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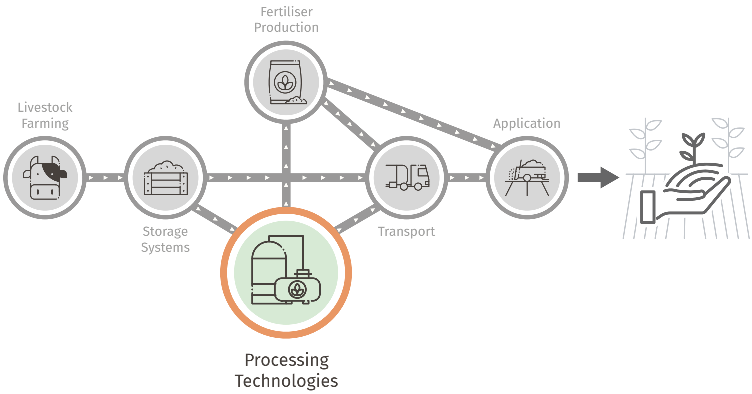
Processing Technologies

Technologies, tools and recommended practices from NUTRI-KNOW's EIP-AGRI Operational Groups

Introduction

The restrictions on nutrient application on the fields combined with the presence of intensive livestock, nutrient scarcity (e.g. phosphorus) and volatile prices for fossil-based mineral fertilisers drive farmers to invest in (nutrient) processing technologies. Processing technologies mainly refer to technologies used to process agricultural products to a better quality, or to treat agricultural waste for fertiliser production, energy generation or to mitigate their environmental impact. Examples of such technologies include anaerobic digestion, composting, solid-liquid separation, thermal drying, incineration, nitrification-denitrification etc.

The booklet gives an overview of decision support tools, technologies and recommended practices that are the outcomes of key EIP-AGRI Operational Groups. These groups and associated projects have focused on improving processing technologies to recover nutrients and provide knowledge about innovations and the advantages and challenges of adopting them.



Processing Technologies

This booklet highlights innovations and improvements in technologies for agricultural waste processing. The technologies presented here support the management of livestock manure as well as the circular economy on farms. For more information see the links to the home pages of the Operational Groups presented below.

Bio-Based Products and Organic Farming

The creation of bio-based products can help to encourage more closed-loop supply chains through the recycling of organic manures and other waste materials. They can also stimulate innovative practice uptake and new business opportunities in the organic sector. Sustainable biogas production, for instance, has the potential to reduce methane emissions from the storage of manure, generate renewable energy, and support crop yields through digestate application. Processing technologies and materials used to produce bio-based products must be in line with organic principles and standards. Bio-based products, for example, derived from animal waste obtained from permanently housed operations are not permitted in organic farming owing to potential contamination risk.

Livestock **Manure Management**

Livestock manure management poses environmental and economic challenges for farmers, especially in high-density livestock areas. The Slurry Concentrator addresses this by separating manure into a nutrient-rich semi-liquid phase and a low-nutrient liquid phase. It concentrates 85-95% of solids, 45-55% of nitrogen, and 85-95% of phosphorus, reducing total volume by 20-30%. The nutrient-rich semi-liquid fraction is ideal for long-distance transport, cutting costs and enabling nutrient export to non-vulnerable areas, while the liquid fraction, with higher volume and lower nutrients, is suitable for nearby fields. This process is cost-effective, minimises emissions, and uses minimal energy.

How it works: The slurry concentrator technology is installed in a slurry pond, with floats ensuring it is positioned on the surface of the pond. An additional pond is required near the slurry pond to collect the diluted slurry discharged from the concentrator. The remaining equipment is therefore located between these two ponds, with a connecting pipe directing the flow to the additional pond.

Benefits

- Efficiency and environmental impact: Its low maintenance requirements and energy efficient operation result in reduced resource consumption and lower energy costs over time. In addition, the concentrator's ability to efficiently separate and apply nutrients minimises waste and environmental impact, in line with sustainable farming practices and regulatory standards.
- Versatility and ease of use: Simple installation with minimal infrastructure needs. Requires two separate ponds, but its mobile design allows easy transport between farms, suiting both individual and cooperative use.

