ANNUAL REPORT
2019

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

Foods of Norway reached several important milestones in 2019. We passed our midway evaluation, three PhD dissertations were completed, and we welcomed two new industry partners with valuable expertise and technology into the centre.

I am very proud that, with our green light from the Research Council of Norway, the centre can continue achieving important results. The feedback from the evaluation was very positive; we are a well-organized centre that works closely with industrial partners and with great potential for innovation and value creation.

Three PhD students successfully completed their degrees this year. Hanne Dvergedal defended her thesis on new methods for improving feed efficiency of fish. David Lapeña Gomez has studied the potential of converting sugar from Norwegian wood and by-products from Norwegian meat and fish industries into protein-rich yeast; and Ana Cruz has documented yeast as a sustainable and local feed resource on growth performance and health of piglets and broiler chickens.

A major milestone was when Lallemand, a world leader in yeast fermentation, joined the Foods of Norway consortium. Their strong expertise in fermentation technology and access to large-scale infrastructure will be important in further developing the centre's technology. We also welcomed BioMar, one of the leading suppliers of high-performance feed to the global aquaculture industry, as an industry partner. Together with our partners we have established a task force, enabling us to work together on topics like economy, sustainability, commercialisation and regulations.

Research carried out in 2019 includes a large trial feeding yeast to dairy cows, and we also ran a trial feeding seaweed to lambs – resulting in a healthier meat product. We have also performed laboratory trials feeding salmon various yeast strains that were exposed to different downstream processing conditions. These results will be important for our next steps in Foods of Norway.

We are now halfway through our period of operation, having spent the past four years building the centre as a knowledge platform. This means that we can pave the way toward bringing feed innovations closer to commercialization. This includes assessment of the environmental impact of new feed solutions, as well as the economic and technological aspects of upscaling production. I am excited to see where 2020, and the following years, will take us.

Centre Director,
Professor Margareth Øverland

Margareth Øverland

"We are a well-organized centre that works closely with industrial partners and with great potential for innovation and value creation

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

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

Sustainability of future farmed fish and animal production will depend on the increased use of local and novel feed ingredients. Novel feed ingredients should be produced from resources not suitable for food and have a low environmental impact. 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. This can provide a basis to produce novel feed ingredients.

Photo: Sandeep Sharma

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 **(see p.10)**, each led by an NMBU researcher and with industry partners well integrated in the work. Research is multidisciplinary with close synergies across the work packages.

Foods of Norway will continue to develop microbial ingredients, such as yeast as a protein source in diets for farmed animals and farmed fish. The research plan for the next three years will focus on optimizing the growth medium to achieve high yield at a low cost, and to optimize the downstream

processing conditions to ensure high nutritional value, functionality and cost-efficient yeast production. We are currently working on finding the best yeast strains that grow well on this media.

Cultivation technologies for seaweed and downstream processing methods are being refined to develop novel seaweed-based feed resources. A major emphasis will be to upgrade the nutrient value of the seaweed by a biorefinery process 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. Improvements 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 if this method can be used for other farm animals in large production systems.

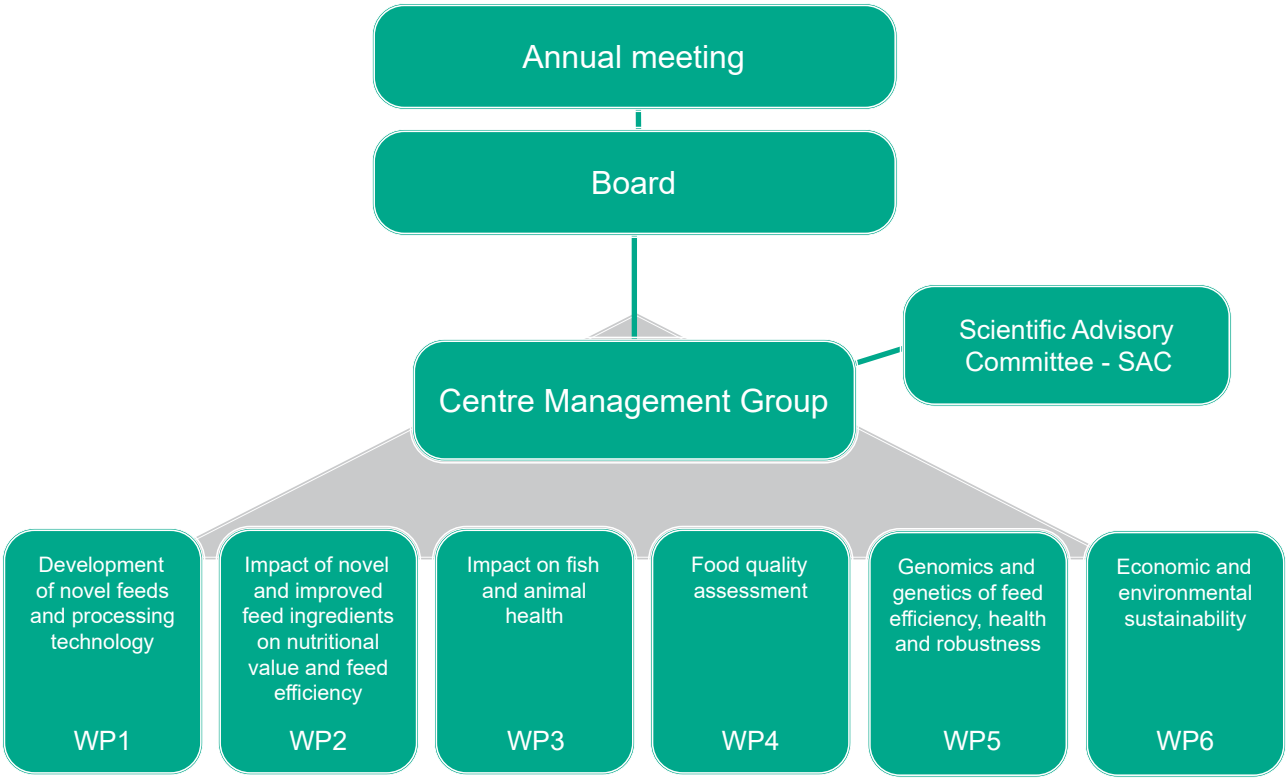
ORGANISATION

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.

