh at SLU.

Oil4Feed – High-value oils for feed from food by-products and woody biomass

There is an urgent need to find alternatives to fish oil used in feed for farmed fish. The OIL4FEED project aims at developing a process for producing microbial oils from animal fat by-products and second-generation sugars derived from Norwegian woody feedstock. The project will be led by professor Volha Shapaval at NMBU and is funded by the Norwegian Research Council.

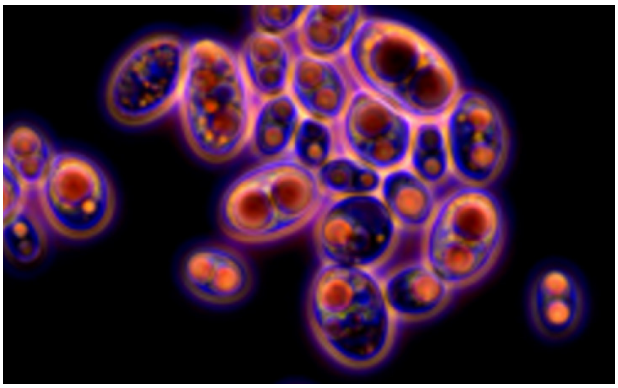


Photo: Oil4Feed

This will allow a new value chain from Norwegian by-products to microbial feed oils to be established for the first time in Norway, increasing the financial and environmental sustainability of Norwegian aquaculture, agriculture, forestry and food industry.

OIL4FEED will deliver a complete set of new insights into the effect of algal/fungal oil on the growth performance and health of fish.

Feeding lambs seaweed gives us better health

Seaweed in the lamb's trough improves meat quality and shelf life – and even benefits our health.

Seaweed lambs fed 2.5 or 5 per cent dried, unprocessed seaweed have similar feed intake, growth rate, feed utilization and carcass quality to lambs fed grass and concentrate.

Photo: Foods of Norway

It is a win-win story when feeding seaweed to lambs. A trial evaluating the effect of adding seaweed from the Norwegian coastline to lambs' feed, shows that meat from seaweed-fed lambs is more tender, has better colour and longer shelf life.

Per Berg is director of research at Nortura

Photo: Nortura

Studies also revealed a positive impact on the taste of the meat, and even some unique health benefits for the consumer.

Per Berg is director of research at Nortura, Norway's leading manufacturer of meat and eggs. He has followed the project closely and highlights the positive effects seaweed has on iodine levels in the meat we eat.

- This meat's iodine content is high enough to qualify for labelling, and it is seldom we can use claims like this for our products. There is too little iodine in the food we eat, and iodine is necessary for our production of thyroid

hormones which are important for our energy levels as well as developing the brain and nervous system, he says.

Quality and health

The meat was tested by a professional tasting panel as well as by people visiting the food and tech festival SmakÅs, where the meat was made into meatballs and served next to meatballs from lambs that have not been fed seaweed. The feedback was clear: the seaweed appears to give the meat a more herbal, unique flavour – appreciated by the testers.

The project is part of Foods of Norway's research on novel feed ingredients from renewable, Norwegian bioresources. Previous studies from the centre confirm that seaweed can be used as a feedstock to produce yeast as a protein source in diets of salmon and monogastric animals like pigs.

The lambs in this trial, however, were given natural, chopped seaweed, without any bioprocessing. They also seemed to take to the flavour of the new feed.

From tasting to table

Seaweed is a resource there is plenty of in Norway, thanks to the country's extensive coastline. Sustainability is important for consumers - and for Nortura, Per Berg says.

- Local commodities are in demand, and especially when it comes to innovative products where there are health benefits for the consumer - even if the price is higher, he states.

However, successful lab results still have a way to go before making it to the dinner table, Berg points out. The results need to be verified and upscaled.

- Still, the findings so far are more than promising, and I would be surprised if further research would lead to any other conclusions. And where there are marketing opportunities, there is always a way to make it happen, says Per Berg.

The lambs in the trial seemed to take to the flavour of the new feed.
Photo: Foods of Norway

Unveiling the hidden value of Norwegian seaweed

Seaweed can be a lot more than a vegetable. Researchers in Foods of Norway at NMBU aim to find out how. For instance with its potential to make our food better and our animals healthier.