The innovative system yields two liquid fractions

- Cost savings and profitability: Shared use of equipment for both liquid fractions cuts investment and operating costs, leading to significant long-term savings.
- Enhanced Monitoring and Precision Fertilisation: Integrated monitoring systems provide real-time nutrient data, enabling precise fertilisation tailored to soil and crop needs, optimising soil health, minimising nutrient loss, and reducing emissions. The slurry concentrator's integrated monitoring systems enable farmers to track and manage nutrient application more effectively. Online devices provide real-time data on nutrient content in the liquid fraction, allowing for precise fertilisation practices tailored to specific soil and crop requirements. This capability optimises soil health and productivity and minimises nutrient losses and reduces emissions, promoting sustainable agricultural practices and environmental stewardship.

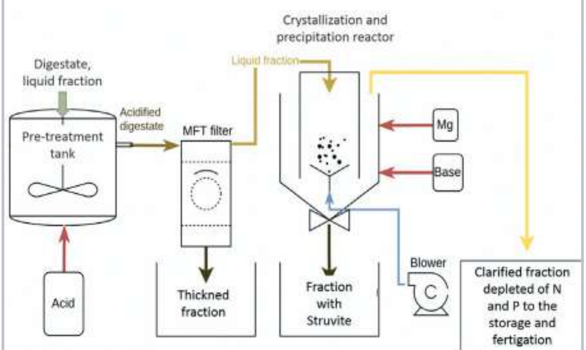
Current Status

Operation at pilot scale demonstrated the technological and economic viability of the proposal for use on farms and by the cooperative for efficient manure management. Additionally, the Cooperative Plana de Vic offers a free simulation to assess the viability of the slurry concentrator on your farm.

More information can be accessed at the home page of the Operational Group **Slurry Concentrator**

Digestate Treatment to **Produce Struvite**

The Operational Group STRUVITE designed and implemented a farm-scale prototype capable of recovering struvite (hydrated ammonium magnesium phosphate - $NH_4MgPO_4{\cdot}6H_2O$) from agricultural digestate. This way, a nutrient surplus from high livestock areas can be relocated to regions with a demand for chemical fertilisers. The digestate treatment consists of a solid-liquid separation by a screw press. The liquid fraction with a pH of 8.5 is then acidified up to a pH of 7.5 to mineralise the organic phosphorus. Microfiltration at 40 microns partially removes suspended solids and organic matter that hinders the struvite formation. In the end, in a crystallisation and precipitation reactor, magnesium and a base (to bring the pH to 9) are added to promote the formation of struvite crystals and efficient nitrogen and phosphorus recovery.



Treatment plant layout

Benefits

- The prototype struvite system effectively recovered phosphorus and nitrogen from the digestate, providing technical feasibility.
- The precipitate containing struvite can be exploited by fertiliser producers or it could be used as a “raw material” to produce phosphate fertilisers to replace finite phosphate minerals.
- Tests involving acidification, basification, and microfiltration reveal reduced nitrogen and phosphorus levels in the supernatant-treated fraction.
- By reducing P, N and dry matter content in livestock manure and digestate, ammonia, methane and nitrous oxide emissions were reduced from the liquid digestate storage and soil application phase.

Pilot treatment plant for struvite recovering from digestate

Current Status

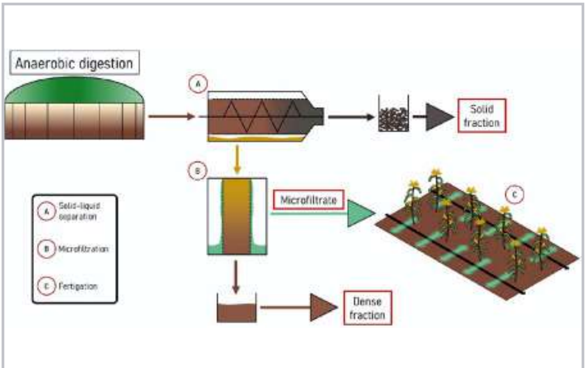
The struvite-containing precipitated fraction requires additional refinement by a fertiliser manufacturer to replace phosphate minerals with recovered P from digestate. The high concentration of solids and organic matter in the digestate, even if microfiltered, is still a critical issue in treatment efficiency.

