

ANNUAL REPORT 2021

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. 237841/030), our partners and our host institution - the Norwegian University of Life Sciences (NMBU).



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EXECUTIVE SUMMARY

2021 was yet another exciting year for Foods of Norway, and I am proud to see that the results of our years of focused research are continuously reaching new heights. Thanks to the dedicated partners in the centre and its many talented researchers and technicians, we have been able to continue our path towards more sustainable feed resources for fish and livestock.



We are in the process of reaching major milestones in the centre, and one of the main highlights this past year was the successful industrial scale-up of 1,600 kg of yeast produced from sugars from Norwegian spruce trees. Our achievements in process development, production and research activities have all been splendid examples of the value of the collaboration in the centre: between academia and industry, but also between industry partners (*read more on page 20*).

Foods of Norway is building recognition as a valuable knowledge provider in the public sphere. In August, the Norwegian non-profit environmental organisation Bellona asked the centre to participate in its report “Råvareløftet”, which aims to shed light on a wide range of candidates for new, alternative feed ingredients.

Several feeding trials with yeast were carried out in 2021 with Atlantic salmon, broiler chickens and weaning piglets. The results so far are very promising, and with some of the trials still ongoing, we are expecting more valuable findings throughout 2022.

Studying the potential of seaweed is also a major part of our research, and in an ongoing field trial we are investigating the product quality of meat when including seaweed in cattle feed. We are also evaluating various components extracted from seaweed for use in several applications.

The Covid-19 situation has also affected our research in 2021, with limited access to research facilities and the challenges it has imposed on the collaboration with our international partners. Still, the centre’s results and accomplishments are steadily increasing in number. In December, two PhD candidates associated with Foods of Norway successfully defended their theses on topics such as insects grown on organic leftovers in fish feed and how feeding pigs with yeast can promote healthy gut bacteria.

As we reach these significant milestones in our research, we are now able to see the effects of our work with alternative feed ingredients on a larger scale through production processes and several extensive field trials. We are looking forward to continuing this work in 2022 and anticipate yet another eventful year for the centre.

Margareth Øverland



Foods of Norway is building recognition as a valuable knowledge provider in the public sphere.

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.

The secondary objectives are to

- **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 livestock industries rely heavily 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 livestock and farmed 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 for producing novel feed ingredients.

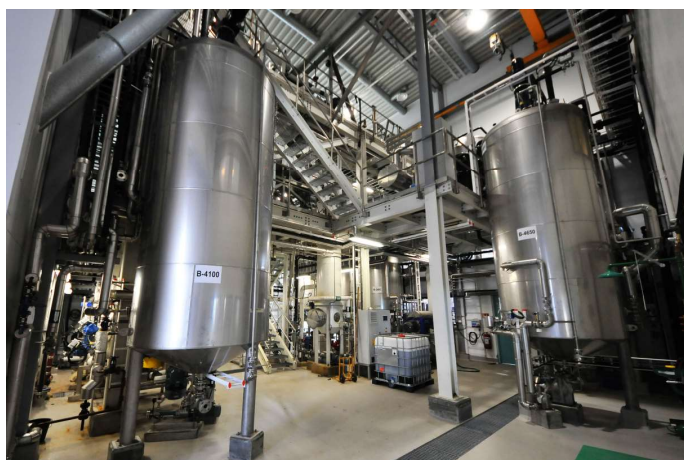
Foods of Norway develops sustainable feed ingredients from renewable bioresources which have the potential to be produced in large quantities at a competitive cost.

The research plan for the centre 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.



Ongoing field trials: Trials with salmon fed yeast at LetSea's fish farm at Dønna (top), and beef cattle fed seaweed at a farm in Vestfold, Norway (right) will continue in 2022.

Photo: LetSea (top) and Nortura (right)



Upscaling yeast production: Borregaard's biorefinery demo plant (left), and the Lallemand yeast production plant in Salutaguse, Estonia (below).

Photos: Borregaard (left) and Lallemand (below)



The research plan for the next two years will focus on developing technology to produce microbial ingredients such as filamentous fungi that have a higher protein content than yeast and can grow on sugars and cheaper organic substrates from industrial side streams. Researchers in the centre will evaluate nutritional value and effects that can be beneficial to animal health, as well as sustainability and techno-economical aspects of these ingredients.

Researchers are investigating low-processed seaweed (sugar kelp) as a functional ingredient to improve meat quality of beef cattle and the yield and quality of milk from dairy cows. Fucoidan is a component extracted from sugar kelp, which will be used in functional feeds for Atlantic salmon and broiler chickens.

Different technologies will be evaluated to preserve the nutritional value and functional properties of seaweed during storage. Use of seaweed or seaweed fractions as a substrate for cultivating filamentous fungi will also be investigated.

The centre has a special focus on improving the 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 novel indicator traits for individual feed efficiency in salmon, based on stable isotope profiling. Over the next years, we will assess whether the indicator traits can also be applied to dairy cows and pigs.