More than a tonne of frozen sugar kelp has been processed in the Biorefinery lab at NMBU

Photo: Bente Paulson

In the biorefinery lab at the Norwegian University of Life Sciences (NMBU) in Ås, frozen blocks of organic matter are thoroughly ground before being transferred into a large tank reactor. The substance is frozen sugarkelp, or *Saccharina latissima,* a brown seaweed harvested from one of Europe's largest seaweed farms located in Frøya on the west coast of Norway. Over the past months Foods of Norway researchers have processed more than a tonne of this biomass.

The seaweed is mixed with hot water and acid in the pilot-scale tank reactor and the mixture is left stirring at high temperature, allowing the valuable polysaccharides from the seaweed to percolate.

- It is almost like brewing a very large cup of tea, says Leszek Michalak.

Through this process researchers are developing a method to extract products from the seaweed with beneficial health effects for farmed salmon, chickens and other farm animals.

The parts more valuable than their sum

Leszek Michalak is responsible for the seaweed processing. He emphasizes how seaweed is a resource which can be used in its entirety, and how he uses the zero-waste approach in order to extract everything he can from the biomass. After two rounds of extraction and filtration the residual product can actually be used as a fertiliser for plants.

The biomass is thoroughly ground up.
Photo: Bente Paulson

There is a long history of using seaweed as feed for animals and there are long-standing traditions in many places around the world for consuming it as a vegetable. The aim of this trial is to investigate the value of the individual compounds which can be extracted from the seaweed after the biomass is broken down. Michalak gets technical:

- The individual components of the seaweed have interesting biological properties, and the parts are much more valuable than their sum. We are working towards a cost-efficient extraction and separation of these compounds, with a view to including them in multiple value chains. Fucoidan for instance has numerous bioactivities; it can stimulate the immune response and act as an antioxidant or a prebiotic in the animal or human gut, and we have plans for feeding trials using fucoidan as a functional ingredient.

Researcher in Foods of Norway,
Photo: NMBU

- Laminarin is a beta-glucan, a glucose polymer similar to those found in a number of plants we humans already eat, such as oats. We already know that beta-glucans have health benefits, and we will test the laminarin on cell cultures and in feeding trials. One of our by-products, alginate, can be used as a stabilizer in food processing, or be hydrolysed and included in the production of yeast, which is a single-cell protein source. Fortunately in this work we benefit from NMBU's extensive in-house expertise on enzymatic processing, he says.

It is almost like brewing a very large cup of tea, Michalak explains

Photo: Bente Paulson

Used for making yeast

Thus according to Michalak, the processes will break down the seaweed into high-value components which will not only be used in fish and animal feed but also find many other applications. Keeping in mind that the ability to bring any findings to market is an important factor in the research, the methods are selected based on the criteria of low cost and minimal environmental impact in order to facilitate the scalability of the process.

Professor Margareth Øverland is very enthusiastic about the headway being made in acquiring greater insights when it comes to seaweed, a biomass which we have in abundance along Norway's long coastline.

- This process is based on using all the biomass in the most cost-efficient way, she says.
- The seaweed hydrolysates can together with tree sugars be used as a nutrient source in growth media to produce yeast. Yeast can be used as a high-quality protein source in animal and fish feed – which is one of our main areas of expertise in Foods of Norway, she explains.

Yeast made from a combination of seaweed hydrolysate and sugars from spruce trees (Borregaard's BALI™ sugar) has already been used in feed for Atlantic salmon, with excellent results. Looking ahead, Leszek Michalak and Foods of Norway are hoping to examine the entire value chain from seaweed harvest to health-promoting feed ingredients:

- Seaweed is a clean and sustainable source of potential ingredients which can be used in the production of medicines and as a food additive, as well as food and feed ingredients. Importantly, it does not compete with land-based agriculture for space or resources. If we can document the many valuable applications of the products we are able to extract from the biomass, seaweed will become a more attractive raw material. Eventually, this will grow the market for seaweed, more biorefineries and processing plants will be developed, and seaweed will become a valuable industrial commodity rather than just an exotic vegetable, says Leszek Michalak.

