# Practice Abstracts – Batch 1

**Deliverable D5.13**

INNOVATIVE DECISION-MAKING TOOL FOR DEFINING THE MOST SUITABLE MANURE MANAGEMENT STRATEGIES TO ACHIEVE A SUSTAINABLE LIVESTOCK FARMING SYSTEM DURING THE WHOLE VALUE CHAIN

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## 1. INTRODUCTION

Livestock farming is a key sector that involves 40 % of the total agricultural activity in Europe. representing a total value for products equal to € 170 billion. However, there is an increasing concern due to livestock farming's contribution to environmental pollution since it generates more than 1.4 billion tonnes/year of manure leading to significant greenhouse gases (GHG) and air pollutants emissions (NH3, NOX)as well as to soil and water contamination caused by hazardous manure chemicals and biological contaminants (called here emerging contaminants). In this context extensive effort has been carried out for years to assess the detrimental effects of farming systems and to develop abatement methods to be implemented. However, despite major advancements, many fundamental issues are beyond the scope of existing legislation.

The main objective of NUTRITIVE is to develop a decision-making tool (DSS, decision support system) able to define the most efficient and sustainable (in its three pillars: environmental, economic, and social) manure management strategies for a given livestock farm limiting manure air emissions as well as soil and water contaminants. This will allow for the formulation of technical guidelines and recommendations that will support policy makers with enhanced knowledge to establish requirements for future European policies.

To fulfil this objective, the project is divided into six work packages (WP): WP1 Up-to-date inventory; WP2 Novel management strategies/technologies investigation; WP3 Modelling and Life Cycle Assessment (LCA); and WP4 Guidelines formulation; WP5 Communication, dissemination, and exploitation; WP6 Management (Figure 1).

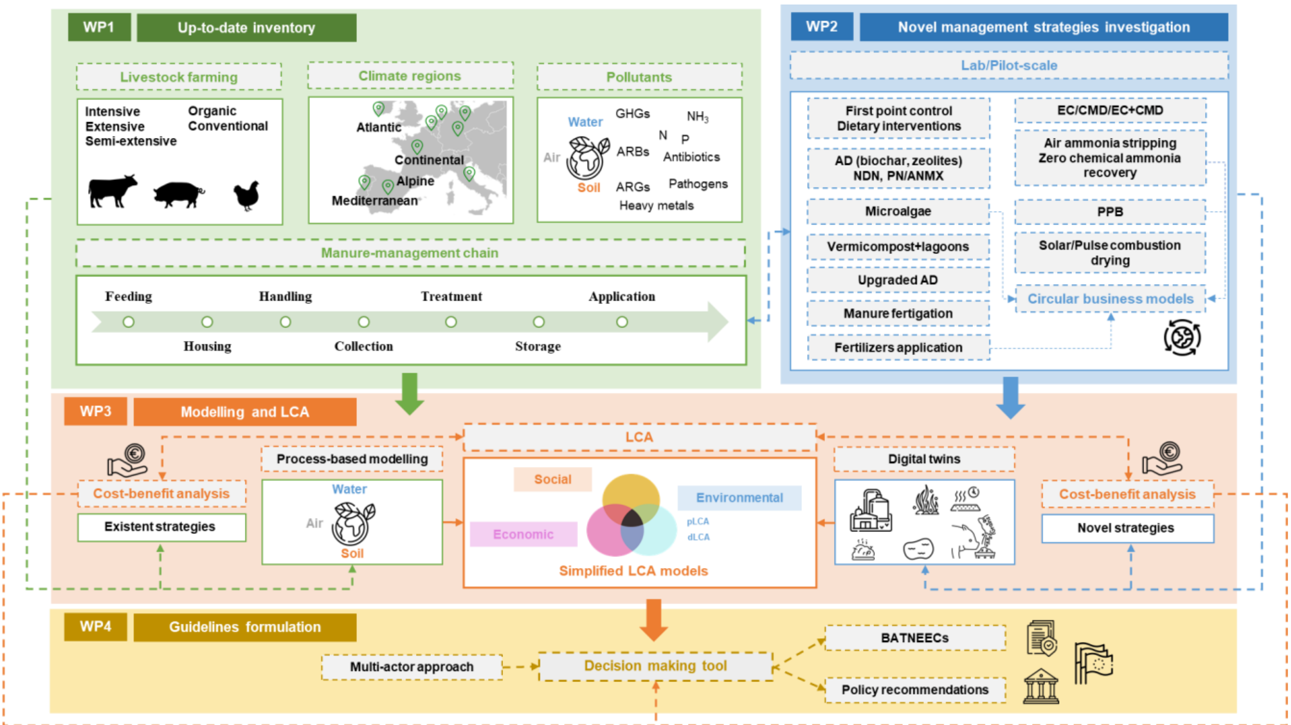


*Figure 1. NUTRITIVE methodology.*

NUTRITIVE anticipates a wide spread of the project outcomes, with the synthesis of the consortium as a baseline: 22 partners (4 Chinese) from 8 different countries across Europe, covering 6 climatic regions (2 Chinese ones), representing the whole supply chain experts, from animal feed to soil application.