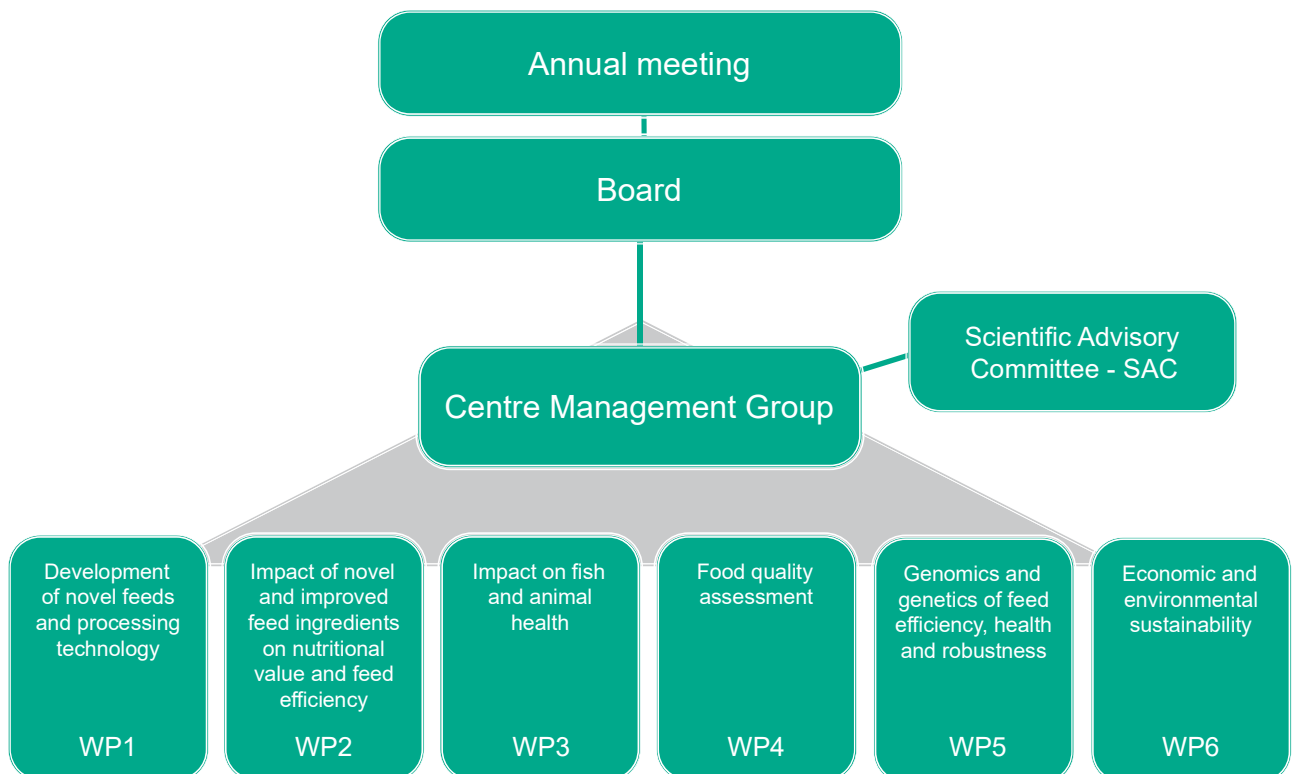
ORGANISATION

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 Annual Meeting convenes once a year.

The Scientific Advisory Committee (SAC) is comprised of leading international experts who can contribute to the centre in terms of quality assurance, inspiration and support in scientific matters. SAC members are appointed for a period of two years to accommodate the need for different areas of expertise throughout the centre's lifetime. 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)



Kari Kolstad

Deputy chair

NMBU / Faculty of Biosciences



Eirik Selmer-Olsen

Member

Tine



Hege Rivedal-Ødegaard

Member

Denofa



Cecilie Hultmann

Member

Nortura



Eli Grindflek

Member

Norsvin



Gudbrand Rødsrud

Member

Borregaard



**Solveig Fossum-
Raunehaug**

Member

NMBU / Research Department



Sigrid Gåseidnes

Member

NMBU / Faculty of Chemistry,
Biotechnology and Food Science

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

FOODS OF NORWAY

Industrial partners



Supporting partners



Academic 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
- eniferBio
- Felleskjøpet Fôrutvikling
- Geno
- Lallemand
- Norilia
- Felleskjøpet Agri
- 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

In a Centre for Research-based Innovation (CRI), industry participation is very important. Foods of Norway collaborates across three sectors – agriculture, aquaculture and forestry.

The aim is to promote discussion and close collaboration, leading to new research ideas and innovation potential across sectors. Foods of Norway hosts joint partner meetings in addition to frequent meetings between academia and industry partners.

In 2021, partner meetings were virtual due to the covid-19 situation. In the partner meeting in June, the main topics were results obtained so far, with focus on innovation potential and research activities with seaweed, yeast in diets for chicken and dairy cows, and methods to select for improved feed efficiency. Partner meetings in autumn focused on how to reach the goals of the centre when it comes to fermentation processes and health effects of yeast, as well as use of seaweed as a resource for feed and functional feed components.

Several trials with yeast in diets for salmon have been carried out in 2021, through valuable collaboration between partners, including Lallemand, Borregaard, Denofa and BioMar.

To further evaluate methods developed by scientists from NMBU and AquaGen on improved feed efficiency in salmon, AquaGen plan to analyse samples from slaughter tests to investigate if a method based on natural isotopes to measure feed efficiency is also valid for large salmon.

Foods of Norway reached a major milestone in 2021: the first successful large-scale production of 1600 kilos of autolyzed *C. jadinii* yeast grown on local, sustainable resources. This accomplishment required close cooperation of several of the partners in the centre. Viken Skog and NMBU applied for funds from The Forest Initiative Fund (Skogtiltaksfondet) to produce sugar from spruce trees at Borregaard's refinery. This sugar was used to ferment yeast at the Lallemand production site in Estonia. The processes were developed by scientists at NMBU and Lallemand.

The yeast will be used in large-scale feeding trials; Biomar started a trial with yeast in diets for salmon in seawater in October, which will last until April 2022. Felleskjøpet Fôrutvikling started a field trial with yeast in feed for piglets at a Norwegian pig farm in November, which will last until March 2022. Both trials will investigate growth performance, animal health and welfare, as well as the sustainability and economy of using yeast as a feed ingredient.