The brew is further processed to collect all the different components

Photo: Bente Paulson

Just another day in Foods of Norway:

Fish on four wheels

Will tomorrow's fish feed grow on trees? 450 small fish in seawater tanks by the Oslo Fjord will hopefully bring us a little closer to the answer.

Carefully placed in bags with water and oxygen, the 450 fish are on the road to the research facilities.

Photo: Bente Paulson

It is a Tuesday morning in September, and 450 fish are being packed up and will soon be on their way from the fish lab at the Norwegian University of Life Sciences (NMBU) in Ås to the research facilities at the Norwegian Institute for Water Research (NIVA) in Solbergstrand by the Oslo Fjord.

During the next five weeks the fish will gradually be exposed to seawater while being fed novel feed based on sustainable resources – research right at the heart of Foods of Norway. The protein in their feed will be partially replaced with yeast grown on sugars from Norwegian spruce trees and by-products from the poultry industry.

From tree to sea

In Ås, the fish are weighed and carefully placed in large plastic bags filled with water and oxygen, before being placed in the back of a van that will take them to the research facilities

The fish are carefully weighed and measured as they are placed in the plastic bags,

Photo: Bente Paulson

in Solbergstrand just outside the little coastal town of Drøbak. NMBU and Foods of Norway are fortunate to have access to their own facilities at NIVA, providing opportunities for unique trials, monitoring and dissection.

The 12-kilometre drive to the research institute at Solbergstrand is a leisurely one. The winding country road takes us through a short stretch of tall spruce trees, a reminder of what we are doing here. The purpose of this trial is to document the use of feed made from trees, and to see the effects this feed can have on the intestinal health of the fish as well as their health in general. The fact that this experiment is performed while transitioning them from freshwater to saltwater, their most vulnerable phase, makes the findings even more interesting.

The yeast used in this experiment has been cultivated in the biorefinery laboratory NorBioLab at NMBU from residual biomass from Norwegian forestry and hydrolysed protein from by-products from the poultry industry. From this yeast researchers and technicians in the centre have manufactured the feed in the laboratory at NMBU.

- We believe that wood-based yeast can improve the health of salmon during their most vulnerable stage of life, the transition from freshwater to seawater, explains PhD student in Foods of Norway Jeleel Opeyemi Agboola.

- This is what we hope this experiment will help shed light on. We are also documenting what other positive effects yeast-based feed can have, beyond its nutritional value. This is a follow-up trial from our previous results in freshwater, where yeasts have proved to improve the Atlantic salmon's immunity against diseases, intestinal health and growth.

Jeleel is responsible for the trial, which is part of his doctoral degree. Together with master's student Dominic D. Mensah and researcher Sergio Rocha he makes up the team transporting the fish from Ås to Solbergstrand.

PhD student in Foods of Norway Jeleel Opeyemi Agboola

Photo: NMBU

We believe that wood-based yeast can improve the health of salmon during their most vulnerable stage of life, the transition from freshwater to seawater.

Jeleel Opeyemi Agboola, PhD student in Foods of Norway

Valuable research facilities

Upon arriving at NIVA, the bags with the fish are carefully carried into a room with 18 tanks, each holding 25 fish. Foods of Norway has unique access to this room, which for this experiment is priceless, says Jeleel. The facilities are right on the shore, and the use of these tanks can help simulate the water quality and ecology the fish would normally live in.

- When using these facilities, we can conduct the trial in similar conditions as in the sea. In this way, knowledge gained from this trial will be available to stakeholders in Norwegian salmon farming, such as fish farmers and feed manufacturers, in order to improve yield and overall productivity, he emphasizes.

In about five weeks, the 450 fish will be dissected and analysed. The research team will look at the microbiotic culture in their intestines, but also study immune responses in the spleen and head-kidney for indications relating to health.

However, until then 450 small salmon must be cared for and fed. Every day – for five weeks. The amount of feed they digest must be monitored and documented daily by Jeleel or one of his colleagues, by measuring the amount of feed falling to the bottom of the tank.