A Scientific Advisory Committee (SAC) was appointed by the board in 2016 to ensure quality and excellence of the centre's work. SAC has three members: Wendy Rauw, researcher at INIA - Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, in Spain; Birte Svensson, Professor at the Technical University of Denmark, and Anders Karlsson, Professor at the Swedish University of Agricultural Sciences. 3



THE BOARD

Knut Røflo
Chair

Felleskjøpet Fôrutvikling (FKF)

Ragnhild Solheim
Deputy chair

NMBU, Research Department

Kari Kolstad
Member

NMBU / Faculty of Biosciences

Eirik Selmer-Olsen
Member

TINE

Gudbrand Rødsrud
Member (until June)

Borregaard

Christine Tørklep
Member (from July)

Denofa

Morten Sollerud
Member

Norilia

Nina Santi
Member

AquaGen

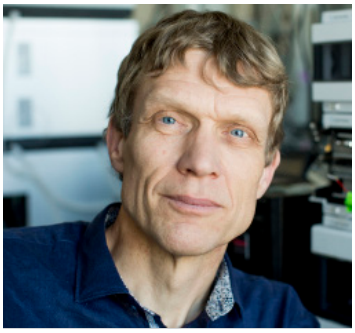
Ågot Aakra
Member

NMBU / Faculty of Chemistry, Biotechnology and Food Science

CENTRE MANAGEMENT GROUP

Margareth Øverland
Centre Director

Professor, NMBU
Faculty of Biosciences



Vincent Eijsink
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 20 partners in industry and innovation. We also work closely with several international partners and collaborators.

Strengthening expertise and technology through new partnerships

As a Centre for Research-based Innovation (CRI), close collaboration with industry is crucial to Foods of Norway.

Lallemand, a global company with strong expertise in fermentation technology, is now an official partner, strengthening the development of innovative feeds for aquaculture and agriculture. With Lallemand as a partner, Foods of Norway now has a greater level of expertise in fermentation technology that the centre can draw on, as well as access to large-scale infrastructure. This is important when developing further.

BioMar also joined the team in 2019, bringing with it more than 50 years of experience with feed and sustainability in aquaculture. BioMar is one of the leading suppliers of high-performance feed to the global aquaculture industry, operating 14 feed factories across the globe, including Norway. As a partner, Biomar will contribute to the centre with its expertise in sustainability assessment of feed resources, fish feed formulation and feed production.

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 Energy Solutions
- Yara

Supporting partners

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

COOPERATION BETWEEN PARTNERS

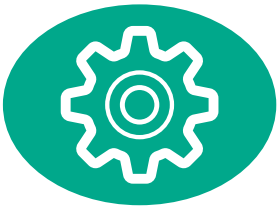
Cooperation with our partners is very important to Foods of Norway. Our industry partners represent three sectors – agriculture, aquaculture and forestry.

The aim is to promote discussions and close collaboration, leading to new research ideas and innovation potential across sectors. The centre hosts partner meetings annually, as well as continuous meetings between academia and industry partners throughout the year.

The main topic of the partner meeting in June 2019 were the results on yeast production from woody biomass so far, and as a discussion on the next steps going forward. This meeting was also followed up by a workshop on the same topic, where all the partners in the centre participated.

In a bid to strengthen the cooperation in the centre even further, a task force was established early 2019. This will be a meeting platform for the industry partners, enabling them to address topics relevant throughout Foods of Norway such as sustainability, economy and our business plan. The task force had four meetings in 2019, and this activity will continue in 2020.

Several feeding trials have been conducted during 2019 and all of them in close collaboration with our industry partners. A large trial feeding yeast to dairy cows was performed and became a great example of how academia and industry can work closely together to provide unique documentation along the whole value chain – from Norwegian biomass to final milk and dairy products. The trial involved all three faculties in the centre - with expertise in nutrition, health and product quality. Borregaard and Lallemand provided the yeast, Tine and Felleskjøpet helped designed the trial, and Tine was involved with the assessment of the final dairy product quality.



INTERNATIONAL COOPERATION

Foods of Norway continued to work closely with several of our existing international academic partners in 2019

The University of Copenhagen co-supervised an industrial PhD student funded by Felleskjøpet and the Research Council of Norway. Foods of Norway also worked with the Swedish University of Agricultural Sciences on optimizing the fermentation conditions for yeast, as well as on finding the yeast strains with the best growth on the substrates that have been developed in Foods of Norway.

Foods of Norway initiated a collaboration with the Helmholtz Centre for Environmental Research (UFZ) in Germany to develop methods based on Flow cytometry. This method is used to assess the impact of novel protein sources and bioactive compounds derived from yeast or seaweed biomass on immune responses or microbiota community in the gut and feces of salmon and other farmed animals.

Foods of Norway has also in close collaboration with Seaweed Energy Solutions and Nortura conducted research in Institute of Agrifood Research and Technology (IRTA), Spain, to evaluate the product quality of cured leg of lamb from animals that have been fed seaweed.

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 experiences and results from research on local feed resources

Students from the faculty of Chemistry, Biology and Food Science, NMBU.

Photo: Håkon Sparre, NMBU

for pigs, and how to best assess how these results will affect the economy, society and environment. In 2019 the centre, together with the Faculty of Biosciences at the Norwegian University of Life Sciences, hosted the network's partner meeting.

Researchers are also participating in a Nordic Centre of Excellence, SureAqua, focusing on developing novel feed resources for aquafeeds. The collaboration includes possibilities for PhD students to participate in exchange programmes with other research environments.

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 the project will be important for future work in the centre and will further strengthen this research collaboration.

Salmon collaboration with Chile

In 2019 we continued to collaborate closely with the Pontifical Catholic University of Valparaiso and the University of Santiago in Chile on research related to the impact of yeast on our development of advanced methods to assess health effects of novel feed ingredients.

RESEARCH HIGHLIGHTS IN 2019

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.