A field trial with seaweed in feed rations for beef cattle has been performed, in a collaboration between Nortura, Seaweed Solutions, Felleskjøpet and NMBU. The cattle were fed a ration containing one per cent seaweed. The aim is to evaluate if the seaweed can improve meat quality.

INTERNATIONAL COOPERATION



Foods of Norway continued to work closely with several of our international collaborators in 2021

Foods of Norway has three international partners: the University of Copenhagen (UC), the Canadian company Lallemand, and new Finnish partner eniferBio. In 2021, collaboration with UC has mainly been through an experiment with yeast in diets for broiler chickens, and in planning a joint manuscript from this work. Lallemand participated in a major upscaling of yeast grown on Bali sugars. The yeast is now being used in field trials with salmon and piglets.

The Finnish start-up company eniferBio became a partner in Foods of Norway in May. eniferBio has developed a method for producing a highly nutritious single cell ingredient derived from filamentous fungi – the PEKILO® mycoprotein. This partnership will facilitate further development of microbial ingredients from woody biomass based on cheap substrates, with a higher nutritional value.

Postdoctoral fellow Byron Maximiliano Morales Lange from Pontificia Universidad Católica de Valparaíso in Chile has extended his stay as a guest researcher in Foods of Norway. In collaboration with fellow researchers Byron has carried out ground-breaking studies on yeast as a functional ingredient in salmon feeds, and he is currently working with different seaweed components in functional feeds for salmon.



Photo: Shutterstock

International ongoing spin-off projects

NORDICFEED

NORDICFEED (Bio-conversion of non-food bio-resources to novel feeds for salmonids – a Nordic approach) aims to enhance the performance, health and robustness of rainbow trout and Atlantic salmon at various life stages and environmental conditions.

The project's goal is to develop optimized feed formulations based on sustainable microbial feed ingredients from locally available waste streams.

Resilient Salmon

The project Resilient Salmon (Trained immunity and nutritional programming for resilient salmon) will investigate beneficial effects on animal health by using bioactive feed components from yeast from woody biomass and brown seaweeds.

Specifically, the project investigates growth performance, stress and health responses in Atlantic salmon from two genetic backgrounds - with low and high levels of resilience. The fish are fed today's standard feed and tomorrow's feed with yeast, both in freshwater and during seawater transfer.



Photo: Shutterstock

OIL4FEED

The OIL4FEED project (Oil from oleaginous microbial biomass derived from Norwegian resources to replace fish/plant oils in fish feed) aims to develop a process for producing microbial oils from

animal fat by-products and second-generation sugars derived from Norwegian woody feedstock.

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

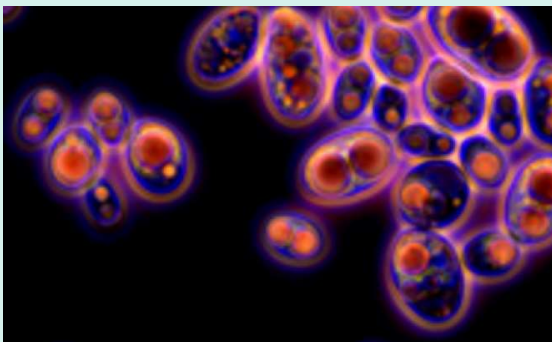


Photo: Oil4Feed

RESEARCH HIGHLIGHTS IN 2021

The main goal of Foods of Norway is to develop novel protein sources in diets for livestock and fish. The centre focuses on the use of woody biomass and seaweed, both abundant resources in Norway and which do not compete with resources for human food. This is a sustainable approach to some of the challenges we see in agriculture and aquaculture today.

1 Biomass processing and production of yeast

Foods of Norway studies the potential of using biorefinery processing and enzyme technology to develop yeast from underutilized bioresources for the aquaculture and agricultural industry.



The key to making the most of our bioresources is to develop processes to convert these resources into microbial ingredients, such as yeast. Developing these processes and documenting how we can use the yeast as a novel protein source, are some of the centre's main areas of research.

The first successful large-scale production of 1,600 kilos of autolyzed *C. jadinii* yeast grown on spruce sugars was a joint effort between partners Borregaard, Lallemand and NMBU, and an important achievement towards developing alternative and sustainable feed ingredients from local resources. The yeast, produced at the Lallemand production site in Estonia, will be used in large-scale feeding trials: Biomar has started a field trial with yeast in feed for salmon in seawater, which will last until April 2022, and Felleskjøpet Fôrutvikling has started a field trial



Hydrolysis equipment in Borregaard's biorefinery demo plant used for converting cellulose to sugars.

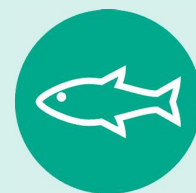
Photo: Martin Lersch/Borregaard

with yeast in feed for piglets at a Norwegian pig farm. Both trials will investigate growth performance, health and welfare for the animals, as well as the sustainability and economy of yeast as a feed ingredient.

Organic hydrolysates from slaughter by-products from Norilia have been evaluated as enriched nitrogen sources in the fermentation media for yeast fermentation. Initial results show that the yeast grew well on all hydrolysates.

2 Testing the impact of novel feed ingredients

Foods of Norway evaluates the effect of novel feed ingredients on nutritional value, growth performance and the health of farm animals and fish; as well as the product quality of meat and milk.