Based on this trial, Jeleel and his colleagues in Foods of Norway will be able to document ground-breaking research. Meanwhile, the fish swim around in their tanks, munching on food made in a lab in Ås, totally unaware of the importance of their existence.

The fish are eased into their new environment, and are monitored daily.

Photo: Bente Paulson

RECRUITMENT

Foods of Norway increased its staff with researchers and two new senior research technicians in 2020

Christine Haugen

Senior Research Engineer

Molecular Biology

Khaled Itani

Researcher

Poultry Nutrition

Sergio Rocha

Researcher

Microbiology and immunology assessment

Veronica Blihovde

Senior Research Engineer

Molecular Biology

KNOWLEDGE SHARING

The researchers in Foods of Norway are often invited to participate in meetings and conferences as keynote speakers, panel participants or as presenters of our research and results.

Even though 2020 became a very digital year, our researchers have participated in several scientific conferences and webinars.

As an example, researcher Hanne Dvergedal presented her research on feed efficiency for salmon and the indications it may have for other species, at a meeting for one of the major swine genetics companies, Norsvin Topigs.

Ingrid Marie Håkenåsen presented her work with yeast-based feed for weaning pigs at Forsker Grand Prix in Oslo, in September 2020.

Photo: Yngve Vogt, UiO

PhD student Ingrid Marie Håkenåsen was one of ten young scientists picked out for the Research Council's Researcher Grand Prix (Forsker Grand Prix), where she presented her work with piglets and feed based on Norwegian woody biomass.

Centre director Margareth Øverland participated in several events, one of which was the 5th International Feed Processing Technology Symposium in Singapore, discussing the Development and use of yeast from forest in aquafeed. She also participated in several major Norwegian events as a knowledge provider on novel feeds in the blue and green sectors, contributing with a perspective on innovation and self-sufficiency.

One of the digital events of 2020.

Professor Svein Jarle Horn, along with professor Øverland, was in March invited by The Norwegian Biotechnology Advisory Board (Bioteknologirådet) to discuss biotechnology's role in the green shift.

COMMUNICATION & DISSEMINATION

Foods of Norway's research and innovations are constantly being noticed by both domestic and international media, and in 2020 the dissemination of news was the result of both reactive and proactive communication activities.

Due to Covid-19 restrictions there have been few opportunities for the centre to invite the media to our facilities, and some planned media visits had to be cancelled. Several interviews have been conducted, recorded, and published digitally, for example for Norwegian radio (NRK P2) and some international news outlets. Our proactive communication efforts have also been fruitful. We have a good standing with the media, and our contributions are welcome. We have developed even closer connections with relevant media during 2020, which will be valuable for the coming years.

The centre's communication strategy going forward will be the continued focus on our main target audiences: decision and policy makers, farmers' associations, other stakeholders, and the general public in Norway. We also aim to continue building our brand as a knowledge provider for feed and food industries as well as agriculture and aquaculture industries in Norway and abroad.

International media coverage of Foods of Norway is continuous.

Article from FeedInfo, 07 January 2020

FEEDINFO

INTERVIEW: Why Grow Yeast on Tree Waste? To Address N. Europe's Protein Deficit

07 Jan 2020

Source: FEEDINFO

Fishmeal , Our content

07 January 2020- First, by-products from lignocellulose (woody biomass) are cut into wood chips. Next, the tree fibers are spilt into lignin, cellulose and hemicellulose by thermo-chemical processing. Using tailor-made enzymes, the cellulose and hemicellulose are broken down into simple sugars. Those sugars go into a fermenter, along with nitrogen and other nutrients, and then special yeast strains are added to grow on these nutrients. That yeast is harvested, washed, and dried, and may be subject to further processing, such as cracking to open the cell walls. Then it is ready to be used in animal feed as a protein source.

Kortreist raps i fôret gir bedre kjøtt og dyrehelse

Viten

Margareth Øverland ,
professor, senterleder, Foods of Norway

Forsøk med fôring av norsk edelgris viser positiv effekt av lokale råvarer. Det kan gjøre oss mindre avhengige av import.

