Fish farms moving onshore

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A major challenge linked to land-based facilities for fishfarming is the adequate control of microbial conditions and chemical water quality. The project DigRAS will look into this. This is how future land-based fish farms are going to look like. Credit: AKVA Group

Land-based fish farming offers many benefits to both the fish and the environment. In traditional offshore farms, the fish are vulnerable to sea lice infestation and infectious diseases. Modern land-based aquaculture systems are able to offer local fish products in landlocked countries.

In order to promote more widespread land-based fish farming, researchers are employing international collaboration, artificial intelligence and advanced analytical approaches.

"Norway has a great deal of previous experience in land-based aquaculture in that much of the salmon smolt now living in Norwegian net pens was born and raised in such facilities," says Roman Netzer, a Senior Research Scientist at SINTEF.

"The knowledge that Norway has generated in the field of land-based salmon farming in state-of-the-art Recirculating Aquaculture Systems (RAS) during the last 20 years has been very attractive internationally, especially in connection with the farming of other species. Enclosed land-based facilities of this type in which the water is recirculated enable fish to be produced almost anywhere, and not least close to the market," he says.

An example of this is the Fresh Cooperation facility in Germany that produces fish for local customers in central Europe in so-called 'zero water exchange' (RAS) facilities, which are run on electricity from renewable sources and use sustainable feeds that are free of wild-caught fish components. This type of production system is thus not only eco-friendly but also helps to conserve wild fish populations. Today, while large volumes of fish are transported by air over great distances, RAS facilities offer a sustainable alternative.

However, land-based fish farming is not free of challenges. The sector suffers from mass mortalities and fish meat tainted with an earthy flavor because the biological conditions in land-based facilities are difficult to control and very young fish are sensitive to poor water quality. In the worst cases, many thousands of smolt can die relatively suddenly, which can lead to major losses if we consider the profit that could be generated from the sale of fully grown salmon.

Research drives development

The international insurance sector requeststhat operators make greater efforts to mitigate the problems resulting from biological conditions in the water. This is why a new European research project, called DigiRAS, is currently attempting to address a number of challenges linked to land-based fish farming. The project is being coordinated by SINTEF Ocean and involves the participation of eleven research partners from five different countries. Norway is represented by the research partners Norwegian University of Life Sciences (NMBU), the aquaculture research center LetSea, the technology supplier AKVA Group and SINTEF.

"The project will be looking closely into the farming in RAS facilities of five fish species," says Netzer. "The international project consortium intends to study the microbial communities both inhabiting the fish and in the facilities' water. The aim is to design strategies to improve water quality, develop sensors, and study fish welfare using camera systems and artificial intelligence," he says.

Demanding microbiology

A major challenge linked to land-based RAS facilities today is the adequate control of microbial conditions and chemical water quality. Significant variations may also arise within a single facility. A number of different physical components are also involved, such as mechanical filters, biofilters, degassers for the removal of CO_2, and the 'tanks' in which the fish are reared.

"This is why effective water treatment and stable microbiological conditions are key to responsible and sustainable production from such facilities," explains Netzer.

As part of the project, the microbial communities both within the RAS facilities and those inhabiting the skin and gills of salmon, Arctic charr, bream, European bass and Seriola will be studied using next and third generation gene sequencing technology.

The project's industrial partners LetSea, Norwegian Fish Farms Tydal AS, Fresh Cooperation and Andromeda Group are supplying the fish for use in the research project and providing their fish farm infrastructure.

"Our aim is to identify the bacteria species that are important for maintaining adequate water quality, and at the same time those that may represent a threat to fish health," says Netzer. "This work is being led by my colleague at SINTEF Deni Ribičić, who is an expert in the mapping of microbial communities in aquatic environments.

Ribičić is working closely with researchers at Bielefeld University in Germany, which offers specialist expertise in sequencing technology and bioinformatics," he adds.

AI and machine vision detecting disease and water contamination

The risk of mass fatalities is very great in seawater rearing facilities. This is because seawater contains sulfate, from which highly toxic hydrogen sulfide (H_2S) can be formed by the activity of certain bacteria that are commonly found naturally in water and biofilms. The numbers and levels of activity of these bacteria will be analyzed using molecular biological methods such as real-time quantitative and digital polymerase chain reactions (PCR).

"H_2S, or hydrogen sulfide, has repeatedly been highlighted as the cause of mass fatalities in RAS facilities," says Netzer. "This happens because

we currently have no analytical method of identifying H_2S before the fish display clear signs of toxification, by which time it's usually too late to save them," Roman Netzer says.

"So a key aim of this project is to devise a method that can monitor toxin formation by developing a portable sensor that facilitates accurate H_2S analyses, even of ultra-low concentrations, based on nanomaterial technology. This work is being headed by our Portuguese research colleagues at INL in Braga," says the researcher.

The project will also be employing underwater camera systems to monitor fish behavior. Discomfort and stress will generally cause the fish to change their behavior in the form of different swimming patterns, or deviations in gill and/or tail-beating frequencies.

"My research colleague Bjarne Kvæstad has built an underwater camera system to monitor fish behavior," says Netzer. "By using artificial intelligence, we hope to identify early stage indications of behavioral change in response to worsening environmental conditions," he says.

The aim is to develop an early warning system that sends out an alert in response to water quality changes before the fish become harmed. Researchers are hoping that artificial intelligence will enable them to see at an early stage if the fish are suffering discomfort due to causes such as sulfide toxification. Similar algorithms have already been developed and tested in traditional salmon pens and will now be used to monitor fish in closed RAS facilities.

Netzer adds that for the most part, fish experience good welfare conditions in such facilities, not least because they are free from parasites such as lice, as well as toxic algae with which traditional farmed fish may be afflicted. They also live in an environment where the water quality is tailored to their needs. The health of the fish will also be

studied by researchers from the University of Patras in Greece.

Removing earthy taints

A further problem is that fish kept in land-based RAS facilities right up until slaughter often develop meat tainted with an earthy flavor (so-called off-flavor), which is unacceptable to the market. This often means that the fish have to remain for several weeks prior to slaughter in a flow-through tank for 'depuration," which significantly increases production costs. The problem is greatest in species with high fat contents, such as Arctic charr, trout and salmon. According to Netzer, the researchers are convinced that they will be able to resolve this problem as well by designing new water treatment methods in collaboration with a water treatment expert from LUT University in Finland.

Ideal for combined production systems

Another advantage of closed fish farming facilities is that the waste generated can be used as fertilizer in so-called aquaponics systems, involving a combination of aquaculture and hydroponics, or in the cultivation of new bioresources such as bristle worms, sea cucumbers, shellfish or seaweeds.

"We already have examples of how fish farming and vegetable production can be combined," says Netzer. "This is efficient food production and effective exploitation of resources in practice, and is a concept that will be explored as part of a sister project calledSidestreams," he says.

Big Data

Large volumes and a wide variety of data will be generated by the

DigiRAS project—everything from water quality data to DNA sequences and videos. The NMBU will be heading the work to collate these data and ensure that fish farming in RAS facilities can be optimally digitalised to improve operational control. This is where project partner AKVA Group will have an important role to play since this company specializes in aquaculture technologies and related expertise.

Provided by SINTEF