More information can be accessed at the home page of the Operational Group **STRUVITE**

Digestate Microfiltration for Fertigation in **Subsurface Drip Lines**

Fertigation with digestate from biogas plants is a practice that significantly enhances nutrient use efficiency in growing crops. However, it is not yet widespread because of the chemical-physical characteristics of digestate. Even when clarified, it can cause nozzle clogging in a fertigation line.

SOS_AQUA tests and promotes an innovative integrated system to valorise the liquid fraction of digestate in fertigation, aiming to maximise nutrient reuse efficiency and reduce the need for mineral fertilisers. Initially, the digestate undergoes common solid-liquid separation, resulting in a solid fraction and a clarified liquid fraction. The clarified fraction is then microfiltered at 50 µm, thereby producing microfiltered digestate. This is then transferred to the field and mixed with water for fertigation on growing crops and injected into a subsurface drip irrigation system with drip lines buried at a depth of 25-30 cm.



SOS_AQUAE technologies layout

Benefits

- Microfiltered digestate in sub-fertigation drip lines is a technically and economically viable solution with low filtration costs.
- The microfiltration process avoids the clogging and fouling of the nozzles of the fertigation line. The drip lines have been specially developed for this purpose.
- The liquid fraction of the digestate (the most present and most problematic fraction to be valorised) is mixed with water in fertigation for efficient use of nutrients and to save mineral fertiliser and water.
- Odour, ammonia emissions and nitrate leaching are reduced.
- Chance of extending the agronomic period for digestate spreading.

Digestate Microfiltration unit

Fertigation with microfiltered digestate from slurry tank

Current Status

The microfiltered digestate that can be injected with fertigation drip-line technology is now on the market. Other applications also exist.

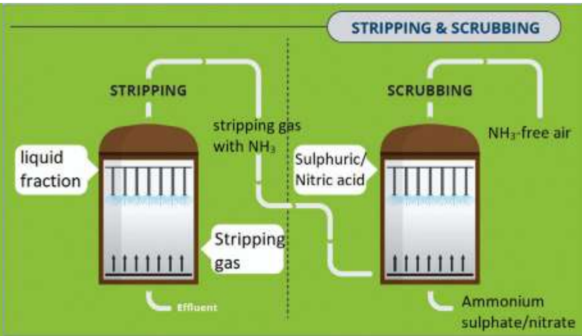
More information can be accessed at the home page of the Operational Group **SOS_AQUAE**

Recovery of **Ammonium Salts** From Manure

Stripping and scrubbing as a market-ready, innovative technology makes it possible to recover ammonium salts (ammonium nitrate and ammonium sulphate) from manure and use them as RENURE (REcovered Nitrogen from manuRE) products. The process consists of two steps:

- Stripping: Air is blown into the first compartment to remove the gaseous ammonia released from the thin fraction of manure or digestate due to increased pH and/or temperature.
- Scrubbing: The ammonia-rich air is sprayed with a strongly acidic solution, such as sulfuric acid or nitric acid, to form ammonium sulphate or nitrate, respectively.

Ammonium sulfate (left) and ammonium nitrate (right) recovered from manure stripping and scrubbing process



Theoretical scheme of stripping and scrubbing process for recovery of ammonium sulphate/nitrate from manure and digestate

The estimated price of the operational installation is approximately €100-150/m^3. It requires an annual manure processing capacity of 20,000 tons to achieve the desired economic viability.