Foods of Norway aims to increase value creation in the Norwegian aquaculture, meat and dairy industries. One of our main tasks is to develop novel feed ingredients from natural bioresources. In September 2019 David Lapeña Gomez defended his thesis "Production of yeast from spruce sugars and hydrolysates of protein-rich by-products as feed ingredient". His thesis shows that sugar from Norwegian wood and by-products from the meat and fish industries can be converted into protein-rich yeast **(more on p. 22)**.

Photo: Gunn Evy Auestad

To find the yeast strain most suitable to grow on sugars derived from Norwegian spruce trees and enriched nitrogen sources, three different strains have been evaluated. These were Cyberlindnera jadinii (CJ), Blastobotrys adeninivorans (BA) and Wickerhamomyces anomalus (WA). Each yeast strain was either downstream-processed by autolysis or kept intact, followed by spray-drying.

Researcher Leszek Michalak working with seaweed in the biorefinery lab.

Photo: Gro Steine

The choice of downstream processing method was based on previous research aiming at optimizing the process in terms of energy cost, nutritional value and value-added effects of the yeast on animal health.

We are developing methods to upgrade the nutritional value of brown seaweed (Saccharina latissima) in a biorefinery process where we make use of the whole biomass to produce microbial ingredients. In addition, bioactive components are isolated for use in functional feeds.

We have developed protocols to upscale the fractionation of the seaweed extracts. The bioactivity of the seaweed extracts will be evaluated by using different *in vitro* tests. This will serve as a basis to upscale the seaweed extraction for use in functional feeds for fish and animal trials.

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.

Our current objective regarding **health effects** of yeast as a protein source in feed is to understand the impact of cell wall compositions and configurations of the yeast cells, and their processed fractions on nutritional value and health in Atlantic salmon. *In vitro* assessment methods are used to evaluate beneficial health effects of the yeast products. To further evaluate the impact of yeast and their processed fractions on health, we will use our established *in vivo* infection model. In this model we study survival and resistance to infectious pathogens, such as *Aeromonas salmonicida*, in zebra fish.

The different yeast strains and their autolysates have been evaluated in a trial with Atlantic salmon in fresh water, with the main emphasis on gut barrier function, immune modulation and general health responses. Comprehensive health assessments will be performed from the samples obtained from the trial.

This will be important information for selecting the optimal yeast strain, fermentation conditions and downstream processing conditions for upscaling the yeast production for future trials. Results obtained from piglet and broiler chicken trials have been further analysed and some results have now been published.

Results show that yeast can support high growth performance and improve gut function in piglets by improving the digestive function, preventing inflammation in the gut, and by modifying the gut microbiome. Ana Cruz, industrial PhD candidate, defended her thesis in November 2019. The title of her thesis was “Yeast: an alternative protein source in pig and poultry feed” **(more on p. 20)**.

Results from two trials with **seaweed in the diets for ruminants** were completed in 2019. For one month, lambs and lactating goats (as models for dairy cows) were fed diets with 2.5 and 5 percent cultivated sugar kelp. Results from the lamb experiment showed that seaweed in the diet had no adverse effect on growth performance or carcass quality, but tenderness and storage stability of the meat improved, and the iodine content increased, which has health benefits for the consumer. According to a consumer test, the meat also had a unique spicy and herbal odour, whereas results from the sensory test of the lamb meat showed only minor differences in the sensory characteristics of the lamb meat.

Milk samples from cows fed yeast from trees.
Photo: Gunn Evy Auestad

Results from a large trial with dairy cows fed concentrates with 7 percent yeast or soybean meal showed that replacing soybean meal with yeast did not have any adverse effect on milk yield, milk quality or the cheese-making properties of the milk. Results suggest that feeding dairy cows a local diet based on yeast as a protein source provides milk and dairy products of high quality.

3 Genomics and genetics

Today, farm animals and fish are mainly selected based on growth rate, but fast-growing animals are not necessarily the most feed efficient. Methods for direct selection for improved feed efficiency based on individual metabolic efficiency have been developed in Foods of Norway.

Indicator phenotypes for **individual feed efficiency** in Atlantic salmon by using stable isotopes have been established. This was a part of Hanne Dvergedal's PhD thesis "Novel indicator traits for individual feed efficiency in Atlantic salmon (Salmo Salar)" **(more on p. 24)**. The isotopes act as proxies for individual feed intake and have the potential to revolutionize selection for feed efficiency in fish. Further research has been performed in diets for rainbow trout to verify the method, before performing large-scale trials with salmon in the sea and to evaluate the use of isotopes that exist naturally in various feed ingredients.

To evaluate whether the method developed for Atlantic salmon can be used for other farm animals in large production systems, an experiment was carried out with lambs as a model for ruminants. The results look promising and confirmed the results that were obtained in the salmon trial.

SPIN-OFF PROJECTS IN 2019

Two spin-off projects were granted funding in 2019.

One of the spin-off projects in 2019 is LIVESTOCK - Sustainable Livestock Production, in which the totality of consequences of producing meat and milk in Norway will be documented. This will be achieved through a holistic life cycle analysis of domestic livestock production, meaning that the project will investigate the whole cycle, from soil to product, not only the emissions from single animals or a single farm.