I en verden i krise ser man tydelig behovet for en større grad av selvforsyning for å sikre mat på bordet og fôr i fjøset. Husdyrnæringen i Norge er i stor grad avhengig av import av proteinrike råvarer. Men det finnes også gode, nære råvarer som egner seg godt som proteinkilder til dyrene våre. Kortreist raps viser seg å gi bedre kjøttkvalitet i tillegg til en helsegevinst hos griser.

I fjøset på Ås gård har vi i forskningssenteret Foods of Norway gjort flere forsøk med norsk edelgris som vi har gitt kortreist fôr basert på raps fra Norge og nabolandene våre, sammen med korn og åkerbønner dyrket i Norge. Disse lokale råvarene har vi brukt som alternativer til andre proteinkilder, for eksempel soya, som vi i dag importerer fra utlandet. Vi fant ut at grisene som fikk det kortreiste fôret, vokste like mye og med like god fôrutnyttelse og kjøttprosent som de grisene som fikk fôr basert på importert soya.

FAKTA

Dette er FeedMileage

Forsøkene er finansiert av Foods of Norway og FeedMileage.

Forskningssenteret Foods of Norway (SFI), som ligger på Norges miljø- og biovitenskapelige universitet (NMBU) i Ås, jobber med å utvikle lokale fôrressurser fra blå og grønn biomasse med bruk av ny teknologi og metoder.

Prosjektet FeedMileage er finansiert fra Bionær-programmet i Norges forskningsråd.

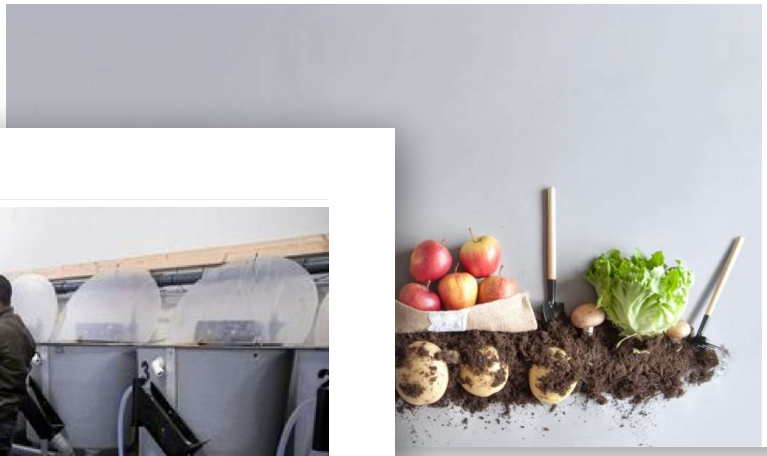
Article from Afteposten 25 June 2020 - based on findings from our fellow NMBU project

ASIAN SCIENTIST

October 22, 2020 Features By IPI

The Frontiers Of Food

The key to securing long-term food security is investing in innovative technologies like alternative proteins, said experts at IPI's AgriFood Innovation Webinar.



Article from Asian Scientist 22 Oct 2020

IntraFish

Stipendiat i Foods of Norway, Jeleel Opeyemi Agboola (lengst til høyre), sammen med masterstudent Dominic O. Mensha, forskningstekniker Sergio Rocha og senterleder for Foods of Norway, professor Margareth Øverland, har sørget for at småfisken fikk en så lite stressende reise som mulig. Foto: Bente Paulson, Foods of Norway

Kommer fremtidens fiskefôr fra skogen?

I sjøvannstanker i Drøbak svømmer 450 småfisk som skal hjelpe oss litt nærmere svaret.

7. november 2020 14.00 OPPDATERT 7. november 2020 14.00

Av Bente Paulson/NMBU

Det er en tirsdag i september, og 450 smålaks, også kalt smolt, skal fraktes fra fiskelaben på Norges miljø- og biovitenskapelige universitet (NMBU) i Ås til NIVAs forskningsstasjon ved Solbergstrand i Drøbak.

I fem uker skal fiskene svømme i tanker hvor de gradvis skal tilvennes saltvann. Samtidig vil fiskene få et fôr basert på alternative proteinkilder: Proteinet i fiskefôret skal delvis byttes ut med gjær som er dyrket av sukker fra norske grantrær, og tilsatt biprodukter fra kyllingindustrien.