In 2020, the European Commission proposed the "RENURE" criteria to allow the safe use of recovered nitrogen from manure to replace chemical fertilisers. This way, a nutrient surplus from areas with high livestock density can be redistributed to regions with a demand for (chemical) fertilisers. Ammonium salts recovered through stripping and scrubbing process are recognised RENURE candidates that have a high potential to fully replace chemical fertilisers at field application.

Current Status

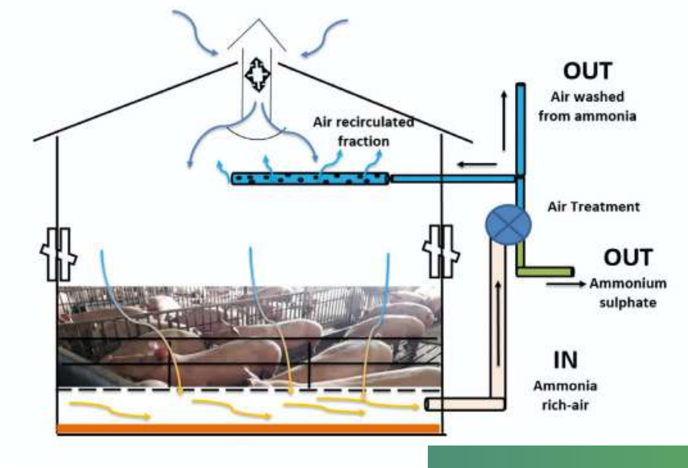
Several pioneers are currently producing these products in Flanders (Belgium). The European Commission is currently working on how to allow the use RENURE, including extensively treated digestate, above the limit of 170 kg N/ha/year for animal manure. The draft amendment under Annex 3 of the Nitrates Directive 1/676/EEC, would give Member States the option to allow a separate additional limit of 100 kg N/ha/year for RENURE products on top of the current limit.

More information can be accessed at the home page of the Operational Group **RENURE**

Ammonia Air Washing in Pig Livestock

Gas Loop has developed an advanced air treatment system to effectively reduce ammonia emissions from pig livestock. Air washing systems remove ammonia from the air inside the pig rooms and recover it in an ammonium sulphate solution. The device draws ammonia-rich air from the stable through suction ducts located below the slatted floor. In this way, the ammonia emissions are captured and prevented from spreading into the environment above where the animals are housed. The air treatment is based on the chemical absorption of ammonia by counter-current acid washing into a tower. Sulfuric acid solution (H_2SO_4) is used to react with ammonia (NH_3), thereby forming a stable suspension of ammonium sulphate ($(NH_4)_2SO_4$) which accumulates in a tank at the base of the tower. A significant emission reduction with lower treatment flow rates was observed (14 m^3/h per pig). This increases animal welfare and productivity due to better air quality. The treatment was tested for 2 years in stables of fattening pigs for the PDO Parma ham supply chain.

Sant'Anna pig farm, partners of the Gas Loop operational and experimental site



Treatment process layout

Benefits

- The air treatment reduces ammonia emissions from pig livestock by 1.94 kg NH_3 per animal housing per year.
- The air treatment improves the indoor air quality, reducing the ammonia concentration inside the treated room by 62% compared to the control room.
- Positive effects of the treatment on the productivity of pigs by increased animal welfare and health.
- Ammonia present in the air inside the pig house is recovered as ammonium sulphate solution. This solution can then be valorised as mineral nitrogen fertiliser.

Current status

Gas Loop has implemented the air treatment system to capture ammonia in pig livestock up to a technological maturity level equal to technology readiness levels (TRL 8). The device is installed in the pig housing of the Operational Group partners. The innovative air treatment system is ready for practical application.

