Better utilisation of fish waste in agriculture – strengthening the local collaboration

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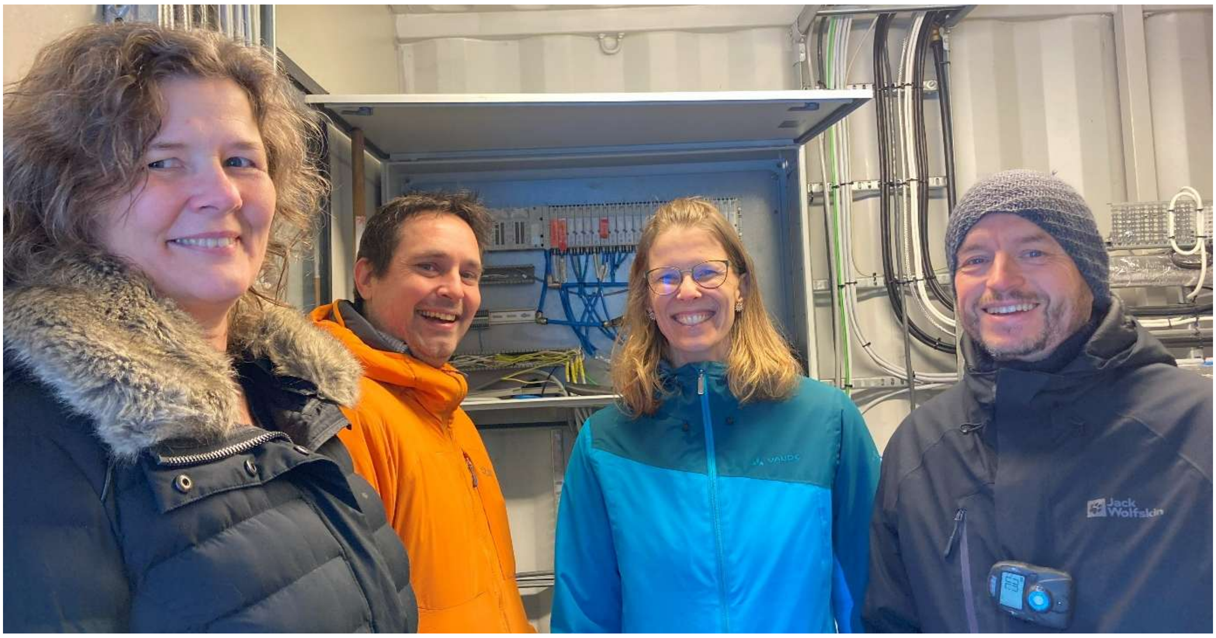
Researchers Andre Meriac and Turid Synnøve Aas from Nofima visited Tingvoll on February 3, 2025 to discuss collaboration and common research interests with Ingvar Kvande, Tatiana Rittl, Sissel Hansen, Joshua Cabell and Anne-Kristin Løes. The national research institute Nofima has a department in Sunndal, about 60 km from Tingvoll. In addition to a common interest in nutrient management, this proximity favors a closer collaboration.



From left: Turid Synnøve Aas, Andre Meriac, Tatiana Rittl, Ingvar Kvande. Photo AK Løes.