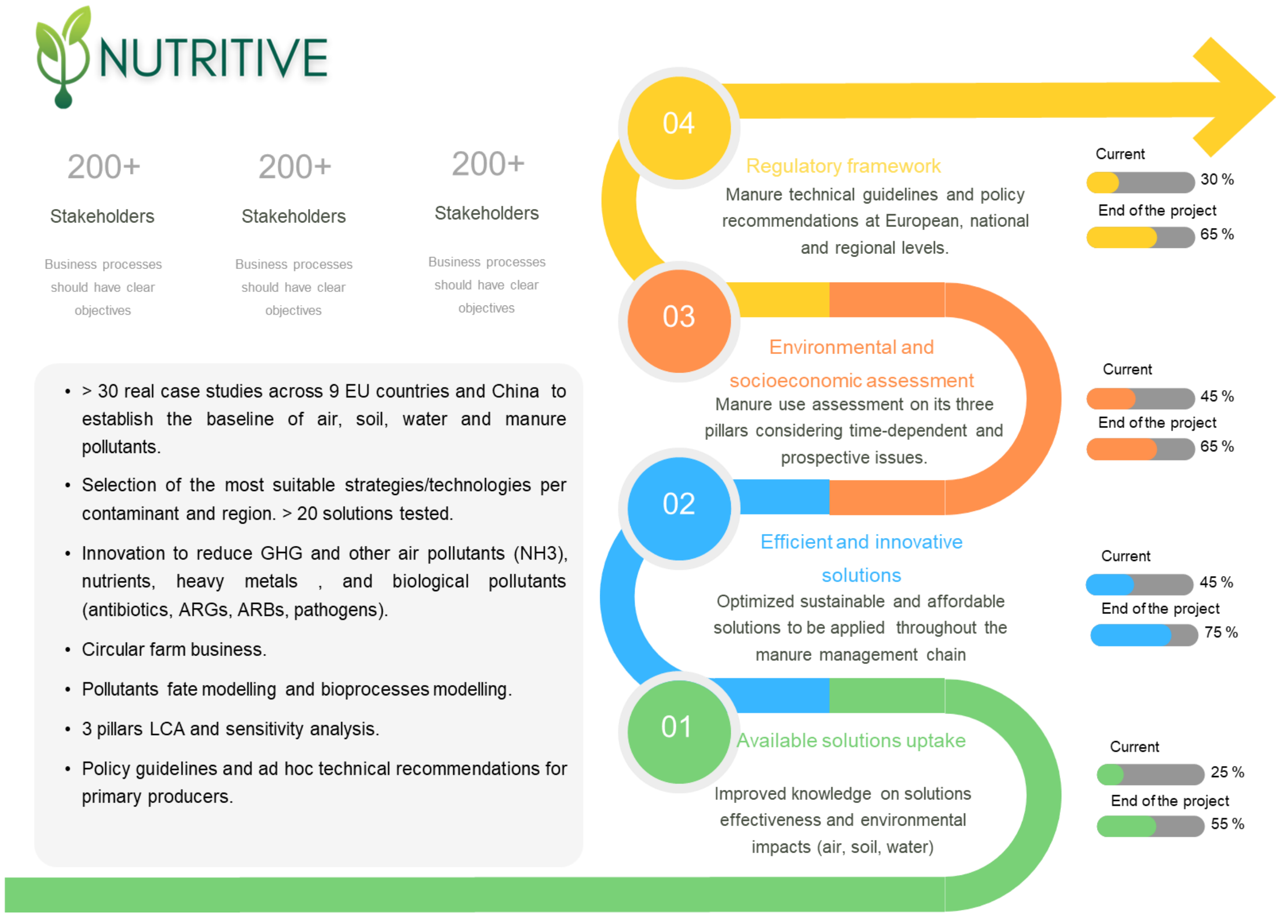


*Figure 2. NUTRITIVE overview.*

## 2. PRACTICE ABSTRACTS

A collection of EIP-AGRI Practice Abstracts, to share the project results and practice-oriented solutions in concise summaries is compiled below. These were developed according to the guidelines provided by the EU CAP Network (see the template in Annex I).

| PRACTICE ABSTRACT #1 |
|---|
| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| **STATE OF THE ART ON POLLUTANT ASSESSMENTS ORIGINATE FROM THE LIVESTOCK MANURE CHAIN INCLUDING POLLUTANTS IN WATER, SOIL AND MANURE** |
| **Summary**<br><br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |
| This review provides an overview of current approaches to assess pollutants originating from livestock manure, including antibiotic residues, pathogens, antibiotic resistance genes, and heavy metals. Existing manure treatment technologies often have limited effectiveness in reducing these pollutants. In the absence of systematic surveillance, manure is routinely applied as fertilizer, which can increase contaminant levels in soils. These soils act as reservoirs for antibiotic residues and resistance genes, and pollutants can spread further to crops, waterbodies, and other environmental compartments, creating risks for both human and animal health. For example, contaminated irrigation water or food products can serve as indirect exposure pathways.<br>The Nutritive project addresses these challenges by applying standardized and integrated monitoring methods across manure, soils, and water. Unlike most existing studies, which examine single compartments in isolation, Nutritive establishes novel linkages across the entire manure-environment chain. The project integrates agricultural context factors such as climate, livestock type, and management practices into contamination pathways. Insights from this work will support evidence-based policymaking, harmonized monitoring systems, and sustainable manure management strategies. |
| **Main findings**<br><br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?<br><br>This summary should at least contain the following information (max. 2000 characters):<br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users?<br>• Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies).<br>• Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc. |

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| This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting research results in scientific language, which does not respond to real needs of the practitioners, should be avoided. |
| Manure, soils, and waterbodies are not subjected to mandatory monitoring for pollutants such as antibiotic residues, pathogens, or resistance genes, even though a robust scientific framework for their assessment exists in research settings. Ultra-high-performance liquid chromatography coupled with tandem mass spectrometry (UHPLC-MS/MS) is the gold standard for analyzing antibiotic residues, enabling the identification of antibiotic classes contaminating soils and the quantification of their concentrations. *Escherichia coli*, widely used as a fecal indicator, is frequently incorporated into One Health monitoring programs as a proxy for fecal contamination. Regarding heavy metals, standard protocols typically involve microwave digestion followed by inductively coupled plasma mass spectrometry (ICP-MS). However, these current pollutant assessment strategies are unharmonized, remain limited in scope, restricted to a predefined and small set of analytes and often fail to establish links between different pollutants. For instance, resistance monitoring frequently overlooks the presence of antibiotic residues, despite their role in driving selective pressure and maintaining resistance. This disconnect highlights the urgent need for integrated monitoring strategies. |
| **Additional dissemination and exploitation material(s)**<br>*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).* |


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**Geographical location**

- Please include the geographical location where the research and innovation activities took place.

Drag to re-order selected items.


Figure 1: NUTS3 regions of involved casestudies.