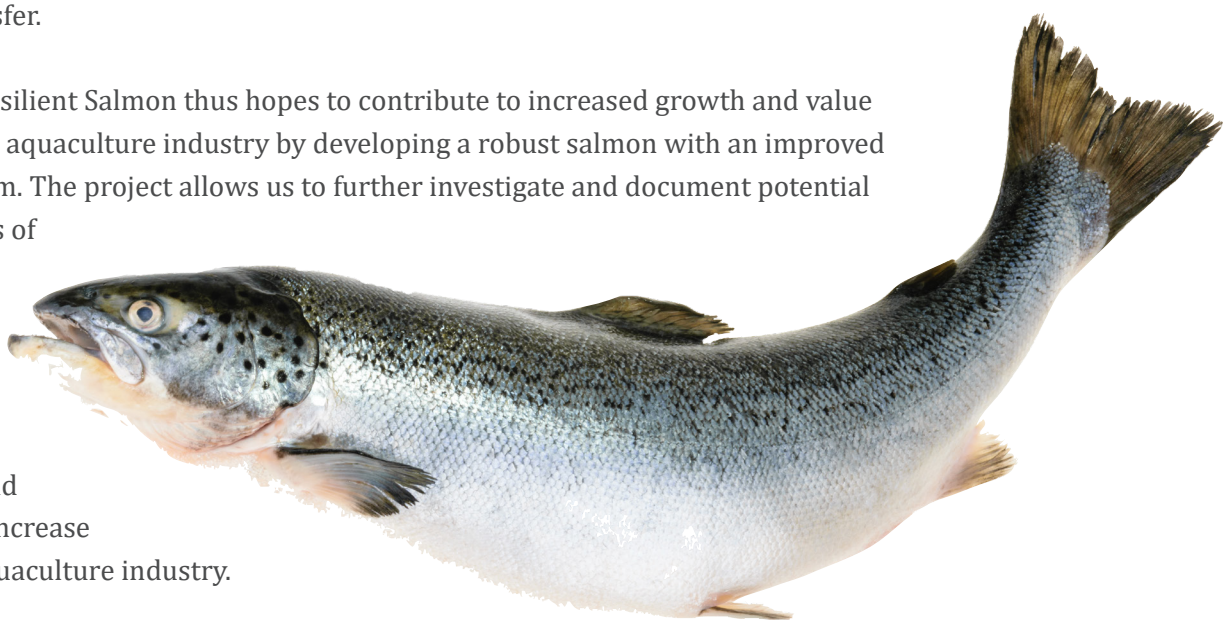
The project aims to assess the environmental, economic and social sustainability of livestock production. Livestock is a natural part of the resource cycle in Norway. In order to contribute to rational thinking about the future of livestock production the project has a special focus on novel, innovative feed resources, such as yeast produced from Norwegian spruce trees.

Novel feeds can improve salmon survival

Resilient Salmon (*Trained immunity and nutritional programming for resilient salmon*) is the second add-on project to Foods of Norway. Trials with Atlantic salmon show that bioactive feed components derived from natural resources can strengthen the immune system of fish and make it more robust when exposed to stress and infectious diseases.

The project will assess beneficial effects of bioactive feed components from yeast from woody biomass and from brown seaweeds to animal health. Specifically, the project will investigate growth performance, stress and health responses in Atlantic salmon from two genetic backgrounds - with low and high levels of resilience. The salmon will be fed today's standard feed and tomorrow's feed with yeast and seaweed extracts - in freshwater and during seawater transfer.

The project Resilient Salmon thus hopes to contribute to increased growth and value creation in the aquaculture industry by developing a robust salmon with an improved immune system. The project allows us to further investigate and document potential health benefits of yeast and seaweed biomass, which could improve fish welfare and considerably increase yield in the aquaculture industry.



Piglets thrive on Norwegian proteins

Studying pigs fed yeast produced from trees has never been done before. The results pave the way for a new era in the feed industry.

Piglets at Ås Gård

Photo: NMBU

Using yeast as a feed ingredient is not new, as it has been used as an additive in feed since the 1950s. Yeast as the main source of protein, however, has not been done before. This is mainly due to the technological advances that are now opening for a sustainable and profitable fermentation process.

In order to feed a growing population, there is an urgent need to develop new protein sources from resource-efficient material and biomass not directly used to produce human food. This is one of the main objectives of Foods of Norway.

Young pigs need high-quality feed with 17 to 19 per cent protein in order to grow well - mainly from grain, soybeans, fish meal and rapeseed. However, according to the research of the industrial PhD candidate, Ana Cruz, up to 40 per cent of the protein in the pigs' diet can be replaced with yeast from Norwegian spruce trees.

Yeast from Norwegian spruce trees

Photo: Foods of Norway

I am sure we will see protein factories being built in less than 5 years after the technology has proven to be profitable

Knut Røflo, managing director in Felleskjøpet Fôrutvikling

This study is valuable to the entire livestock sector in Europe, to feed producers such as Felleskjøpet, to distributors, farmers and even consumers. The consumers will benefit from more sustainable meat products, as they have become more conscious about the environment and animal welfare, says Cruz.

Knut Røflo, Managing Director of Felleskjøpet Fôrutvikling.
Photo: FKF

New feed solutions to market

Cruz has studied the use of yeast from Norwegian spruce trees as a protein source in feed for young pigs for the past three years. This is the first study of its kind. In November 2019 Ana Cruz defended her thesis. The yeast strain used in this research has already been approved as a feed ingredient in animal diets by the European Commission, making the next steps towards commercialization easier to put into practice.

Knut Røflo, managing director in Felleskjøpet Fôrutvikling, says that Ana Cruz' findings are very important in bringing new feed solutions to market.

- Now we are in the starting phase of a new era. From now on we will see more and more feed, as well as food, derived from sources that currently do not belong in the food chain. I am sure we will see protein factories being built in less than 5 years after the technology has proven to be profitable. Nobody will invest the amount needed unless there is a healthy business case behind. It is as simple as that, he says.

Ana Cruz

Industrial PhD in Foods of Norway, employed by partner Felleskjøpet Fôrutvikling

PhD thesis: *Yeast (Cyberlindnera jadinii): an alternative protein source in pig and poultry feed*

Norwegian leftovers can become valuable animal feed

Less than two thirds of farm animals and fish meant for the dinner table end up as human food. The rest can become high-quality feed for salmon and pigs.

PhD researcher David Lapeña Gomez and researcher Gergely Kòsa, upscaling the experiments at Borregaard
Photo: Gunn Evy Auestad

About 35 per cent of the biomass received by the Norwegian meat industry is classified as sidestreams or by-products. Also, the fish farming industry generates large volumes of by-products – 418.000 tons in 2018, according to SINTEF.

PhD student in Foods of Norway, David Lapeña Gómez, has studied the potential of these abundant Norwegian biomasses in the production of novel protein sources for farmed animals and salmon.
– My thesis shows that we can convert sugar from wood together with by-products from meat and fish industries into protein-rich yeast - a viable alternative to imported feed ingredients. My study aims to contribute to developing a circular bioeconomy in Norway, Lapeña explains.