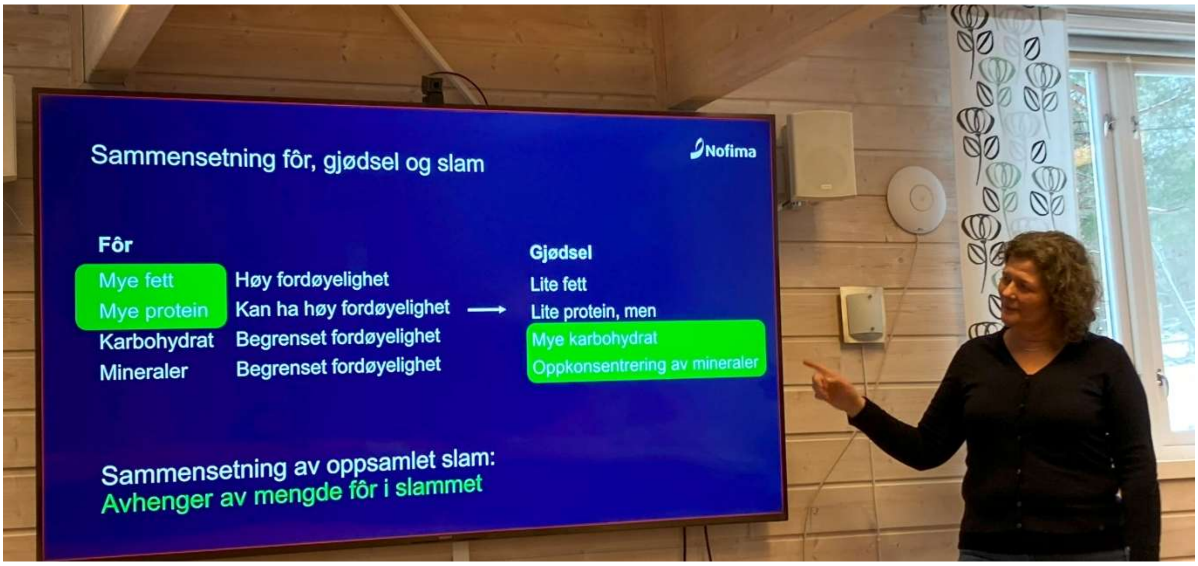
The day started outdoor, showing our guests around on the Tingvoll farm biogas plant, where the slurry from the herd of 22 dairy cows is treated in a 50m^3 concrete reactor. Some oxygen is added to remove hydrogen disulfide, and a filter of active carbon applied to clean the biogas before it is incinerated in a Sterling combined heat and power motor. NORSØK has laboratories and growth rooms for plant and soil studies, and lab reactors for biogas studies (owned by NIBIO).

To prepare for discussions about collaboration, Dr. Ingvar Kvande presented the Horizon Europe project **Nutrient balance and resource optimization in regional ecosystems through holistic, sustainable, and zero-pollution solutions (**Greenhood, 2025-2029, GA 101181712). In Greenhood, Trøndelag is one of four regional European cases where the N and P budgets will be monitored to reduce nutrient surpluses. Fish sludge and animal manure are central nutrient inputs in Trøndelag, and Svanem biogas in Hellandsjøen will be a practical case.

Dr. Tatiana Rittl presented the national project **Transforming Marine Residuals into Energy and Sustainable Fertilizer** (Circulizer, 2024–2027). One important goal is to study how fish sludge and silage from dead fish will affect the quality of biogas digestate applied as manure. How much fish sludge can be included in a biogas substrate? Svanem biogas is a partner also in this project, which is led by NORSUS. Tatiana presented results of field experiments in 2024, comparing an untreated control with application of untreated substrate (80% cattle slurry + 20% fish sludge) and non-separated and separated anaerobically digested substrate (the liquid fraction). The rates of organic fertilizers corresponded to 30 kg P/ha/year. The trial comprised a set of treatments with the same organic fertilizers plus complementary mineral N fertilizer to reach the recommended N rate of 250 kg N/ha. The ley yields correlated closely with the amounts of N applied for the plots fertilised with non-digested substrate or digestate, while the plots receiving additional mineral N had similar yield. The liquid fraction digestate had much higher N efficiency. Field trials will be conducted also in 2025 and 2026.

Dr. Sissel Hansen presented results from a case study of greenhouse gas (GHG) emissions from farm scale manure storage. Eight storages were compared, and methane was the most important GHG. On two quite similar dairy farms, the manure behaved quite differently in storage. One farm had a very solid crust, about 1 m thick, whereas the other had no crust, but a lot of gas production, due to regular addition of lime with a dispersant additive. The methane emissions from the storage with no crust were surprisingly small, and the explanation for this is unclear. In the storages, the temperature levels were generally low (< 15 C), and measured methane levels varied considerably. GHG emissions from manure storage are challenging to study on a practical level, but farm level studies provide unique information.

Research in Nofima on nutrient management in aquaculture was presented by Dr Andre Meriac. Nofima has nearly 400 employees spread on 5 locations (Tromsø, Bergen, Stavanger, Ås, and Sunndal). In Sunndal, the research is on aquaculture, especially fish biology, fish feeding and management of fish sludge. Nofima Sunndal conducts analyses of fish feed, fish blood, and water samples, such as DM%, Kjeldahl N, amino acids, LOI, lipids, NO3, NO2, NH4, tot C, dissolved organic C. Extensive research infrastructure has been developed in Sunndal over time, thanks to projects like CtrlAQUA (2015-2023). However, that project was mostly about diseases, health and welfare and less about feed, sludge or nutrient management. A general goal in recycling aquaculture systems (RAS) is to reduce water throughflow. This demands a stricter control regime, e.g. of fish excrement. Feces may be filtered out, but dissolved waste (N, P, DOC) is a challenge, and a significant proportion of N is lost by metabolic activity via gills, and excretion of urine. H_2S is a big risk in RAS; feed loss will increase this risk. All factors (feed, water quality, water consumption, type of filter etc.), affect each other, making the study of utilizing excess nutrients very exciting.