**Additional information**

List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters)

The Nutritive project delivers a comprehensive, standardized assessment of manure, soil, and water contamination by integrating two complementary strategies: an in-depth screening of trace levels of antibiotic residues and heavy metals, and a broad approach to detect resistance mechanisms using both culture-based and metagenomic protocols. In parallel with general monitoring of *E. coli*, the project looks for extended-spectrum β-lactamase (ESBL)-producing *E. coli* and vancomycin-resistant enterococci (VRE) to capture phenotypic resistance. Key pathogens of public health relevance, such as *Salmonella* and *Campylobacter*, will also be systematically screened. The analytical and sampling design ensures methodological rigor, representative sampling, and cross-study comparability, while integrating multiple pollutant classes into a coherent framework for manure assessment. Such harmonization enhances data reliability, enables cross-regional evaluations, and provides a stronger foundation for evidence-based decision-making. Equally important is the strategic selection of 35 sampling locations. Most existing studies are confined to one region or are limited to one or a few case studies, often neglecting the variability across pollution sources. The Nutritive project addresses this gap by evaluating contaminants across a wide spectrum of soils differing in region, composition, and agricultural practices. In addition, longitudinal monitoring of soils and water will generate valuable insights into the persistence and dynamics of these contaminants over time. The Nutritive project represents a major step forward in harmonizing pollutant monitoring across the livestock manure chain and in generating actionable data for both policy and practice.

| PRACTICE ABSTRACT #2 |
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| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| **HARMONISING APPROACH TO IDENTIFY AND QUANTIFY POLLUTANTS FROM MANURE, AIR, SOIL AND WATER ALONG THE MANURE MANAGEMENT CHAIN** |
| **Summary**<br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |
| Most studies emphasising pollutants from manure management focus on one single (group of) pollutant(s), or a single farm/ region or a single ecological niche (manure, air, soil and water). This results in a lack of linkage between the pollutants and the different ecological niches. Also, this limits the possibility to compare the pollution of different (climatic) European regions with one another in a harmonised way.<br>Nutritive tackles this focus by broadening the scope involving numerous pollutants from manure, water, soil and air. By collecting data and analysing samples from different farms across Europe in a harmonised way, comparison between these different European regions becomes feasible. Moreover, by targeting different pollutants, possible links can be revealed. |
| **Main findings**<br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?<br>This summary should at least contain the following information (max. 2000 characters):<br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users?<br>• Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies).<br>• Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.<br>This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting research results in scientific language, which does not respond to real needs of the practitioners, should be avoided. |
| A wide range of pollutants (greenhouse gases, $NH_3$, antibiotic residues, antimicrobial resistance genes, pathogens, heavy metals,physicochemical properties, trient content) have been vastly studied and identified in different ecological niches (manure, air, soil and water) originating from the manure management chain of a farm. However, most studies rely on a single farm, a single (group of) pollutant(s) or a single niche. Regarding air pollutants, the mix of measurements and inventories suffer from method specific biases and a limited ability to capture farm-level variability. |

Regarding manure pollutants, literature highlights standard sampling procedures and homogenisation of manure fractions to ensure comparability across studies. But this standard sampling procedure is limited by complex logistics, dependence on advanced equipment and the challenging homogenisation of manure. Regarding water or soil pollutants, recommended techniques for analysing AB residues exist as well as the focus on one specific indicator (eg. E. coli) to determine antibiotic resistance and predict the presence of certain pathogens. This approach limits the scope.

A specific focus does not offer information on the link between pollutants (e.g. antibiotic residues and resistance genes) nor between the different matrices or the agricultural context. Moreover, the diversity of measurements and inventories applied, result in a poor spatial and temporal representativeness. Nutritive aims to identify and quantify these pollutants in all the different ecological niches through a harmonised approach. Pollutants from 35 different farms spread across Europe will be analysed following a harmonised procedure for water, soil and manure matrices. This could result in cross-study comparability and the integration of multiple pollutant classes into a framework for manure management. Regarding air pollution, detailed data of the 35 different farms will be collected through interviews regarding the management possibly affecting air pollutions and mitigation approaches of the farm. This harmonised data will feed sophisticated emission inventory models, utilizing up to date emissions from DATAMAN database and other sources. These models will result in more accurate, politically relevant and region-specific emission estimates.

**Additional dissemination and exploitation material(s)**

*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).*

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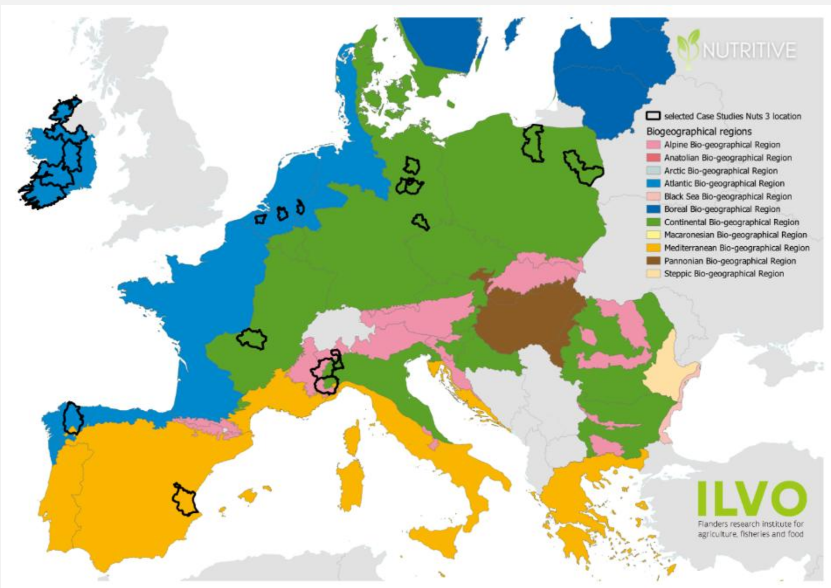


Figure 1: NUTS3 regions of involved casestudies.

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| **Additional information**<br>List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters) |
| The identified and quantified pollutants from soil, water and manure could reveal main contaminants which origin from the manure management chain across the different case studies. This revelation could be a guideline to focus on the fate and transport modelling of these main pollutants, which will feed the DSS tool further developed during the Nutritive project. Moreover, differentiation between the different regions regarding contaminants would aid in regio-specific data to support regional pollution legislation. In the case of air pollutants, detailed data on manure management strategies at farm level can aid models to generate region-specific emission factors to ensure accuracy, transparency and policy relevance.<br>If it is possible to link the fate of pollutants with specific case studies, a manure management design and antibiotic regimes for livestock depending on the farm setting could become feasible. This information can support targeted and cost-effective mitigation strategies.<br>However, the context of the case study farm should be accurately defined, which requires reliable communication with farmers. Moreover, , clear guidelines to all the case study (responsibles) are required to collect data in a harmonised way.<br>The Nutritive project furthermore acts a feasibility study to illustrate that different pollutants in different matrices across different case studies in Europe can be determined in a harmonised way which allow comparison between different regions and support region-specific pollution policy. Future projects could target broader EU-wide livestock farm networks to illustrate the possibilities of providing harmonised data. However, regular survey of manure management strategies on the farm will (always) be needed to keep an up-to date view of the manure management strategies. |