Feed from animals, fish and spruce
In his PhD studies, Lapeña investigated whether it is possible to produce yeast efficiently on Norwegian resources only - wood and by-products from animals and fish.
– We found that these by-products can be used as a nitrogen source in the production of yeast for feed, and they can be combined with sugars from spruce trees. Our nitrogen preparations worked just as

well as, or even better than, the best commercial substrates, says Lapeña.
The use of yeast to exploit by-products from the meat industry represents great new opportunities, as safety regulations prohibit the direct use of such by-products in feed. In addition to providing protein, yeast also have health benefits for farmed animals and salmon.

Photo: Gunn Evy Auestad

- Double impact
If yeast can be produced locally and profitably with by-products from biobased industries here in Norway, such yeast would provide a alternative to today's imported proteins.

Norilia works with side streams from the meat and egg industry. The company is an industrial partner and one of several biomass providers in Foods of Norway.

— The impact of this research on Norwegian food production is twofold: the potential for a new type of feed from local sources, and a new process to create added value from side streams from the meat industry. Both contribute to more sustainable Norwegian food production, says Senior Advisor on Technical Business Development in Norilia, Marije Oostindjer.

Finding value in "plus products"
Norilia refers to side streams from the meat and egg industry as "plus products", as they represent a potential for added value.

— Plus products are all parts of the animal that are not eaten by Norwegian consumers. These include edible products such as organs, natural casings, tendons and bones, but also hides and skins, wool and eggshells. The most interesting products for yeast production are those that are not used for human consumption and currently do not represent a high value for us, Oostindjer explains.

David Lapeña Gómez

PhD researcher in Foods of Norway

PhD thesis: *Production of yeast from spruce sugars and hydrolysates of protein-rich by-products as feed ingredient*

Identifying the bodybuilders of the ocean can revolutionize aquaculture

Foods of Norway researchers have discovered a pioneering method to identify the salmon that make the most of their feed.

Photo: AquaGen

Aquaculture has experienced enormous growth and plays an increasingly important role in providing the world's protein supply. Norwegian salmon and trout production is today 1.35 million tonnes, making Norway the leading exporter of Atlantic salmon and rainbow trout in the world. Norwegian production is projected to reach 5 million tonnes by 2050.

Foods of Norway has developed a new, ground-breaking method for selecting salmon with higher feed efficiency, with the potential to considerably reduce production costs and the environmental footprint of the aquaculture industry. In Norway, feed costs amount to 2.3 billion euros – nearly 50 per cent of the production costs of Atlantic salmon and rainbow trout. Improving feed efficiency by only one per cent will increase the present annual value by at least 23 million euros, according to the Norwegian Directorate of Fisheries.

– With new indicator traits for feed efficiency, you get faster growing fish at a lower cost. In selective breeding, this could be of great significance, says Foods of Norway's PhD student Hanne Dvergedal at the Norwegian University of Life Sciences (NMBU).

– It's like trading in an old Ford Granada for a modern hybrid - the mileage is better, she adds.

With new indicator traits for feed efficiency, you get faster growing fish at a lower cost. In selective breeding, this could be of great significance.

Hanne Dvergedal, PhD researcher in Foods of Norway

Can increase profitability by millions

Dvergedal has been studying feed efficiency in Atlantic salmon for three years, in close collaboration with AquaGen, a breeding company and partner in the centre. The results open for selecting fish with higher feed efficiency, without measuring individual feed intake.
This has never been done before.

Photo: Foods of Norway

– The results from Hanne's PhD work are of great interest to AquaGen as they may enable us to improve feed efficiency through breeding, which fits very well with our strategy to facilitate a responsible and sustainable development of the aquaculture industry, says senior researcher Trina Galloway in AquaGen.

Locating the "bodybuilders"

It is a fact that the fastest growing fish are not always the most efficient. Dvergedal has now successfully documented genetic variations in feed efficiency in Atlantic salmon by measuring the utilization of nutrients from the feed in body tissues. The results show that some fish are indeed more efficient in converting nutrients into muscle – they are better "bodybuilders".

Senior Scientist in AquaGen and Associate Professor at NMBU, Jørgen Ødegård, has been working closely with Dvergedal through the entire study. Ødegård originally proposed finding a way to measure individual feed efficiency without registering feed intake.

– This new method may enable us to identify parent fish in our breeding population that display a particularly high feed efficiency, allowing us in turn to enhance this trait in the eggs that we sell to our customers, says Ødegård.

Hanne Dvergedal

PhD researcher in Foods of Norway

PhD thesis: *Novel indicator traits for individual feed efficiency in Atlantic salmon (Salmo salar)*

RECRUITMENT

During 2019, Foods of Norway increased its staff with researchers, PhD students and a new communications advisor

Özgün C. Onarman Umu
Researcher

Gut microbiota

Leszek Michalak
Researcher

Processing of seaweed

Bente Paulson
Communications Advisor

Digital communication and strategy

Live Heldal Hagen
Post-doc

Bioinformatics on gut microbiota

Jeleel Opeyemi Agboola
PhD student

Downstream processing of yeast, salmon nutrition and health

Eirin Stork
PhD student

Product quality of milk

KNOWLEDGE SHARING

Foods of Norway is a group of highly skilled and experienced scientific staff. Our researchers are often invited to participate in meetings and conferences as keynote speakers, panel participants or as presenters of our research and results.

In 2019, the centre was fortunate to participate at several important scientific conferences across the world. A group of our researchers travelled to the 70th European Association for Animal Production (EAAP) meeting held in Ghent, Belgium in August, and at the same event, centre director Margareth Øverland was invited as a keynote speaker.

Foods of Norway sent a delegation to the Aquaculture Berlin 2019 conference, and some of our researchers also travelled to the International Conference on Fish & Shellfish Immunology (ISFSI) in Las Palmas de Gran Canaria.

Foods of Norway delegates at the Aquaculture Berlin 2019 conference
Photo: AquaGen

Other participation includes our contribution at the International Specialised Symposium on Yeasts in Antalya, Turkey, and at Arendalsuka in Norway, where our PhD student Martine Andrea Olsen presented Foods of Norway at two events.