More information can be accessed at the home page of the Operational Group **GAS LOOP**

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Green Energy Production From On-Farm **Biomass**

Small-scale digesters, or pocket digesters, can produce biogas from on-farm biomass to meet the farm's energy demands. These installations are almost exclusively located on dairy farms due to the easily fermentable properties of cattle slurry. After digestion, biogas and digestate are produced. The biogas is valorised to electricity and heat using a combined heat and power unit (CHP). The electrical power of the CHP linked to a pocket digester does not exceed 200 kW. The digestate can be spread on fields as a high-quality organic fertiliser or soil improver. Greenhouse gas emissions are reduced by (partly) avoiding long-term manure storage and by replacing (part of) the fossil fuels required to meet the farm's energy demand.

Tips sheet - available online

Although the technology initially boomed when introduced in Flanders (Belgium), several bottlenecks emerged, including technical imperfections, biological challenges, limited knowledge and experience, communication difficulties, and a high administrative burden. The Operational Group

Pocketboer II aims to address these persistent and common issues with pocket digesters. The project promotes the implementation of solutions at existing and future plants to enhance digester performance and efficiency. By creating and disseminating hands-on information, it has increased awareness and interest among farmers in this technique.

Pocket digester with nitrogen stripper (©Biolectric)

Current Status

Pocketboer II has been able to improve digester performance. In 2022, there were 55 pocket digesters in Flanders (Belgium). The uncertainty regarding nitrogen and investment support has a major impact on the investment climate and the economic feasibility of existing and new projects.

More information can be accessed at the home page of the Operational Group **Pocketboer II**

Grass Circular Economy

Efficient use of raw materials will help reduce imports of biofuels, proteins and fertilisers. By diversifying grass production and resolving significant challenges in traditional agriculture, a small-scale on-farm grass biorefinery was established in Southwest Ireland to help meet those market needs.

Grass biorefinery crush, press & separator

Fresh grass was cut, transported and loaded into the grass biorefinery hopper. The grass was crushed and pressed using an extruder to separate over 50% into a high-solid fibre press cake. This solid fraction contains all the proteins that ruminants need while removing the components that they do not use very effectively. This solid fraction can be bailed and fed directly back to the cows, allowing farmers to continue to feed their cattle with reduced emissions.

Grass being crushed and pressed inside the biorefinery

Three co-products are also produced in the biorefinery process from the liquid juice fraction, which contains the other 50% of the total protein content. It may increase the overall farm efficiency.

- High-protein product that can be used to feed chickens and monogastrics.
- High-value stream of sugars that are prebiotic and can be used in animal nutrition.
- The remaining residues contain a lot of monosaccharide sugars and nutrients that can be used for biogas production or the production of biobased fertilisers.


Dried high-protein monogastric feed

These types of small-scale biorefineries are being developed with built-in automation, making this type of technology more accessible to farmers. It also allows farmers to increase resource efficiency while addressing key emissions challenges. The biorefinery model could allow farmers to continue to feed their cattle, with reduced emissions, while producing three co-products which can increase their overall farm efficiency and income.

Current Status

A pilot-scale grass biorefinery is currently in operation on a farm in Southwest Ireland, where grass press cake and the three co-products are produced at the farm level.

More information can be accessed at the home page of the Operational Group **Biorefinery Glas**

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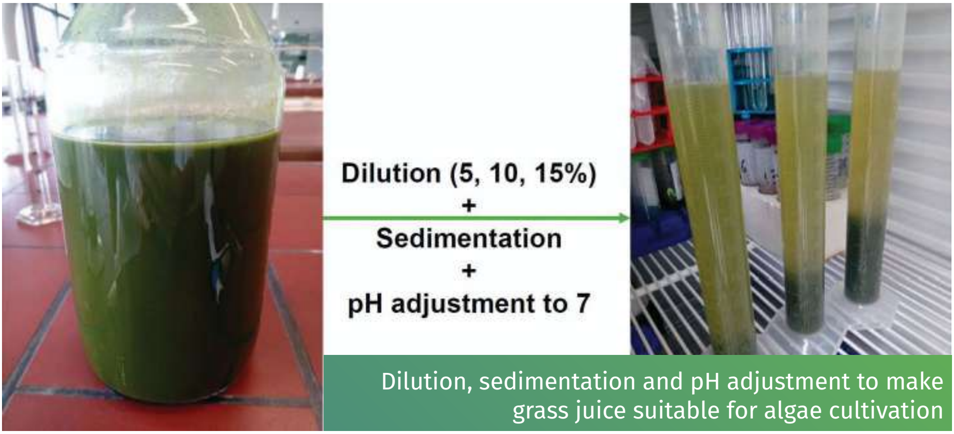
Grass Juice for Growing Microalgae