| PRACTICE ABSTRACT#3 |
|---|
| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| **ISOACIDS SYNERGIZE WITH COBALT SUPPLEMENTATION BY INCREASING FIBER FERMENTATION WHILE PARTIALLY OFFSETTING METHANE PRODUCTION** |
| **Summary**<br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |
| Increasing microbial synthesis and fiber digestibility in the rumen is a key aspect of improving ruminal efficiency. Supplementation of cobalt is one potential approach. Cobalt is required by specific bacteria to synthesize vitamin B12 which, in turn, is a growth factor for fibrolytic bacteria (Spears, 2020). Satisfying this requirement increases both bacterial growth and fiber digestibility. Another such approach is the supplementation of branched-chain fatty acids or isoacids. Fibrolytic bacteria are unable to transport preformed branched-chain amino acids across their cellular membrane and must rely on cross-feeding from proteolytic bacteria to supply these carbon skeletons for the synthesis of branched-chain amino acids and long chain branched-chain fatty acids (Firkins et al., 2024). Supplemental isoacids may be more efficiently utilized by fibrolytic bacteria vs obtaining them via cross-feeding mechanisms. Both types of supplementations tend to be effective when applied to high forage diets. Increased fiber digestion in high-forage diets is commonly associated with greater production of methane (Parnian-Khajehdizaj et al., 2023). Being one of the greenhouse gases with the greatest global warming potential, an increase in methane production would negatively affect the sustainability of dairy production. However, it is also suggested that improving microbial anabolism can act as a sink for methane precursors, $CO_2$ and $H_2$, that result from increased fiber digestion (Yi et al., 2023). Moreover, cobalt is involved in propionate-producing pathways (Tiffany et al., 2006) which also act as an $H_2$ sink. Thus, the objective of this study was to improve the understanding of the impact of two organic cobalt sources (Cobalt glucoheptonate – CoPro and (Cobalt source under development) CobaltD) and isoacid supplementation on the methane production during ruminal fermentation and evaluate potential synergy between the two.<br>Based on methane yields, it was concluded that the cobalt Cobalt [under develop.] is more efficient at promoting fiber fermentation than its glucoheptonate form, possibly due to greater bioavailability and/or microbial transmembrane transportation. Regardless of previous literature indicating increased fiber fermentation, isoacids supplementation does not affect methane production significantly, reducing concerns related to its sustainability impact. Supplementing isoacids together with cobalt, especially in the form of Cobalt [under develop], provides a synergistic opportunity to increase fiber degradation in the rumen and generate greater microbial protein while partially offsetting the increased methane yield. In fact, it is hypothesized that part of the excess $H_2$ and $CO_2$ produced with cobalt supplementation are then sunk into fibrolytic bacteria anabolism. |
| **Main findings**<br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?<br>This summary should at least contain the following information (max. 2000 characters):<br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users? |

- Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies).
- Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.

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**Introduction**

Increasing microbial synthesis and fiber digestibility in the rumen is a key aspect of improving ruminal efficiency. Supplementation of cobalt is one potential approach. Cobalt is required by specific bacteria to synthesize vitamin B12 which, in turn, is a growth factor for fibrolytic bacteria (Spears, 2020). Satisfying this requirement increases both bacterial growth and fiber digestibility. Another such approach is the supplementation of branched-chain fatty acids or isoacids. Fibrolytic bacteria are unable to transport preformed branched-chain amino acids across their cellular membrane and must rely on cross-feeding from proteolytic bacteria to supply these carbon skeletons for the synthesis of branched-chain amino acids and long chain branched-chain fatty acids (Firkins et al., 2024). Supplemental isoacids may be more efficiently utilized by fibrolytic bacteria vs obtaining them via cross-feeding mechanisms. Both types of supplementations tend to be effective when applied to high forage diets. Increased fiber digestion in high-forage diets is commonly associated with greater production of methane (Parnian-Khajehdizaj et al., 2023). Being one of the greenhouse gases with the greatest global warming potential, an increase in methane production would negatively affect the sustainability of dairy production. However, it is also suggested that improving microbial anabolism can act as a sink for methane precursors, $CO_2$ and $H_2$, that result from increased fiber digestion (Yi et al., 2023). Moreover, cobalt is involved in propionate-producing pathways (Tiffany et al., 2006) which also act as an $H_2$ sink. Thus, the objective of this study was to improve the understanding of the impact of two organic cobalt sources (Cobalt glucoheptonate – CoPro and Cobalt Cobalt [under develop] – CobaltD) and isoacid supplementation on the methane production during ruminal fermentation and evaluate potential synergy between the two.

**Materials and methods**

Methane production during ruminal fermentation was studied through batch tests using the Gas Endeavour III (BPC Instruments, Sweden). The system was composed of 18 1-L glass vessels with airtight stoppers and mechanical stirring. The vessels were individually connected to $CO_2$ traps (NaOH ≥3M mixed with thymolphthalein as pH indicator) and to gas-measuring cells working by liquid displacement/buoyancy. Data of each vessel was recorded and visualized within BPC instruments software (Aurora™). The duration of the batch was set at 24 h after the inoculation. Each vessel was filled with 200 mL of inoculum collected from cannulated Holstein cows and 400 mL of buffer solution (prepared similarly to Roman-Garcia et al. (2021)). The diet was fed as 25 g DM per vessel and its composition was as follows (% DM basis): 35.2% corn silage, 22.9% grass silage, 17.6% fine-ground corn grain, 11.1% soybean meal, 6.88% dry beet pulp, 4.59% ground soybean hulls, 1.15% wheat straw, 0.43% urea, 0.19% mineral mix. An isoacid blend (IA) was fed at a 40g/kg DM ratio whereas both cobalt sources (CoPro and CobaltD) were fed at 1.0 ppm Co/kg DM.The treatments were formulated as follows: positive control (CON), isoacids (IA), cobalt glucoheptonate (COPRO), cobalt amino acid (COBALTD), isoacids mixed with cobalt glucoheptonate (COPRIA) and isoacids mixed with cobalt amino acid (COIA). All treatments were tested by quadruplicate, except for the positive control by duplicate.

**Results**

All treatments, except for isoacids alone (Fig. 1a), showed greater methane production than the control (Fig. 1b). This tendency suggested that fiber fermentation is indeed promoted by the inclusion of cobalt sources. The Cobalt [under develop] (COBALTD) appears to be more efficient at providing cobalt to the microbiome given the greater increase in gas production in comparison with the glucoheptonate (COPRO). Interestingly, the positive change in gas production is partially offset when isoacids are mixed with both cobalt sources (Fig. 2), especially in the Cobalt [under develop] case (COIA). The inclusion of IA might indicate IA-promoted fibrolytic bacteria growth might serve as a sunk for $CO_2$ and $H_2$. Overall, the percentage change between control and all treatments slightly diminished overtime possibly because treatments affected fermentation kinetics; speeding up NDFd and subsequent gas production especially at the beginning of the test (3 h).