PhD student Martine Andrea Olsen serving ice cream from spruce-fed cows' milk at Arendalsuka 2019
Photo: Stine Solbakken, AT Skog

Also a highlight: centre director Margareth Øverland was invited as keynote speaker at Feed Additive Europe in Amsterdam, The Netherlands. Her presentation was entitled "A New Generation of Novel Feed Ingredients - Reviewing the research into new feed ingredients that are addressing some of the challenges in animal husbandry".

COMMUNICATION & DISSEMINATION

Now that Foods of Norway has reached its halfway mark, the results we are able to present and communicate are more frequent. Some of these results have earned some well-deserved attention during 2019.

Even though the centre was without dedicated communication resources from July until November, the pressure from Norwegian and international media rose in 2019 and is still increasing. There is more awareness of the centre's activities and we also see higher expectations of results. At the moment, the level of reactive communication exceeds the proactive communication activities.

A new communications advisor started in December 2019, and the aim for 2020 is to establish our communication strategy and execution even further. The strategy going forward will be to continue to focus on our main target groups: decision and policy makers, farmers' associations, our stakeholders and the general public in Norway. We also aim to build our brand as a knowledge provider for feed and food industries and agriculture and aquaculture industries in Norway and abroad.

International media coverage of Foods of Norway is continuous.

Article from Scientific American, 06 March 2019

Faux Fish Might Help Aquaculture Keep Feeding the World

Some unexpected alternatives could avoid depleting the wild fish that farmed seafood eats

By Leslie Nemo on March 6, 2019 أعرض هذا باللغة العربية

Man feeding the trouts swimming in a pool in a trout farm at Bussi, in Abruzzo. Credit: Getty Images

Of the 160 million tons of seafood that end up on people's plates each year, 50 percent comes (pdf) from aquaculture. Growing all that salmon, tilapia and shrimp requires a steady supply of the perfect food supplement: oily anchovies and sardines, often called forage fish, which are rich in proteins, fats and vitamins. About 90 percent of the 20 million tons of forage fish pulled from the wild each year is ground into meal or oil to nurture fish farmed for human consumption.

But with expectations aquaculture will continue to boom—the United Nations predicts production to increase by 34 percent by 2026—the industry is outgrowing its feed supply. This dilemma has spurred researchers to try to synthesize a stand-in that will provide the nutrients

Falt i smak: – Isen var kjempegod, seier professor Siv Borghild Skeie ved NMBU. Foto: Gunn Evy Auestad/NMBU

«Tre-mjølk»: VGS-elevar forsynte seg med softis laga av mjølk frå kyr som er fôra opp på fôr av norsk treverk, på NMBU sitt Campus på Ås, førre onsdag. Foto: Gunn Evy Auestad/NMBU

Foods of Norway

Serverte softis av norsk «tre-mjølk»

I høve open dag på NMBU på Ås fekk VGS-elevar smake på noko heilt nytt: Softis laga på mjølk frå kyr som hadde ete fôr laga av norske tre.

– Isen var kjempegod, seier professor Siv Borghild Skeie ved NMBU. Ho er òg leiar for ein arbeidspakke i Foods of Norway-det som får tradisjonelt fôr, seier Skeie.

Ho fortel at det har gjort ett forsøk på å lage ost av den same

Article from
Nationen
12 March 2019

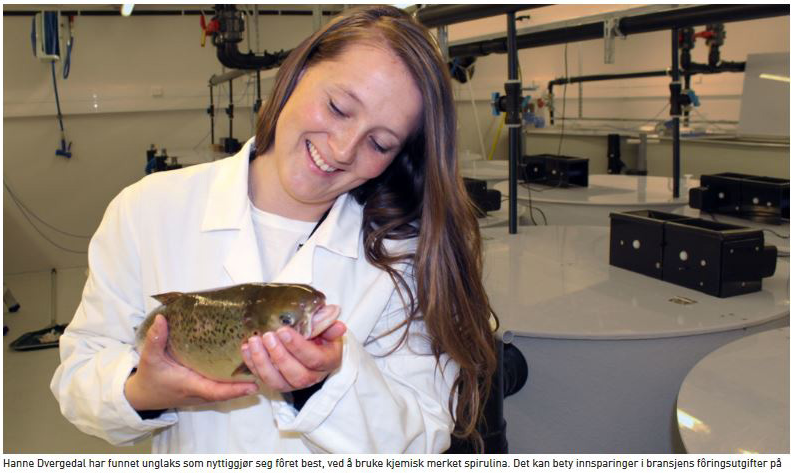
Tenk Tre

Gris kan spise flis

BÆREKRAFT

Økt befolkningsvekst og klimaendringer gjør at verden står overfor store utfordringer – ikke minst når det gjelder matproduksjon. I fremtiden kan vi ikke lenger fôre dyra våre med menneskemat. Flis derimot, det har vi nok av. Og grisen gomler mer enn gjerne gran!

Article from
www.tenktre.no
09 Dec 2019



Hanne Dvergedal har funnet unglaks som nyttiggjør seg fôret best, ved å bruke kjemisk merket spirulina. Det kan bety innsparinger i bransjens fôringsutgifter på sikt. Her med en laks i fiskelaben ved NMBU. (Foto: G. E. Auestad/Foods of Norway)

Slik fant forskerne laks som trenger mindre mat for å bli stor

Norske forskere har identifisert ung laks som kan vokse seg stor med mindre fôr enn andre.

Anne Lise Stranden
JOURNALIST

PUBLISERT Onsdag 26. juni 2019 - 04:30

Norge setter stadig nye rekorder i eksport av laks. I 2018 eksporterte vi sjømat for 99 milliarder kroner. Havbruksnæringen står for om lag 70 prosent av verdiene.

Men fortsatt er det rom for at bransjen kan bruke mindre fôr i produksjonen. Det vil både spare bransjen for penger og gi en mer bærekraftig næring.

Article from
www.forskning.no
26 June 2019

IN NUMBERS: COMMUNICATION OUTPUT IN 2019

+ 21 %

We increased the number of Facebook-followers by 21 per cent.