Grass2Algae uses grass juice to grow microalgae, which can be an additional source of income for farmers and ensures a circular economy on their farms. Through a sequence of sedimentation, coarse filtration and pH adjustments, grass juice is separated from the fibers of roadside grass or low-quality grass that cannot be used as animal feed. The grass juice accounts for 40-60% of the total grass weight and is an excellent source of nutrients, being rich in macro- and micronutrients that are necessary for the growth of microalgae.

Microalgae cultivation using grass juice at lab-scale

Results from microbial analysis and the algae product showed that the quality of the produced biomass is up to spec for food application resulting in a new source of income for farmers. Still, future studies are needed to further explore the potential of grass juice as fertiliser and the produced algae biomass as animal feed.



Dilution, sedimentation and pH adjustment to make grass juice suitable for algae cultivation

Microalgae cultivation using grass juice at pilot scale - Picture taken on Kris Heirbaut's farm

Current Status

Currently the grass juice is mainly produced at the farm level and used at the same farm for algae cultivation at a pilot scale.

More information can be accessed at the home page of the Operational Group **Grass2Algae**

Summary

Tools to **Optimise Manure Processing**

- Adopting processing technologies for manure or digestate management to recover nutrients allows farmers to increase the value of their agricultural waste. *(OG Slurry Concentrator)*
- Extraction of nutrients from manure or digestate to create fertilisers (e.g. struvite, ammonium salts). *(OGs Struvite, Gas Loop, RENURE)*
- Reduction of agricultural emissions (e.g. ammonia, methane) in combination with energy production. *(OG Pocketboer II)*
- Sustainable grass use and algae production. *(OG Biorefinery Glas, Grass2Algae)*

Technologies for **Manure Processing**

- Separation of manure to obtain a semi-liquid phase and liquid phase can minimise transport costs and optimise nutrient application to the soil. *(OG Slurry Concentrator)*
- Digestate treatment to recover nitrogen and phosphorus as struvite. *(OG Struvite)*
- Digestate microfiltration to make it suitable for injection in fertigation with drip lines instead of mineral fertilisers. *(OG SOS_AQUAE)*
- Nitrogen recovery from ammonia emissions into ammonium sulphate fertiliser, which can replace synthetic fertilisers and reduce GHG emissions. *(OG GAS LOOP)*
- On-farm digestion of manure to produce biogas for electricity and heat and digestate as organic fertiliser, thereby reducing GHG emissions linked to manure storage and fossil energy use. *(OG Biorefinery Glas)*
- Valorisation of grass to produce press cake, prebiotics and protein rich monogastric feed, increasing the value of low-quality roadside grass.

- Valorisation of low-value grass by biorefineries and separation technologies to produce nutrient-rich grass juice for algae cultivation as alternative animal feed, improving the sustainability of algae production and increasing farmers' income. *(OG Grass2Algae)*

Future Benefits

- Decreasing dependencies on mineral fertilisers and fossil energy, reducing import costs, transport costs and electricity costs, therefore, contributing to the circularity of the bioeconomy.
- Decreasing agricultural emissions by implementing (nutrient) processing technologies (e.g. pocket digestion, stripping-scrubbing) and sustainable manure management.
- Further development and implementation of local (nutrient) processing technologies at farm scale (e.g. biorefineries).
- Bringing farmers together in knowledge cooperatives, providing guidance and creating hands-on information to positively impact the awareness, implementation and improvement of nutrient management technologies.

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