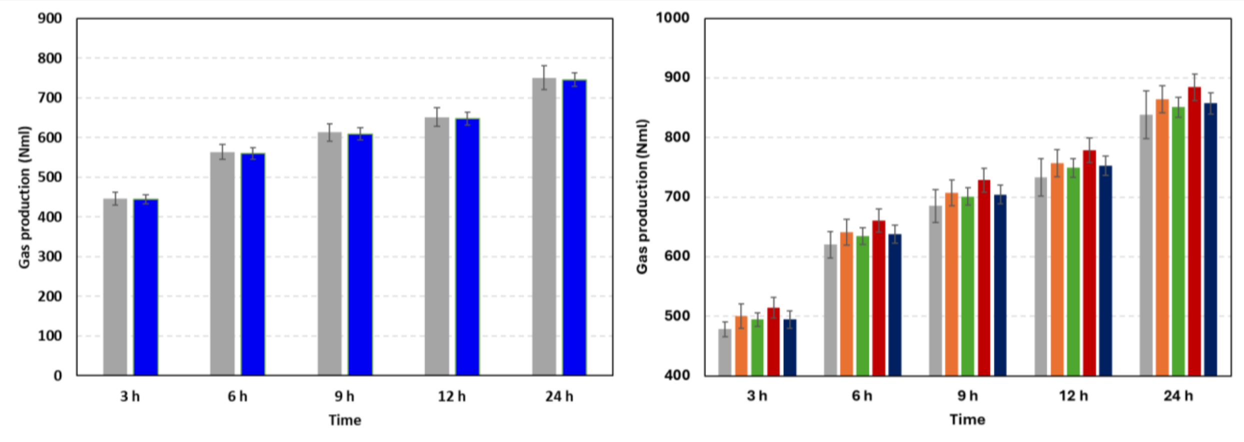


**Figure 1.** Cumulative methane production at different time points of the test: a) comparison between control (CON, grey) and isoacids alone (IF, blue); b) comparison between control (CON, grey) and the cobalt source without (COPRO, orange, COBALTD, red) and with isoacids (COPRIA, green, COIA, dark blue).

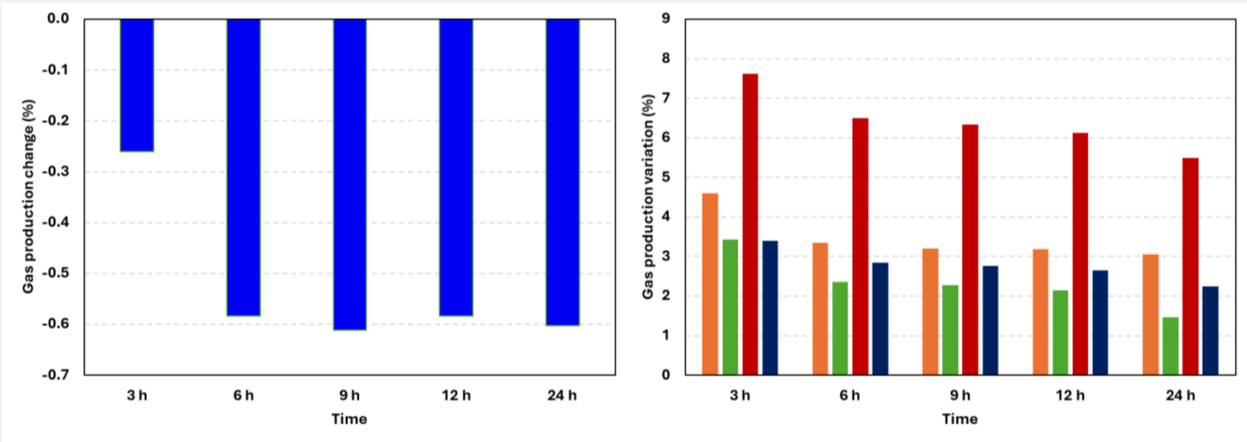


**Figure 2.** Methane production percentage change at different time points of the test: a) comparison between control (CON, grey) and isoacids alone (IF, blue); b) comparison between control (CON, grey) and the cobalt source without (COPRO, orange, COBALTD, red) and with isoacids (COPRIA, green, COIA, dark blue).

**Conclusions**

Based on methane yields, it was concluded that the cobalt Cobalt [under develop] is more efficient at promoting fiber fermentation than its glucoheptonate form, possibly due to greater bioavailability and/or microbial transmembrane transportation. Regardless of previous literature indicating increased fiber fermentation, isoacids supplementation does not affect methane production significantly, reducing concerns related to its sustainability impact. Supplementing isoacids together with cobalt, especially in the form of Cobalt [under develop], provides a synergistic opportunity to increase fiber degradation in the rumen and generate greater microbial protein while partially offsetting the increased methane yield. In fact, it is hypothesized that part of the excess $H_2$ and $CO_2$ produced with cobalt supplementation are then sunk into fibrolytic bacteria anabolism.

**Additional dissemination and exploitation material(s)**

*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).*

References:


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**Geographical location**

- Please include the geographical location where the research and innovation activities took place.
- Drag to re-order selected items.

Main research was carried out in Galicia (Spain).

**Additional information**

List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters)

This is just the initial exploration of the potential for a new cobalt source to aid in the supplementation of animals for the reduction of emissions by decreasing methane emissions directly and lower Nitrogen/Ammonia emissions by increasing the digestibility of the fiber.