Fra trær til gjær til merd

På fiskelaben veies og pakkes fisken omhyggelig i store poser med vann og oksygen. Deretter tas de med på en rolig biltur de om lag 12 kilometerne til Solbergstrand, og NIVA. Her disponerer NMBU og Foods of Norway egne fasiliteter for forsøk, overvåking og slakt.

Les også: Et av de vanligste plantevernmidlene funnet i lakseför er nå forbudt i Europa

Underveis tar den svingete landeveien oss gjennom en kort strekning med høystrakte bartrær, en liten påminnelse om hvorfor vi er her. For hensikten med akkurat dette forsøket er å bruke fôr som er laget av trær, og å se hvilken effekt dette fôret kan ha på tarmhelsen til fisken, i tillegg til på fiskens helse generelt.

At dette forsøket gjøres i den sårbare fasen hvor smolt overføres fra ferskvann til saltvann gjør funnene enda mer interessante. Gjæren brukt i fôret har Foods of Norway selv laget på bioraffinerilaboratoriet NorBioLab på NMBU, fra restbiomasse fra norsk skogdrift og hydrolysert protein fra biprodukter fra kyllingindustrien.

FOODS OF NORWAY

- Foods of Norway er et senter for forskningsdrevet innovasjon (SFI) ved Norges miljø- og biovitenskapelige Universitet (NMBU) i Ås.
- Senteret har 20 industri- og innovasjonspartnere.
- Foods of Norway utvikler alternative proteinråvarer til bruk i fôr til både husdyr og fisk.
- Forskningen fokuserer på bruk av biomasse fra skogen og tare fra sjøen for å utvikle nye fôrråvarer.

Article from IntraFish 07 Nov 2020

IN NUMBERS: COMMUNICATION OUTPUT IN 2020

+ 12 %

We increased the number of Facebook-followers by 12 per cent.

+ 15 %

We increased the number of Twitter-followers by 15 per cent.

307

The average reach of our Facebook posts.

Articles in editorial media	Norwegian	33
	International	6
Newsletter*	Sent out	1
	Subscribers	169
Facebook	Followers	902
	Average reach	307
	Average engagement (post clicks / reactions, comments & shares)	19 / 14
Twitter	Followers	482
	Impressions	22 730

* Created in December 2020, in accordance with GDPR.