Several feeding trials with yeast have been carried out during 2021:

- Experiments with salmon fed a challenging soybean meal-based diet evaluated the impact of yeast on gut health. Results showed that the yeast's ability to prevent intestinal enteritis in Atlantic salmon depends on both the type of yeast and the downstream processing method
- Two yeast species (*C. jadinii* and *W. anomalous*) were evaluated in a trial with Atlantic salmon fed soybean meal-based diets. The best result on gut health was obtained with intact and autolyzed *C. jadinii*.
- Preliminary results from a trial with broiler chicken fed increasing levels of yeast show that the chickens performed well with protein replacement levels up to 30 per cent.
- Two trials with weaning piglets fed yeast-based diets showed that the bacterial compositions in the small and large intestine were improved by the yeast



Chicken perform well with yeast in their feed.

Photo: Foods of Norway

Seaweed processing and seaweed as a feed ingredient

A major part of the centre's research is unveiling the potential of seaweed by upgrading its nutrient value through a biorefinery process. The aim is to use the entire biomass; both as fermentation media to produce yeast and for high-value bioactive components for use in functional feeds.

As part of this, 1,500 kilos of sugar kelp were processed at NorBioLab at NMBU, producing a sulphated fucoidan. In the process, sugar kelp was extracted in a 'zero waste' pipeline, breaking down the biomass into fractions which can be investigated for industrial and agricultural applications. The results from a lab-scale screening of processed fucoidan suggest that the seaweed fractions activate and regulate immune functions, and that different extraction procedures result in fucoidan with different bioactivity .

A feeding trial with fucoidan from sugar kelp and laminarin from large kelp in diets for Atlantic salmon showed that fucoidan had immunomodulatory properties, but the immune response depended on the dosage; moderate dosage gave a pro-inflammatory response, and higher dosages gave an anti-inflammatory response. The results hold promise for using fucoidan in functional feeds.

Grass

The centre is also working on increasing the nutritional value of grass, which can impact resource utilization, feed efficiency and cost. A comparison of *in vitro*, *in sacco* and *in vivo* digestibility of grass-based silages in ruminants has been performed. The results show that the "Daisy" *in vitro* method was found to be a considerably cheaper and faster digestibility method than *in sacco* and *in vivo*. This method can be used to better predict the nutritional value of grass silage and thus facilitate increased use of this local feed



Frozen seaweed from Frøya is ground up at NorBioLab at NMBU, the first step of the zero-waste process.

Photo: Foods of Norway

3 Genomics and genetics

Methods for direct selection for improved feed efficiency based on individual metabolic efficiency have been developed.



The centre has developed a method for adding isotopes to feed to measure feed efficiency characteristics of salmon in early life. The next step is to evaluate the use of a method based on natural isotopes in feed and tissue samples from salmon, as an alternative and cheaper method to measure feed efficiency. AquaGen plan to analyse samples from slaughter tests to investigate whether this method is also valid for large salmon.

SPIN-OFF PROJECTS IN 2021

Two spin-off projects were funded in 2021.

SafeKelp - Safe kelp for food and feed – controlling the transfer of iodine and arsenic through the value chain.

The aquacultural production of kelp is on the rise worldwide. Kelp has great potential both as food and feed and contains several essential micronutrients, but can also contain undesirably high levels of certain elements, such as iodine and arsenic. This project studies the presence of iodine and arsenic throughout the value chains from cultivation to human consumption, with the aim to manage food safety of this valuable resource.



Photo: Shutterstock

The project focuses on the species *Saccharina latissima* (sugar kelp) and *Alaria esculenta* (winged kelp), both cultivated in Norway, and *S. japonica* which is cultivated in China.

The project is a collaboration between Norwegian and Chinese partners: NMBU, Sintef Ocean, Institute of Marine Research, Institute of Oceanology, Chinese Academy of Sciences and Yellow Sea Fisheries Institute, and Chinese Academy of Fishery Sciences. The three-year project started in 2021 and is led by associate professor Åshild Ergon at NMBU.

Genetic improvement of feed efficiency of Norwegian Red cows

Genetic selection can improve feed efficiency in dairy production. Direct selection would require the recording of individual roughage intake, which is difficult and costly in dairy cattle.

Consequently, alternative methods for measuring feed efficiency are needed. This spin-off project aims to identify indirect measures of feed efficiency in dairy cattle that can be applied on a large scale or at a lower cost.

Collaborators on the four-year project, which began in the autumn of 2021 and is headed by NMBU professor Bjørg Heringstad, are Geno SA, TINE AS and NMBU.

First successful scale-up of microbial feed ingredients from sustainable resources:

Growing yeast from trees

A fruitful collaboration between industry and research has for the first time successfully achieved a large-scale production of yeast from local, sustainable resources



The Lallemand yeast production plant in Salutaguse, Estonia, where the scale-up was conducted.

Photo: Lallemand

An important milestone has been reached by the partners in Foods of Norway: a successful industrial scale-up of 1,600 kg of yeast produced from sugars from Norwegian spruce trees. Production was a joint effort by partners Lallemand Animal Nutrition, Borregaard and NMBU.

Sugar from Norwegian spruce trees was produced by biorefinery company Borregaard, and this was used to grow the yeast at the Lallemand production site in Estonia. The processes could be scaled up thanks to the extensive work done by scientists at NMBU and Lallemand. The yeast will be used in large-scale feeding trials with pigs and Atlantic salmon, in collaboration with leading feed companies in Foods of Norway.

From lab to industrial production

“We are entering an exciting phase where we will be evaluating yeast in diets for salmon in seawater and for piglets under farm conditions”, says Professor Margareth Øverland, who leads the centre.

“Our work follows the entire value chain from the tree biomass to the final meat and fish products. The larger-scale trials will provide important information on how these novel feeds will affect the growth, health and product quality of the animals as well as the production cost and sustainability of using these ingredients”, she says.