Further research is needed to fully evaluate the product and the impact on emissions.

| PRACTICE ABSTRACT #4 |
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| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters).* |
| MEASURING AMMONIA VOLATILISATION FROM MANURE FERTILISATION: FIELD TRIALS COMPARING TRADITIONAL AND INJECTED APPLICATION METHODS |
| **Summary**<br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters).* |
| This practice focuses on the quantification of ammonia ($NH_3$) emissions from cattle slurry fertilisation under real field conditions. $NH_3$ volatilisation is a major source of indirect greenhouse gas (GHG) emissions, as the loss of reactive nitrogen to the atmosphere contributes to secondary $N_2O$ formation and to air pollution through particulate matter. Reducing $NH_3$ losses therefore improves nitrogen use efficiency and mitigates climate and environmental impacts.<br>ARESA's trials within NUTRITIVE evaluate the effect of application technique—conventional broadcast spreading versus injection—on $NH_3$ losses for two crop systems (grassland and maize) and across different soil types. Passive ALPHA® samplers are deployed on central masts (five heights: 0.25–3.3 m) and background masts (three heights) following the VERA protocol. This provides validated $NH_3$ concentration data (µg $m^{-3}$) for successive exposure periods (first 24 h with high temporal resolution, followed by daily exchanges up to 96 h). The meteorological data (wind, temperature and humidity, among others) are recorded on-site with a dedicated station, enabling the project partner ILVO to calculate $NH_3$ emission fluxes using micrometeorological mass balance methods (Integrated Horizontal Flux).<br>In parallel, agronomic performance of the crops will be monitored to assess trade-offs between reduced emissions and crop productivity. For grassland, measurements will focus on dry matter yield at the first cut (with the possibility of including a short second cut if time allows), together with weekly height curves and, when plate calibration is performed, conversion to daily dry matter accumulation (kg DM/ha/day). For maize, the assessment will concentrate on plant height and total dry matter yield at harvest. This approach enables the quantification of both environmental and agronomic outcomes of the different slurry application methods. |
| **Main findings**<br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?<br>This summary should at least contain the following information (max. 2000 characters):<br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users?<br>• Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies).<br>• Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.<br>This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are |

particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting research results in scientific language, which does not respond to real needs of the practitioners, should be avoided.

**Objective**: To determine how manure application method influences $NH_3$ volatilisation and associated GHG impacts, while assessing crop yield implications.

**Result**: The experimental design provides high-resolution $NH_3$ concentration profiles under realistic conditions, allowing comparison of injection vs. broadcast methods across soil and crop systems. Results will inform whether injection reduces $NH_3$ without compromising crop productivity.

**Practical implications**: Farmers and advisors can use these results to select slurry management techniques that improve fertiliser efficiency and compliance with EU environmental regulations (NEC Directive, CAP eco-schemes). Benefits include reduced N losses, improved yields per unit of applied N, and contribution to climate targets. Costs are associated with investment in injection equipment and operational complexity, which need to be balanced against long-term fertiliser savings and environmental compliance.

**Additional dissemination and exploitation material(s)**

*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).*

To support practitioners in understanding the context and practical implications of the trials, several complementary resources are provided. The **VERA Test Protocol** offers internationally recognised guidance on the measurement of gaseous emissions from land-applied manure, ensuring comparability and scientific robustness. Detailed information on the **ALPHA® passive samplers** used for ammonia monitoring can be found through the UK Centre for Ecology & Hydrology. Broader insights into the environmental benefits of **slurry injection as a sustainable nutrient management practice** are summarised by the European Commission. Finally, the **PURINPRECISO project video** illustrates in practice how precision slurry application contributes to reducing emissions and improving nutrient efficiency.

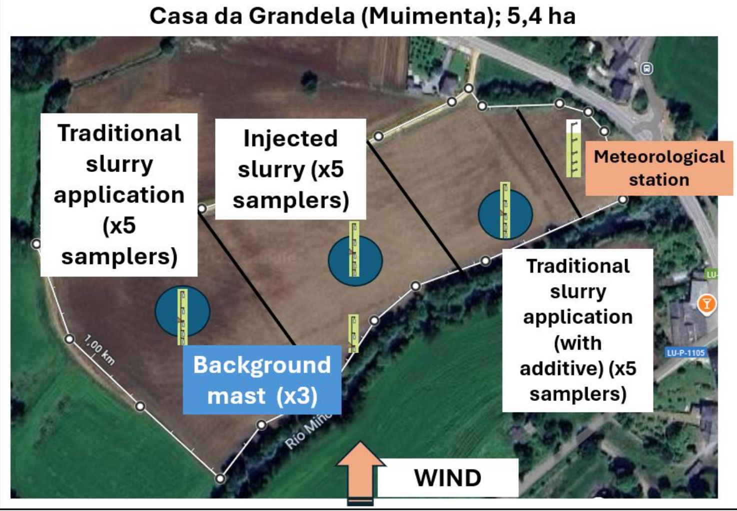
**Geographical location**

- Please include the geographical location where the research and innovation activities took place.
- Drag to re-order selected items.

Galicia (NW Spain) – field trials established in three commercial farms (approx. 0.4 ha experimental plots within parcels of 5–6 ha).

As an illustrative example, the figure shows the layout designed for one of the selected sites ("Casa da Grandela", 5.4 ha). The experimental design has been defined preliminarily, dividing the parcel into three subplots corresponding to the treatments under evaluation: (i) traditional slurry application, (ii) injected slurry, and (iii) traditional slurry with additive for GHG's emissions reduction. Each subplot includes a central mast equipped with five ALPHA® samplers, complemented by a background mast (three samplers) and a meteorological station.

The positioning of the background mast has been planned considering the prevailing wind direction at the site, so that background concentrations of ammonia can be correctly captured and distinguished from treatment-related emissions. This preliminary configuration ensures compliance with the VERA protocol, while allowing adjustments on the day of application depending on actual meteorological conditions.




| Additional information |
|---|
| List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters) |
| Limitations encountered include: (i) difficulty in locating large plots with sandy soils as foreseen in the proposal (such soils are scarce and mainly restricted to inaccessible coastal areas in Galicia); (ii) dependency on farmers equipped with appropriate slurry injection technology and willing to follow strict experimental protocols; (iii) potential variability in weather conditions affecting dispersion and representativeness. These constraints underline the importance of flexible site selection and strong farmer engagement. Future work should address combined mitigation strategies (e.g. injection with slurry acidification) and explore scalability of results across different pedoclimatic regions. |