Turid Synnøve Aas summarizes her knowledge on the connections between fish feed and fish sludge. Photo: AK Løes.

Dr. Turid Synnøve Aas reviewed the effects of feed quality on sludge quality. Sludge is filtrated (possibly in several rounds, including centrifugation), dried, and distributed. All these steps consume energy. Fish plants are land-based, open or semi-open, and this affects the possibility to collect the sludge. The first priority should be to achieve a 100% feed utilization, but the feed efficiency increases with increased feed intensity. Hence, this is not realistic in practice. A lot of efforts (and the regulations) have been towards management of sludge, but much less efforts have been devoted to optimize the feed to reduce the volume of sludge. Possibly, excess feed could be applied as feed again?

The value of sludge for application as biogas substrate and manure is higher with more feed loss. In a mass balance study conducted in a RAS tank of all DM applied to a volume of fish over 3 months, 1/3 was used for fish growth, 1/3 for metabolic loss, and 1/3 was sludge and dissolved losses. Out of the latter fraction, the largest proportion was not possible to collect. The digestibility of fish feed is up to 75% for very young fish, decreasing to about 60% for large fish. The percentage of excess feeding required for efficient growth is a difficult measure to record, but 2-5-10% values are realistic. Most likely, the numbers are lower in open cages in sea than in closed systems.

By 2025, about 2 million tons of fish feed DM are used annually in Norwegian aquaculture. The resulting sludge and dissolved waste comprise an extremely high number of DM to collect. Soy is extracted to soy protein concentrate before application as fish feed. Some non-digestible carbohydrates, ash and lipids will still be present; 62% protein is the average value for soy protein concentrate produced to feed salmon. "Sustainable" feed resources are of high interest, e.g. singular cell materials. These may contain high proportions of cell wall material. Larvae are interesting as feed but contain chitin. Animal byproducts may be applied as fish feed after hygienisation, but the heating decreases the protein digestibility. A salmon is comparable to a cat; they both have a short gut with poor digestion of carbohydrates. Carbs are added mostly to make feed pellets that do not disintegrate too fast in water.

Minerals are also digested. The mineral balance is regulated by demand. The efficiency of P uptake in the gut will be higher when the fish demands P. From a feed/fish nutrition perspective, both P and sink (Zn) could be applied to a higher extent than the current regulation allows for. P in fish bones may be processed to become more readily available for the fish.

Increased utilization of "new" feed ingredients, which is high on the political agenda, will easily lead to increased sludge volume. In conclusion, the composition of collected sludge is very much affected by the proportion of feed in the sludge. It is common that 30% of the feed loss will get dissolved, and the fish feces will also easily dissolve unless the feed is designed with certain compounds e.g. alginate that makes more solid feces. A recent model study by Nofima and NIBIO (Aas, Brod, Solli) showed that an optimized system with less feed loss would decrease the energy potential (for biogas) in the optimized sludge, and increase the mineral concentration, e.g. of P, but also of Cd. Why shall we apply so much energy to collect fish sludge, just because it is technically possible, when the largest proportions of N and P are dissolved and lost anyway?

Joshua Cabell mentioned a trial where sawdust was applied for retention of N and P in fish sludge from RAS, conducted in collaboration with DTU, Hirtshals (see the project MariGreen).

The knowledge in Nofima about nutrient flows and management in aquaculture is highly valuable both for Greenhood and Circulizer. Vice versa, Nofima colleagues identified several possibilities for a closer collaboration, not least linked to application of fish residual materials as soil amendments. Another meeting will follow soon.

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The workshop was completed with a discussion about further collaboration. The laboratory work in Sunndal is project based, and they do not have a large capacity to handle external analyses. One industry company of common interest is the Havila biogas, located in Eidsøra near Sunndal and delivering biogas to Sunndal industry (Hydro). Møre og Romsdal R council may have some money for supporting the establishment of research collaboration. It may be possible to apply for common project funding in the Sustainable Blue Economy Partnership https://www.bluepartnership.eu/ , a call will be launched about 15.9.2025. Contact person at RCN is Kathrine Angell-Hansen, ka@forskningsradet.no