Professor Svein Jarle Horn heads the team responsible for yeast fermentation research at NMBU. He says:

“It is very exciting and unique that laboratory results can be directly applied and scaled up by the industry. The research and development performed in Foods of Norway has clearly shown how biotechnology can be used to develop novel sustainable feed ingredients”.



Industrial fermenter inoculation with yeast, Lallemand yeast production plant in Salutaguse, Estonia.

Photo: Lallemand

Demonstrates potential

“We are proud of this important milestone on our journey towards the development of alternative feed ingredients using local Norwegian resources. There is still a lot to be done before commercial development can be realised, but this achievement reinforces the technical feasibility of the concept developed through Foods of Norway towards a more sustainable feed production,” says Mathieu Castex, Director of Research and Development at Lallemand Animal Nutrition.

Gudbrand Rødsrud, Technology Director at Borregaard, agrees:

“This large-scale production experiment demonstrates the opportunities that exist for developing sustainable feed products from wood and it will enable documentation of business potentials through large scale feeding trials.”

Dr. Ildar Nisamedtinov is vice president of research and development at Lallemand. He says:

“Our partners at NMBU have previously carried out thorough studies when it comes to using Borregaard’s spruce syrup in the cultivation of different yeast species. That knowledge was a good starting point for us to further design and optimize the process that could be industrially utilised.”

“In my opinion, this is an excellent example of how collaboration between academia and industry can lead to new products”, he elaborates.

Closing in on a marketable solution:

Feeding salmon yeast from spruce trees

Locally produced feed based on sustainable, novel ingredients is slowly getting closer to market. At the Norwegian shore, at Dønna, salmon are now being given feed based on by-products from the Norwegian forest.



800 salmon are being fed on yeast cultivated on sugars from Norwegian spruce trees at LetSea's farm at Dønna.

Photo: LetSea

In the cages of LetSea's research facility at Dønna, 800 salmon are being fed on yeast cultivated on sugars from Norwegian spruce trees, as part of a large field trial evaluating yeast in feed for salmon. The fish will eat the yeast-based feed until they reach full size.

The yeast was produced in the scale-up of microbial feed ingredients from local natural resources in the centre. The yeast-based feed was produced at BioMar's technical production facilities in Denmark, and researchers from BioMar in Trondheim will monitor the growth performance, health and welfare of the fish during the trial.

Valuable collaboration

Foods of Norway partner BioMar holds the expertise when it comes to high-performance diets for aquaculture, aiming to bring to market efficient, safe and nutritious feeds with minimal environmental impact.

«We are incredibly proud to have reached this phase where we are feeding salmon yeast-based feed in seawater. We are testing increasing levels of yeast protein in the feed, and through the ongoing research in Foods of Norway we look forward to getting answers related to nutritional quality and other trial parameters,” says Senior Researcher in BioMar R&D Monica Juarez, who leads the collaboration with Foods of Norway at BioMar.

BioMar has been a partner in Foods of Norway since 2019 and has played a vital role in the research on novel feed ingredients. Vegard Denstadli is Technical Director at BioMar, and he explains how this feeding trial represents a new and exciting phase.

“We are now in the final phase of our research, but we believe that these trials represent the start of a completely new way of producing raw materials for feed. We have large amounts of bioresources available in Norway and this project demonstrates how it is entirely possible to use the forest, macroalgae and other waste streams as raw material for feed,” he says.

Head of Foods of Norway Margareth Øverland agrees:

“Our work follows the entire value chain from tree biomass to the final meat and fish products. This large-scale trial will provide important information on how these novel feeds will affect the growth, health and product quality of the fish, as well as the production cost and sustainability of using these ingredients”, she says.

Norwegian news broadcaster TV2 visited LetSea at Dønna as the fish were given the novel feed. LetSea is one of BioMar's research facilities, and is where the field trial takes place.

Photo: TV2.no

2 Nyheter



GRAN: Fiskeforet Henriette Hanssen holder i hendene, er laget av grantrær. Foto: Bendik Årsæther / TV Klipp

Her føres laksen med norske grantrær

Verdens matvareprodusenter ser mot Norge. For første gang mates oppdrettslaks med for utviklet med norsk teknologi, basert på norske grantrær.

Just another day in Foods of Norway:

Can we grow chicks with feed made from sticks?

Six pens are filled with tiny, fluffy yellow chickens. For the next five weeks they will hopefully help pave the way to a more sustainable agriculture in Norway – one foot at a time.



The chicken pens are fully monitored. Humidity, heating, ventilation, light and more can be controlled.

Photo: Khaled Itani/Foods of Norway

In each of the fully lit pens 15 birds are settling into their new home. In their troughs are feed and water, and for the first days of their life the chickens will have light for 23 hours of the day so they can get to know their new surroundings. So far, their life is pretty much like that of many chickens bred in Norway. Their feed is made according to Norwegian standards. But for this trial some of the ingredients have been replaced by yeast from Norwegian spruce trees.

These chickens are part of an important innovation. They play a crucial part in exploring whether we can replace protein-rich feed resources we currently need to import, particularly soybean meal, with sustainable, locally produced ingredients. In this case, yeast produced on sugars derived from Norwegian spruce.

“Using yeast from trees as a feed ingredient can be a more sustainable approach to animal feed, as it enables us to produce protein-rich ingredients right here in Norway,” explains Khaled Itani. He is a researcher in Foods of Norway.



Researcher in Foods of Norway
Khaled Itani

Photo: NMBU

Promising results

Khaled's research aims to investigate the potential for replacing some of the common protein ingredients in chicken feed with protein from yeast, as well as study whether this yeast could be beneficial for the intestinal health and immune system of the birds.