| PRACTICE ABSTRACT #5 |
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| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| ADVANCE ANAEROBIC DIGESTION AND NDN PROCESSES TO MITIGATE THE CARBON AND NITROGEN GHG EMISSIONS OF THE MANURE MANAGEMENT CHAIN. |
| **Summary**<br><br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |
| The industrial livestock farming, specially pig intensive production, has a direct influence over the primary sector GHG production, overcoat related with the manure management. To mitigate GHG emissions is necessary to evaluate technologies and strategies over each position of the manure management chain. Concretely, it was defined the treatments at levels of livestock farming, primary treatment, post-treatment and soil application strategies. Two of the primary treatments selected was Anaerobic Digestion (AD) and the nitrification-denitrification (NDN) treatment.<br><br>The AD is a biological process that converts organic matter into biogas (methane and carbon dioxide) and a liquid effluent called digestate, in the absence of oxygen. This process provides a sustainable solution for organic waste management, enabling circularity in the economy and reducing the carbon footprint. Despite the advantages of the process, the limited efficiency of AD has a negative effect on the expansion of this technology, due to increased operating and investment costs. Therefore, this process requires improvements in productivity to ensure its expansion and sustainability of the value chain.<br><br>One of the commonest strategies to improve the process is the additivities addition. For NUTRITIVE project, it was selected the biochar and zeolite to increase the biogas production and the process stability. Biochar has specific surface properties as porosity or active points, which have a direct interaction with the metabolic activity and the microbial grown. The effect of biochar addition over the biogas production could be a volumetry increase of 20-60% and the digestate quality improve to soil application. Likewise, Zeolite has ammonium adhesion capacity, mitigating the ammonia inhibition of AD process.<br><br>Finally, the NDN is a biological water treatment process to remove the nitrogen in residual effluents, in the presence of oxygen. This process has interest to reduce the GHG emissions of the manure storage, specially of the ammonia emissions. In addition, the NDN process can be realized over pig manure or liquid digestate without previous treatment. |
| **Main findings**<br><br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?<br><br>This summary should at least contain the following information (max. 2000 characters):<br><br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users? |

- Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies).
- Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.

This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting research results in scientific language, which does not respond to real needs of the practitioners, should be avoided.

**Objective**

The main objective of this study is to evaluate the effect of adding biochar and zeolite on the productivity of AD and the quality of digestate for soil application, and the effect of NDN process over the ammonia emissions mitigation.

**Current results**

To reach this objective, it was proposed the operation of pilot-scale systems for the two selected technologies (NDN and AD). The AD operation has been stablished in three-stage: additive selection, dosage evaluation of additives to AD and a semi-continuous performance evaluation. The addition of biochar will require modified selection to improve the efficiency of anaerobic digestion and reduce greenhouse gas emissions from digestate. Through zeolite addition testing, pilot-scale optimisation will be carried out to reduce ammonia emissions from digestate storage.

The NDN will be assayed through a continuous assay with pig raw manure to evaluate the nitrogen removal capacity. Nitrogen is the main chemical pollutant found in the raw manure due to water masses contamination, specially by the liquid fraction. This assay will precise the pilot-scale reactor design to optimize the nitrogen species transformation in volatile molecular nitrogen.

**Practical implications**

The development of these processes pretends to mitigate the methane and ammonia emissions of the primary stage of the manure management chain, reducing the livestock farming impact and the poor image of the sector. Thanks to this study, the sector actors are able to carry out corrective measures to improve her installations and reduce these emissions. This is achieved thanks to the case study data acquisition and the technologies evaluation, which allows provide verified information to the stakeholders. Furthermore, the information developed for this project could provide specific economic and sustainability data for each case, enabling the best strategy to be chosen for each livestock farm.

**Additional dissemination and exploitation material(s)**

*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).*

For the BC adding in AD, it is a high quantity of reviews, however, we are of the next one: Weixin Zhao, Haizhou Yang, Shufei He, Qingliang Zhao, Liangliang Wei, A review of biochar in anaerobic digestion to improve biogas production: Performances, mechanisms and economic assessments,

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| Bioresource Technology, Volume 341, 2021, 125797, ISSN 0960-8524, https://doi.org/10.1016/j.biortech.2021.125797. |
| **Geographical location**<br>• Please include the geographical location where the research and innovation activities took place.<br>• Drag to re-order selected items. |
| All innovation activities are being realized in AINIA's installations (Valencia, Spain). |
| **Additional information**<br>List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters) |
| The technologies included in this PA are easy to implement due to their high TRL and their full-scale installation in livestock farms and wastewater treatment plants. These implementation facilities reduce investment, operating and maintenance costs, allowing high-rate installation regardless of farm size.<br><br>The anaerobic digestion systems require simple reactors designs, stabled in industrial installations, as CSTR. The adding technology could be realized in preestablish reactors or in new reactors, adapting it to the surface and devices availability. In addition, manure storage system could be adapted to treat the raw manure thought AD. The adaptability of AD facilitate the technology implantation, reducing the GHG emissions of the manure management chain.<br><br>On the other hand, NDN technology allows high concentrations of nitrogen in manure to be treated, producing molecular nitrogen (N2). This system requires specific installation and the corresponding investment. However, the advantage of NDN lies in its high efficiency in removing nitrogen from manure effluents, mitigating ammonia gas emissions and soil contamination from uncontrolled spills. |

| **PRACTICE ABSTRACT #6** |
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| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| RAW MANURE NUTRIENTS FIXATION SYSTEMS BY SOLAR DRYING (SD) AND PULSE COMBUSTION DRYING (PCD) TO ORGANIC FERTILIZERS PRODUCE. |
| **Summary**<br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |
| Raw manure or raw anaerobic digestate present high concentration of nutrients which could be used as organic fertilizers to agricultural production. However, the moisture content of the manure has an impact over the manure management due to the low concentration of organic matter and nutrients. This aspect affects to the manure use profitability to agriculture end, due to the logistic costs associate to the high manure volume transport and application. Additionally, the application of diluted nutrients in high water volume can has a negative impact over the aquatic ecosystem's eutrophication. This impact is due to the leaching of nitrogen compounds from the soil surface, which escape and contaminate underwater bodies, and finalise in superficial water bodies.<br><br>To solve this problem, two systems are proposed to reduce the moisture content of manure, producing dry organic fertilisers with all the nutrients from the manure: Solar Drying (SD) and Pulse Combustion Drying (PCD). SD is a low energy demand technology to manure drying using solar energy. This technology precise the chemical treatment of manure to reduce the GHG emissions like the acidification. PCD is a drying technology based on use pulsating combustion-generated hot gases to rapidly and efficiently remove moisture from materials. Neither produce a quality organic fertilizer, PCD is an energetically intensive technology due to high temperature required. The result of these technologies is the fixation of different nutrients (N, P, K) in an organic fertilizer to apply it with agriculture use.<br><br>The proposed technologies aim to promote circular dynamics, closing nutrient cycles to reduce the primary sector's external dependencies. This objective is coherent with EU strategical objectives, which are focus on the strategical autonomy acquisition promote for Ukraine war and the COVID-19 crisis. Furthermore, these technologies aim to reduce the challenges suposed by manure management for livestock farmers, reducing the volume that needs to be managed and allowing manure to be treated on the farm itself. |
| **Main findings**<br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?<br>This summary should at least contain the following information (max. 2000 characters):<br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users?<br>• Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies). |

- Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.