Publications list

- Agboola, J. O., Øverland, M., Skrede, A., Hansen, J. Ø. **Yeast as major protein-rich ingredient in aquafeeds: A review of the implications for aquaculture production.** *Reviews in Aquaculture* 2020; Volum 13(2), pp.949-970.
- Coll Brasas, E., Possas, A., Berg, P., Grabez, V., Egelandsdal, B., Bover-Cid, S., Fulladosa, E. **Physicochemical characterisation of restructured Fenalår and safety implications of salt and nitrite reduction.** *Food Control* 2020; Volum 119, pp.1-8.
- Dvergedal, H., Harvey, T. N., Jin, Y., Ødegård, J., Grønvold, L., Sandve, S. R., Våge, D. I., Moen, T., Klemetsdal, G. **Genomic regions and signaling pathways associated with indicator traits for feed efficiency in Atlantic salmon (*Salmo salar*).** *Genetics Selection Evolution* 2020; Volum 52, Article 66.
- Dvergedal, H., Mydland, L. T., Klemetsdal, G. **The change in 15N stable isotope content in muscle, liver and mid-intestine in juvenile Atlantic salmon (*Salmo salar*) under starvation.** *Aquaculture Research* 2020; Volum 51(12), pp.5265-5268.
- Dvergedal, H., Sagaye, A., Klemetsdal, G., Mydland, L. T., Øverland, M., Olsen, H. F. **Individual phenotyping of feed efficiency in lambs fed stable isotopes through maize silage.** *Livestock Science* 2020; Volum 239, Article 104173.
- Dvergedal, H., Sandve, S. R., Angell, I. L., Klemetsdal, G., Rudi, K. **Association of gut microbiota with metabolism in juvenile Atlantic salmon.** *Microbiome* 2020; Volum 8(1), Article 160.
- Girio Da Costa Cruz, A. R., Sterten, H., Steinhoff, F. S., Mydland, L. T., Øverland, M. ***Cyberlindnera jadinii* yeast as a protein source for broiler chickens: effects on growth performance and digestive function from hatching to 30 days of age.** *Poultry Science* 2020; Volum 99(6), pp.3168-3178.
- Gomez, D. L., Kòsa, G., Hansen, L. D., Mydland, L. T., Passoth, V., Horn, S. J., Eijsink, V. **Production and characterization of yeasts grown on media composed of spruce-derived sugars and protein hydrolysates from chicken by-products.** *Microbial Cell Factories* 2020; Volum 19(1), Article 19.
- Grabez, V., Egelandsdal, B., Kjos, N. P., Håkenåsen, I. M., Mydland, L. T., Vik, J. O., Hallenstvedt, E., Devle, H. M., Øverland, M. **Replacing soybean meal with rapeseed meal and faba beans in a growing-finishing pig diet: Effect on growth performance, meat quality and metabolite changes.** *Meat Science* 2020; Volum 166, Article 108134.
- Håkenåsen, I. M., Øverland, M., Ånestad, R., Åkesson, C. P., Meenakshi Sundaram, A. Y., Press, C. M., Mydland, L. T. **Gene expression and gastrointestinal function is altered in piglet small intestine by weaning and inclusion of *Cyberlindnera jadinii* yeast as a protein source.** *Journal of Functional Foods* 2020; Volum 73, Article 104118.
- Iakhno, S., Umu, Ö. C. O., Håkenåsen, I. M., Åkesson, C. P., Mydland, L. T., Press, C. M., Sørum, H., Øverland, M. **Effect of *Cyberlindnera jadinii* yeast as a protein source on intestinal microbiota and butyrate levels in post-weaning piglets.** *Animal Microbiome* 2020; Volum 2, Article 13.

- Lagos, L., Kashulin Bekkelund, A., Skugor, A., Ånestad, R., Åkesson, C. P., Press, C. M., Øverland, M. ***Cyberlindnera jadinii* yeast as a protein source for weaned piglets – Impact on immune response and gut microbiota.** *Frontiers in Immunology* 2020; Volum 11, Article 1924.
- Lagos, L., Leanti La Rosa, S., Arntzen, M. Ø., Ånestad, R., Terrapon, N., Gaby, J. C., Westereng, B. **Isolation and Characterization of Extracellular Vesicles Secreted In Vitro by Porcine Microbiota.** *Microorganisms* 2020; Volum 8(7), Article 983.
- Øverland, M. **Kortreist raps i fôret gir bedre kjøtt og dyrehelse.** *Aftenposten (morgenutg.: trykt utg.)* 2020 p.46.

Statement of accounts

Foods of Norway costs 2020 (1000 NOK)

Host NMBU	Industry partners (Norway)	International partners	Equipment	Total costs
20 897	5 040	56	0	25 993

Foods of Norway funding 2020 (1000 NOK)

Host NMBU	Industry partners (Norway)	International partners	Research Council	Total funding
5 261	6 815	206	13 711	25 993

Foods of Norway – 237841/O30

List of personnel 2020

Key researchers	
Name	**Main research area**
Margareth Øverland	Centre director; Feed ingredient evaluation
Vincent Eijsink	Fundamental and applied enzymology; bioprocessing; management
Svein Jarle Horn	Bioprocessing, applied enzymology, management
Liv Torunn Mydland	Process; feed ingredient evaluation
Charles Press	Veterinary pathophysiology, veterinary immunology
Henning Sørum	Bacteriology, pre- probiotics, microbiota, antibiotic resistance, fish diseases
Siv Skeie	Product quality
Gunnar Klemetsdal	Genetics; nutrition; feed efficiency
Gro Steine	Economics and sustainability

Permanent research staff		
Name	**M/F**	**Topic**
Anne-Helene Tauson	F	Monogastric nutrition, physiology and metabolism
Bjørg Egelandsdal	F	Product quality of meat
Bjørge Westereng	M	Biorefining facilities, bioprocesses, analytics
Randi Sørby	F	Veterinary pathology
Nils Petter Kjos	M	Pig nutrition
Hanne Fjerdingby Olsen	F	Life cycle assessment