"So far this trial has been a success - we now know that the yeast is safe for the chickens, they ate the feed and their performance was satisfactory," he says, and adds: "More research will improve our knowledge about yeast as a feed ingredient, especially when it comes to digestibility. Therefore, an even higher inclusion rate may also be possible."



At 34 days the chickens were fully grown.

Photo: Khaled Itani/Foods of Norway

The feed was produced at NMBU's Centre for Feed Technology in collaboration with Felleskjøpet Fôrutvikling, and the trial was conducted at the university's Livestock Production Research Centre in Ås. These research facilities are fully computerized, meaning that parameters such as humidity, heating, ventilation, light and more can be controlled and monitored.

One foot at a time

There are numerous factors to take into consideration when it comes to a trial like this. The chickens' feet, for instance, may offer hints as to the chickens' health and welfare. If the litter moisture is too high, that may indicate digestive problems - and stepping in soft litter all day might cause lesions and sores on the birds' feet. There were, however, no indications of increased moisture in the litter or foot lesions.

"Welfare issues are key to us when conducting our research," explains Itani, and adds: "There are adjustments we could have made along the way if necessary, such as adding more wood shavings to the chicks' pens. Luckily, there were no such issues in this trial."

Investigating health effects

Foods of Norway's director, Professor Margareth Øverland, is also optimistic about the results: "This work is very significant for Foods of Norway, as we can now conclude that the yeast-based feed also works well for chickens. We have completed several successful trials with yeast in the diets of other farm animals, so this just adds to its potential as a valuable feed ingredient. The next step is to investigate the positive health effects of yeast in chicken feed, which is yet another important part of our research," says Øverland.

RECRUITMENT

Foods of Norway increased its staff in 2021.



Dominic Duncan Mensah
PhD Student

Fish Nutrition and Health



Ghulam Qasim Khan
Researcher

Ruminant Nutrition



Purushothaman Kathiresan
Postdoctoral Fellow

Molecular Biology and Pathology

KNOWLEDGE SHARING

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

2021 was yet another year where many events were held digitally. Still, Foods of Norway researchers have participated in several scientific conferences and webinars, both in Norway and abroad.



The Foods of Norway delegation in Madeira, Portugal

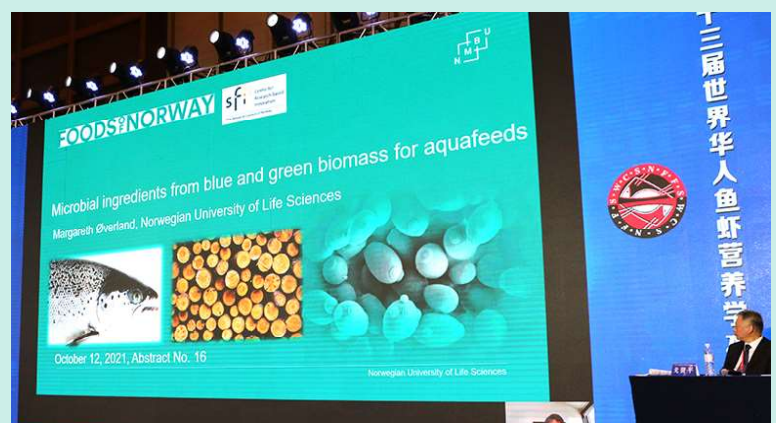
Photo: Foods of Norway

A group from the centre travelled to Funchal, Madeira, for the Aquaculture Europe 2021 event, where they talked about yeast as a protein source in the diets of Atlantic salmon, providing beneficial health effects. At the same event, the group presented the topic «Biotechnological production of microbial ingredients from blue and green biomass».

Researcher Hanne Dvergedal presented her research on new indicator traits for individual feed efficiency for Atlantic salmon, at AquaNor 2021 in Trondheim.

Centre director Professor Margareth Øverland participated in several events during the year, one of which was the 13th Symposium of World's Chinese Scientists on Nutrition and Feeding of Finfish and Shellfish, discussing microbial ingredients from blue and green biomass for aquafeeds.

Professor Øverland also participated in several major Norwegian events looking at novel feeds in the blue and green sectors, where she contributed with perspectives on how to feed salmon in order to meet protein requirements and on the potential of seaweed as a feed resource.



Margareth Øverland presented at the 13th Symposium of World's Chinese Scientists on Nutrition and Feeding of Finfish and Shellfish

Photo: SWCSNFFS

COMMUNICATION & DISSEMINATION

Foods of Norway reached several milestones in 2021, and the media attention has been positive.

Communication efforts from the centre have been well received, both internationally and domestically. In May, the Finnish start-up company eniferBio became a partner, and in June, the successful up-scaling of yeast was a great example of the ground-breaking results the centre has accomplished. Press releases were sent out and received well, and have also led to follow-up news stories. Foods of Norway and the centre's experts have a good standing with the media and close connections with several relevant news outlets.

In many of the centre's communication activities during 2021, the cooperation between partners has been important. Close collaboration between industry and academia adds value to the centre as a knowledge provider and this has strengthened the messages.

The centre's communication strategy is to continue the focus on main target audiences: decision and policy makers, farmers' associations, other stakeholders, and the general public in Norway. The centre also aims to continue building the brand as a knowledge provider for agriculture and aquaculture industries in Norway and abroad.



*Article from
FishFocus,
07 October 2021*

FishFocus
AQUACULTURE / CATCHING / PROCESSING

NORWAY LAUNCHES EXPERIMENT ON FEEDING PIGS AND SALMON



Norway launches experiment on feeding pigs and salmon with spruce feed additive. Norway will launch a high-quality [feed additive](#) made from Norwegian spruce-based yeast that can replace imported protein. It has already been possible to produce on an industrial scale 1600 kilograms of yeast produced in one fermentation cycle from several thousand litres of sugar produced from Norwegian spruce. Yeast, a microbial protein source with 50-60% protein, will be used in large-scale feeding trials of pigs and Atlantic salmon.