+ 38 %

Our number of newsletter subscribers increased by 38 per cent.

+ 42 %

The average reach of our Facebook posts increased by 42 per cent.

Articles in editorial media	Norwegian	77
	International	8
Newsletter*	Number	1
	Subscribers	152
Facebook	Followers	805
	Average reach	1329
	Average engagement (post clicks / reactions, comments & shares)	111 / 81
Twitter	Followers	420
	Impressions	40 142

* Created in June 2019, in accordance with GDPR.

Publications list

- Campbell, I., Macleod, A., Sahlmann, C., Neves, L., Funderud, J., Øverland, M., Hughes, A. D., Stanley, M. **The environmental risks associated with the development of seaweed farming in Europe - prioritizing key knowledge gaps.** *Frontiers in Marine Science* 2019; Volume 6. pp.1-22

- Couture, J., Geyer, R., Hansen, J. Ø., Kuczenski, B., Øverland, M., Palazzo, J., Sählmann, C., Lenihan, H. S. **Environmental Benefits of Novel Nonhuman Food Inputs to Salmon Feeds.** *Environmental Science and Technology* 2019; Volume 53.(4) pp.1967-1975

- Dvergedal, H., Ødegård, J., Mydland, L. T., Øverland, M., Hansen, J. Ø., Ånestad, R. M., Klemetsdal, G. **Stable isotope profiling for large-scale evaluation of feed efficiency in Atlantic salmon (Salmo salar).** *Aquaculture Research* 2019; Volume 50.(4) pp.1153-1161

- Dvergedal, H., Ødegård, J., Øverland, M., Mydland, L. T., Klemetsdal, G**. Indications of a negative genetic association between growth and digestibility in juvenile Atlantic salmon (Salmo salar).** *Aquaculture* 2019; Volume 510. pp.66-72

- Dvergedal, H., Ødegård, J., Øverland, M., Mydland, L. T., Klemetsdal, G. **Selection for feed efficiency in Atlantic salmon using individual indicator traits based on stable isotope profiling.** *Genetics Selection Evolution* 2019; Volume 51.

- Girio Da Costa Cruz, A. R., Håkenåsen, I. M., Skugor, A., Mydland, L. T., Åkesson, C. P., Hellestveit, S. S., Sørby, R., Press, C. M., Øverland, M. **Candida utilis yeast as a protein source for weaned piglets: Effects on growth performance and digestive function.** *Livestock Science* 2019; Volume 226. pp.31-39

- Gomez, D. L., Olsen, P. M., Arntzen, M. Ø., Kòsa, G., Passoth, V., Eijsink, V., Horn, S. J. **Spruce sugars and poultry hydrolysate as growth medium in repeated fed-batch fermentation processes for production of yeast biomass.** *Bioprocess and biosystems engineering* (print) 2019

- Hansen, J. Ø., Hofossæter, M. E., Sahlmann, C., Ånestad, R., Reveco Urzua, F. E., Press, C. M., Mydland, L. T., Øverland, M. **Effect of Candida utilis on growth and intestinal health of Atlantic salmon (Salmo salar**) parr. *Aquaculture* 2019; Volume 511.

- Hansen, J. Ø., Øverland, M., Skrede, A., Anderson, D. S., Collins, S. **A meta-analysis of the effects of dietary canola/double low rapeseed meal on growth performance of weanling and growing-finishing pigs.** *Animal Feed Science and Technology* 2019; Volume 259.

- Reveco Urzua, F. E., Hofossæter, M. E., Kovi, M. R., Mydland, L. T., Ånestad, R., Sørby, R., Press, C. M., Lagos Rojas, L. X., Øverland, M. **Candida utilis yeast as a functional protein source for Atlantic salmon (Salmo salar L.): Local intestinal tissue and plasma proteome responses.** *PLOS ONE* 2019; Volume 14.(12)

- Sählmann, C., Djordjevic, B., Lagos, L., Mydland, L. T., Morales-Lange, B., Hansen, J. Ø., Ånestad, R., Mercado, L., Bjelanovic, M., Press, C. M., Øverland, M. **Yeast as a protein source during smoltification of Atlantic salmon (Salmo salar L.), enhances performance and modulates health.** *Aquaculture* 2019; Volume 513. pp.1-10

- Shomorin, O. G., Storebakken, T., Kraugerud, O. F., Øverland, M., Hansen, B. R., Hansen, J. Ø. **Evaluation of wedge wire screen as a new tool for faeces collection in digestibility assessment in fish: The impact of nutrient leaching on apparent digestibility of nitrogen, carbon and sulphur from fishmeal, soybean meal and rapeseed meal-based diets in rainbow trout (Oncorhynchus mykiss).** *Aquaculture* 2019; Volum 504. pp.81-87

- Skugor, A., Kjos, N. P., Meenakshi Sundaram, A. Y., Mydland, L. T., Ånestad, R., Tauson, A. H., Øverland, M. **Effects of long-term feeding of rapeseed meal on skeletal muscle transcriptome, production efficiency and meat quality traits in Norwegian Landrace growing-finishing pigs.** *PLOS ONE* 2019; Volume 14.(8)

- Vuoristo, K., Fredriksen, L., Oftebro, M., Arntzen, M. Ø., Aarstad, O. A., Stokke, R., Steen, I. H., Hansen, L. D., Schüller, R. B., Aachmann, F. L., Horn, S. J., Eijsink, V. **Production, characterization, and application of an alginate lyase, AMOR_PL7A, from hot vents in the Arctic mid-ocean ridge.** *Journal of Agricultural and Food Chemistry* 2019; Volume 67.(10) pp.2936-2945

- Wang, J., Lei, P., Gamil, A. A. A., Lagos, L., Yue, Y., Schirmer, K., Mydland, L. T., Øverland, M., Krogdahl, Å., Kortner, T. M. **Rainbow trout (Oncorhynchus mykiss) intestinal epithelial cells as a model for studying gut immune function and effects of functional feed ingredients.** *Frontiers in Immunology* 2019; Volume 10.