Postdoctoral researchers with financial support from the centre budget		
Name	**M/F**	**Topic**
Magnus Arntzen	M	Analytics; characterization of biomass and process fractions
Jon Øvrum Hansen	M	Bioprocessing
Fanny Buffetto	F	Bioprocessing and valorization of brewers' spent grain
Vladana Grabez	F	Meat quality, proteomics
Alex Crawford	M	Zebrafish screening.
Hanne Dvergedal	F	Feed efficiency in fish
Özgun Candan Onarman Umu	F	Gut microbiota
Leszek Michalak	M	Processing of seaweed
Live Heldal Hagen	F	Bioinformatics on gut microbiota
David Lapeña Gomez	M	Bioprocessing, enzymatic processes, fermentation
Sergio Da Rocha	M	Microbiology and immunology assessment
Tina Graceline Kirubakaran	F	Bioinformatics
Leidy Lagos	F	Pig nutrition, health
Caroline Marcussen	F	Yeast in diets for broiler chickens

Postdoctoral researchers working on projects in the centre with financial support from other sources			
Name	**M/F**	**Funding**	**Topic**
Peng Lei	F	NFR/Ind	In vitro screening of feed components for health effects
Brankica Djordjevic	F	NFR/Div	Fish nutrition and health
Jørgen Ødegaard	M	NMBU	Genomics of feed efficiency

PhD students with financial support from the centre budget		
Name	**M/F**	**Topic**
Mette Hofossæter	F	Animal health
Stanislav Iakhno	M	Gut microbiota
Martine Olsen	F	Influence of feed on milk quality
Jeleel Opeyemi Agboola	M	Downstream processing of yeast, salmon nutrition and health

PhD students working on projects in the centre with financial support from other sources			
Name	**M/F**	**Funding**	**Topic**
Ingrid Marie Håkenåsen	F	NFR	Nutrition, novel protein sources, nutrition effect on performance, gut function and health.
Pabhoda Weththasinghe	F	Nordic CoE	Growth performance and health in salmon
Eirin Stork	F	NMBU	Product quality of milk

Master students		
Name	**M/F**	**Topic**
Ann Jorun Hansen Hoøen	F	In vitro digestion/methane potential evaluation of different concentrates used in different forage-to-concentrate ratios
Ingvild Solhjem	F	Feeding behaviour of dairy cows fed a diet with protein derived from yeast (Candida utilis) compared with diets containing soybean meal and barley
Thea Brustad	F	Effects of different silage additives on grass silage chemical composition and in vitro NDF degradation characteristics
Pernille Margrethe Olsen	F	Fermentation for Single Cell Protein Production
Kristin Heggen	F	Effects of Candida utilis as a protein source and replacement of soybean meal and yeast with barley on feed utilization and nitrogen use efficiency in dairy cow diets
Ole Berner Bondø	M	Digestibility of grass silages; comparison of in sacco / in vitro rumen degradation, methane production assay and total digestibility in sheep
Maren Oftebro	F	Enzymatic saccharification of the polysaccharides in Saccharina latissima (L.)
Dominic Duncan Mensah	M	Effect of yeast in counteracting soybean meal induced enteritis in Atlantic salmon
Reidun Lund	F	Effect of functional feed in diets for Atlantic salmon from two family groups with low and high level of resilience on growth performance kept in fresh water and sea water
Ashwath Gaudhaman	M	Growth performance, stress and immune responses in Atlantic salmon (Salmo salar, L) from two different families fed with bioactive components

PhD degrees		
Name	**M/F**	**Topic**
Håkon Kaspersen	M	Quinolone resistant Escherichia coli in Norwegian livestock - A comparative genomics study

Visiting researchers				
Name	**Period**	**M/F**	**Affiliation**	**Topic**
Byron Maximiliano Morales Lange	15.10.19-	M	Catholic University of Valparaíso	Mucosal immunity

FOODS OF NORWAY

Annual report 2020

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