Norsk Landbruk

Produserte 1600 kilo gjærprotein

Vellykket industriproduksjon fra Foods of Norway



Foods of Norway skal lage gjærprotein av trebiomasse for å erstatte importert soya.



Øystein Heggdal

Publisert: 16.09.21, 11:46 | Oppdatert: 16.09.21, 11:46

– Vi går i nå inn i en spennende fase hvor vi skal evaluere gjær i før til la og for smågris under oppdrettsforhold, sier professor Margareth Øverland Foods of Norway.

Article from
Norsk Landbruk
16 September 2021

The Fish Site

Finnish alt-protein producer targets Norway's salmon feed sector

STARTUPS FEED INGREDIENTS NUTRITION

by The Fish Site
20 May 2021, at 11:39am

A Finnish startup that converts forestry waste into protein that can be used in aquafeeds has teamed up with Norwegian researchers to refine the process.



eniferBio has developed a method for producing a form of single cell protein derived from fungi called Pekilo and announced plans this week to collaborate with Foods of Norway – part of the [Norwegian University of Life Sciences \(NMBU\)](#).

"eniferBio's expertise fits perfectly into our value chain", says Foods of Norway's centre director, professor Margareth Øverland.

"They specialise in profitable and sustainable production of single cell protein from resources we have a lot of in Norway, our forests. Foods of Norway aims to develop technology that can contribute to a profitable production, and eniferBio produces single cell protein with cheaper substrates and side streams than we are able to today. Our new partner can help create the market we hope will be established for single cell protein as an ingredient in feed. I also believe that we can be a valuable partner for eniferBio, as we possess extensive knowledge and documentation of the nutritional value and beneficial health effects of single cell protein," she adds.

2 Nyheter



GLADE GRISER: Grisene på Vormsund liker det nyutviklede føret. Foto: Goran Jorganovich / TV 2

Har utviklet nytt Fôr av NORSK gran:

Garanterer enda bedre juleribbe

Etter mer enn seks års forskning og teknologiutvikling mates nå norsk gris på kraftfôr basert på norske grantrær. Dette skal redusere behovet for soya, bedre dyrehelsen og ribbekvaliteten.



nyvesta into a single cell protein that can be used in aquafeeds

Article from
The Fish Site
20 May 2021

Article from
TV2.no
13 December 2021

IN NUMBERS: COMMUNICATION OUTPUT IN 2021

+ 11 %

Number of Facebook followers increased by 11 per cent

+ 48 %

Reach of Facebook posts increased by 48 per cent

176

Number of newsletter subscribers



Articles in editorial media	Norwegian	38 ¹
	International	16 ¹
Newsletter*	Sent out	2 ²
	Subscribers	176
Facebook	Followers	965
	Average reach	454
	Average engagement (post clicks / reactions, comments & shares)	22 / 18
Twitter	Followers	468
	Impressions	8 783

¹ Comparison with previous results not accurate due to new media monitoring (NMBU)

² Created in June and December 2021, in accordance with GDPR

Publications list

- Agboola, J. O., Lapeña, D., Øverland, M., Arntzen, M. Ø., Mydland, L. T., Hansen, J. Ø. **Yeast as a novel protein source - Effect of species and autolysis on protein and amino acid digestibility in Atlantic salmon (*Salmo salar*)**. *Aquaculture* 2021; Volume 546, Article 737312. <https://doi.org/10.1016/j.aquaculture.2021.737312>
- Agboola, J. O., Schiavone, M., Øverland, M., Morales-Lange, B. M., Lagos, L., Arntzen, M. Ø., Lapeña, D., Eijsink, V., Horn, S. J., Mydland, L. T., François, J. M., Mercado, L., Hansen, J. Ø. **Impact of down-stream processing on functional properties of yeasts and the implications on gut health of Atlantic salmon (*Salmo salar*)**. *Scientific Reports* 2021; Volume 11, Article 4496. <https://doi.org/10.1038/s41598-021-83764-2>
- Arntzen, M. Ø., Pedersen, B., Klau, L. J., Stokke, R., Oftebro, M., Antonsen, S. G., Fredriksen, L., Sletta, H., Aarstad, O. A., Aachmann, F. L., Horn, S. J., Eijsink, V. **Alginate degradation: Insights obtained through characterization of a thermophilic exolytic alginate lyase**. *Applied and Environmental Microbiology* 2021; Volume 87(6), e02399-20. <https://doi.org/10.1128/AEM.02399-20>
- Djordjevic, B., Morales-Lange, B. M., Press, C. M., Olson, J., Lagos, L., Mercado, L., Øverland, M. **Comparison of circulating markers and mucosal immune parameters from skin and distal intestine of Atlantic salmon in two models of acute stress**. *International Journal of Molecular Sciences* 2021; Volume 22(3), Article 1028. <https://doi.org/10.3390/ijms22031028>
- Djordjevic, B., Morales-Lange, B. M., Øverland, M., Mercado, L., Lagos, L. **Immune and proteomic responses to the soybean meal diet in skin and intestine mucus of Atlantic salmon (*Salmo salar* L.)**. *Aquaculture Nutrition* 2021; Volume 27(6), pp.929-940. <https://doi.org/10.1111/anu.13248>
- Hansen, J. Ø., Lagos, L., Lei, P., Revenco-Urzuá, F. E., Morales-Lange, B. M., Hansen, L. D., Schiavone, M., Mydland, L. T., Arntzen, M. Ø., Mercado, L., Benicio, R. T., Øverland, M. **Down-stream processing of baker's yeast (*Saccharomyces cerevisiae*) – Effect on nutrient digestibility and immune response in Atlantic salmon (*Salmo salar*)**. *Aquaculture* 2021; Volume 530, Article 735707. <https://doi.org/10.1016/j.aquaculture.2020.735707>
- Hansen, J. Ø., Sharma, S., Horn, S. J., Eijsink, V., Øverland, M., Mydland, L. T. **Fecal excretion and whole-body retention of macro and micro minerals in Atlantic salmon fed *Torula* yeast grown on sugar kelp hydrolysate**. *Animals* 2021; Volume 11(8), Article 2409. <https://doi.org/10.3390/ani11082409>
- Håkenåsen, I. M., Grepperud, G. H., Hansen, J. Ø., Øverland, M., Ånestad, R., Mydland, L. T. **Full-fat insect meal in pelleted diets for weaned piglets: Effects on growth performance, nutrient digestibility, gastrointestinal function, and microbiota**. *Animal Feed Science and Technology* 2021; Volume 281, Article 115086. <https://doi.org/10.1016/j.anifeedsci.2021.115086>
- Morales-Lange, B. M., Agboola, J. O., Hansen, J. Ø., Lagos, L., Øyås, O., Mercado, L., Mydland, L. T., Øverland, M. **The spleen as a target to characterize immunomodulatory effects of down-stream processed *Cyberlindnera jadinii* yeasts in Atlantic salmon exposed to a dietary soybean meal challenge**. *Frontiers in Immunology* 2021; Volume 12, Article 708747. <https://doi.org/10.3389/fimmu.2021.708747>