Statement of accounts

Foods of Norway costs 2019 (1000 NOK)

Host NMBU	Industry partners (Norway)	International partners	Equipment	Total costs
23 744	6 374	290	0	30 408

Foods of Norway funding 2019 (1000 NOK)

Host NMBU	Industry partners (Norway)	International partners	Research Council	Total funding
5 470	8 449	0	16 489	30 408

Foods of Norway – 237841/O30

List of personnel 2019

Key researchers	
Name	**Main research area**
Margareth Øverland	Centre director; Feed ingredient evaluation
Vincent Eijsink	Fundamental and applied enzymology; bioprocessing; 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
Anne-Helene Tauson	Monogastric nutrition, physiology and metabolism

Permanent research staff		
Name	**M/F**	**Topic**
Svein Jarle Horn	M	Bioprocessing, applied enzymology, management
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
Stine Vhile	F	Ruminant nutrition and health
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
Caroline Åkesson	F	Veterinary pathology
Alex Crawford	M	Zebrafish screening.
Davide Porcellato	M	Milk mikrobiota
Peng Lei	F	In vitro screening of feed components for health effects
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

Postdoctoral researchers working on projects in the centre with financial support from other sources			
Name	**M/F**	**Funding**	**Topic**
Adrijana Skugor	F	NFR/EU	Nutrigenomics
Brankica Djordjevic	F	NFR	Fish nutrition and health
Christian Sahlmann	M	NFR	Macroalgae ecology and food safety

Alemayehu Sagaye	M	NFR	Upgrading nutritional value of grass and macroalgae
Gergely Kosa	M	NFR	Bioprocessing and fermentation processes
Jørgen Ødegaard	M	NMBU	Genomics of feed efficiency
Leidy Lagos	F	NFR/EU	Pig nutrition, health

PhD students with financial support from the centre budget		
Name	**M/F**	**Topic**
Hanne Dvergedal	F	Feed efficiency in fish
Mette Hofossæter	F	Animal health
Stanislav Iakhno	M	Gut microbiota
Selina Seyoum Hellestveit	F	Health and disease resistance in weaner pigs
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**
Ana Rita Girio da Costa Cruz	F	Felles-kjøpet/ NFR	Nutrition, novel protein sources produced and monogastric animals.
Ingrid Marie Håkenåsen	F	NFR	Nutrition, novel protein sources, nutrition effect on performance, gut function and health.
Håkon Kaspersen	M	FFL	Quinolone resistance in E. coli in the gut microbiota
Pabhoda Weththasinghe	F	NFR/Nordic CoE	Growth performance and health in salmon
Eirin Stork	F	NMBU	Product quality of milk
David Lapeña Gomez	M	NFR	Bioprocessing, enzymatic processes, fermentation

Master degrees		
Name	**M/F**	**Topic**
Elise Hatch Fure	F	Comparison of in sacco, DaisyII incubator and gas production to evaluate digestibility of silage in ruminants
Lars Jordhøy Lindstad	M	Gene Cloning, Purification and Characterization of Novel Hemicellulases for Production of Tailor Made Prebiotics and Biochemicals
Bjørn Pedersen	M	Characterization of a thermostable exolytic alginate lyase from hot vents in the Arctic Mid-Ocean Ridge
Cathrine Nilsen Sebjørnsen	F	Characterization of Yeast Exopolysaccharides
Daniel Nøkland	M	Black soldier fly larvae (acid conserved or dry meal) in extruded salmon diets - effects on feed processing, pellet quality, growth, and nutrient digestibility
Ann Jorun Hansen Hoøen	F	In vitro digestion/methane potential evaluation of different concentrates used in different forage-to-concentrate ratios
Guro Holseth Grepperud	F	Feed intake, digestibility, growth performance and general health of piglets fed increasing levels of black soldier fly larvae meal.
Thea Brustad	F	Effects of different silage additives on grass silage chemical composition and in vitro NDF degradation characteristics

Ingrid Leikvoll	F	Kvalitetsforandringer tidlig postharvest i brunalgen Saccharina latissima ved bruk av ulike lagringsmetoder
Pernille Margrethe Olsen	F	Fermentation for Single Cell Protein Production
Mari Brusletten	F	Fermentation and downstream processing of yeast for production of single-cell proteins and polysaccharides

PhD degrees		
Name	**M/F**	**Topic**
Hanne Dvergedal	F	Novel indicator traits for individual feed efficiency in Atlantic salmon (*Salmo salar*)
David Lapeña Gomez	M	Production of yeast from spruce sugars and hydrolysates of protein-rich by-products as feed ingredient
Ana Rita Girio da Costa Cruz	F	Yeast (Cyberlindnera jadinii): an alternative protein source in pig and poultry feed

Visiting researchers				
Name	**Period**	**M/F**	**Affiliation**	**Topic**
Byron Maximiliano Morales Lange (PhD student/postdoc)	07.08.18-02.10.18; 15.10.19-	M	Catholic University of Valparaíso	Mucosal immunity
Narges Shahbazi (MSc student)	29.10.18-29.04.19	F	Royan Institute of Stem Cell Biology, Tehran	Zebrafish *in vivo* models
Elena Coll (PhD student)	07.12.18-16.12.18; 14.01.19-13.04.19; 08.05.19-15.06.19	F	Inst. of Agrifood Research & Technology, Spain	Fatty acids in lamb
Marcos Cortés	02.05.19-31.08.19	M	University of Santiago	Isolation of EVs from gastrointestinal tract of salmon. Immune response of feed additives
Mateusz Rawski	23.04.19-14.05.19	M	Poznan University of Life Sciences	Fish nutrition, growth performance, feed efficiency, digestibility
Silvia Nogales-Merida	23.04.19-14.05.19	F	HiProMine S.A.	Fish nutrition, growth performance, feed efficiency, digestibility
Federico Melchòn Ramirez (PhD student)	02.05.19-30.08.19	M	University Autònoma de Barcelona	Effect of insect meal on health and microbiota of trout
Ruth Montero	24.06.19-28.06.19	F	Federal Research Institute for Animal Health, Germany	Immune responses in salmon in relation to functional feeds based on novel feed solutions

FOODS OF NORWAY

Annual report 2019

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