- Olsen, M. A., While, S. G., Porcellato, D., Kidane, A., Skeie, S. B. **Feeding concentrates with different protein sources to high-yielding, mid-lactation Norwegian Red cows: Effect on cheese ripening.** *Journal of Dairy Science* 2021; Volume 104(4), pp.4062-4073.
<https://doi.org/10.3168/jds.2020-19226>

Statement of accounts

Foods of Norway costs 2021 (1000 NOK)

Host NMBU	Industry partners (Norway)	International partners	Equipment	Total costs
19 223	5 509	1 158	0	25 890

Foods of Norway funding 2021 (1000 NOK)

Host NMBU	Industry partners (Norway)	International partners	Research Council	Total funding
4 140	6 885	732	14 133	25 890

Foods of Norway – 237841/O30

List of personnel 2021

Key researchers	
Name	Main research area
Margareth Øverland	Centre director; Feed ingredient evaluation
Vincent Eijsink	Fundamental and applied enzymology; bioprocessing
Svein Jarle Horn	Bioprocessing, applied enzymology
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
Bjørge Egelandstad	F	Product quality of meat
Bjørge Westereng	M	Biorefining facilities, bioprocesses, analytics
Randi Sørby	F	Veterinary pathology
Nils Petter Kjos	M	Pig nutrition
Hanne Fjerdingsby Olsen	F	Life cycle assessment
Egil Prestløkken	M	Ruminant nutrition

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
Vladana Grabez	F	Meat quality, proteomics
Hanne Dvergedal	F	Feed efficiency in fish
Özgun Candan Onarman Umu	F	Gut microbiota
Leszek Michalak	M	Processing of seaweed
David Lapeña Gomez	M	Bioprocessing, enzymatic processes, fermentation
Sergio Da Rocha	M	Microbiology and immunology assessment
Caroline Marcussen	F	Yeast in diets for broiler chickens
Peng Lei	F	In vitro screening of feed components for health effects
Brankica Djordjevic	F	Fish nutrition and health
Khaled Itani	M	Yeast in diets for broiler chickens
Ghulam Qasim Khan	M	Ruminant nutrition, upgrading nutritional value of grass
Ove Øyås	M	Bioinformatics

Postdoctoral researchers working on projects in the centre with financial support from other sources			
Name	M/F	Funding	Topic
Jørgen Ødegaard	M	NMBU	Genomics of feed efficiency
Byron Morales Lange	M	NFR	Mucosal immunity
Davide Porcellato	M	NMBU	Milk microbiota
Purushothaman Kathiresan	M	NMBU	Fish health

PhD students with financial support from the centre budget		
Name	M/F	Topic
Martine Olsen	F	Influence of feed on milk quality
Jeleel Opeyemi Agboola	M	Downstream processing of yeast, salmon nutrition and health
Ingrid Marie Håkenåsen	F	Nutrition, novel protein sources, nutrition effect on performance, gut function and health

PhD students working on projects in the centre with financial support from other sources			
Name	M/F	Funding	Topic
Pabhoda Weththasinghe	F	Nordic CoE	Growth performance and health in salmon
Eirin Stork	F	NMBU	Product quality of milk
Mette Hofossæter	F		Animal health
Stanislav Iakhno	M	NMBU	Gut microbiota
Dominic Duncan Mensah	M	NMBU	Fish nutrition and health

Master degrees		
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
Dominic Duncan Mensah	M	Effect of downstream processing of yeast on the gastrointestinal health of Atlantic Salmon during seawater transfer
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 (<i>Salmo salar</i> , L) from two different families fed with bioactive components

PhD degrees		
Name	M/F	Topic
Stanislav Iakhno	M	Porcine gut microbiota, short-chain fatty acids, and gut health in response to a high yeast inclusion diet

Visiting researchers				
Name	Period	M/F	Affiliation	Topic
Byron Maximiliano Morales Lange	15.10.19-31.10.21	M	Catholic University of Valparaíso	Mucosal immunity



FOODS OF NORWAY

Annual report 2021

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