This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting research results in scientific language, which does not respond to real needs of the practitioners, should be avoided.

**Objective**

Evaluate raw manure dehydration systems by Solar Drying (SD) and Pulse Combustion Drying (PCD) to organic fertilizers produce.

**Current results**

For 2026, is looked forward to stablishing the optimal treatment conditions and evaluate the adequate performance for the conversion of raw pig manure in a easy-use organic fertilizer. These technologies will be realised by the partners of NUTRITIVE in collaboration with external entities to confirm the correct treatment, the nutrients fixation capacity and the environmental impact reduction. During 2026, the moisture removal assays will be realised and evaluated through the organic powder physic-chemical characterization, efficiency evaluation and environmental impact measure.

Previous studies have demonstrated the dehydration capacity to reduce the moisture content and the management costs. However, it is necessary the quantification of the nutrient's concentration capacity and the environmental implication of these technologies. Furthermore, is necessary to evaluate the final product quality to ensure the posterior agricultural use.

**Practical implications**

These technologies would have a direct impact over our conception of the manure management, representing two alternatives (one intensive and another extensive, according to their energy and spatial demand) to reduce the manure volume, that must be treated, and fixate nutrients for valorisation technologies. Furthermore, these technologies would allow increase the livestock farms profitability and increase the primary sector competitiveness, thanks to the diversification of livestock farm products. The nutrients concentred powder could be use directly or valorised to purify the compounds to increase her value.

Otherwise, these alternatives ensure the manure removal of the high-volume storage system, reducing the out-of-control GHGs emissions. The treatment expansion could limit the direct raw manure application, reducing the negative environmental impact over the water bodies. Finally, the technological diversification allows adapt the strategy selection for each study case, personalising the manure management solution and reducing the implantation barrier.

**Additional dissemination and exploitation material(s)**

*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).*

Inicio » IRTA

Ekonek | Tecnología de secado y servicios

**Geographical location**

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| • Please include the geographical location where the research and innovation activities took place.<br>• Drag to re-order selected items. |
| IRTA, Caldes de Montbui, Catalunya (Spain)<br>Ekonek, Errenteria, País Vasco (Spain) |
| **Additional information**<br>List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters) |
| SD technology represents a comprehensive strategy for dehydrating raw manure, reducing treatment costs. This technology only requires a greenhouse and a mixing system to facilitate evaporation. However, this system requires a large area to treat large quantities of manure. On the other hand, in PCD technology, the necessary equipment consumes a lot of energy and is complex to operate, requiring specialised personnel. Nevertheless, it can be installed in a small area and fixes nutrients with low greenhouse gas emissions. |

| **PRACTICE ABSTRACT #7** |
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| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| ELECTROCOAGULATION FOR PHOSPHORUS RECOVERY FROM THE LIQUID FRACTION OF ANAEROBIC DIGESTATE: A POST-TREATMENT STRATEGY TO REDUCE NUTRIENT POLLUTION. |
| **Summary**<br><br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |
| Livestock-derived anaerobic digestate contains high levels of phosphorus, ammonium, and organic matter, which can lead to nutrient pollution if discharged untreated. This practice explores electrocoagulation (EC) as a post-treatment strategy to recover phosphorus from the liquid fraction of anaerobic digestate. Preliminary trials were conducted using iron and graphite electrodes, applying voltages between 5 and 15 V, with real-time monitoring of pH, conductivity, current intensity, and temperature.<br><br>The digestate was pre-treated by centrifugation to simulate the liquid fraction. Results showed moderate phosphorus removal (up to ~17%), significant reduction in chemical oxygen demand (COD), and visible foam formation during the EC process. However, no significant floc formation was observed, and the color of the digestate remained unchanged throughout the tests. A biofilm developed on the iron anode, indicating corrosion and possible electrode degradation.<br><br>Despite the limited flocculation, the process demonstrated potential for nutrient recovery and organic load reduction. The effectiveness of EC depends on several factors, including electrode material, current density, reaction time, and initial digestate composition. Further optimization is needed to enhance floc formation and phosphorus precipitation.<br><br>Electrocoagulation offers a low-chemical, scalable solution for farms and biogas plants aiming to valorize digestate and comply with discharge regulations. It can be integrated with other treatment technologies to improve overall nutrient recovery and environmental performance. |

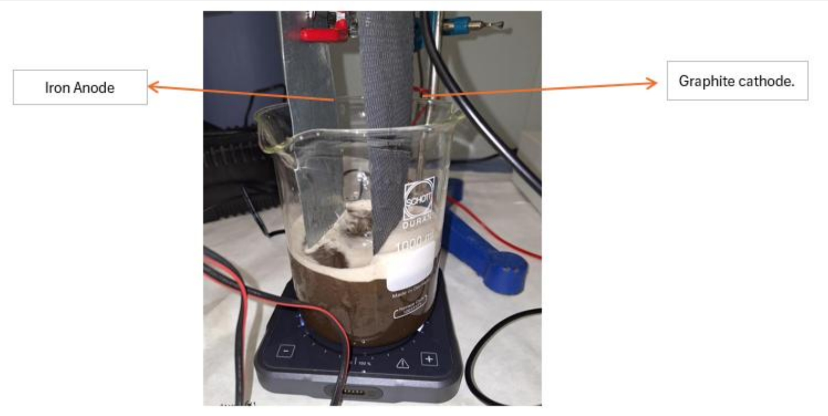


*Figure 1. Set-up of the electrocoagulation process.*

**Main findings**

Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?

This summary should at least contain the following information (max. 2000 characters):

- Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users?
- Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies).
- Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.

This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting research results in scientific language, which does not respond to real needs of the practitioners, should be avoided.

**Objective:**

This research adresses the challenge of nutrient pollution caused by the discharge of untreated anaerobic digestate, especially its liquid fraction. This waste stream is rich in phosphorus, ammonium, and organic matter, which can negatively impact water bodies and soil if not properly managed. Farmers and biogas plant operators need cost-effective, scalable solutions to treat digestate and recover valuable nutrients.

**Results:**

Electrocoagulation (EC) was tested as a post-treatment method to recover phosphorus from the liquid fraction of anaerobic digestate. Using iron electrodes and voltages between 5 and 15 V, the process achieved moderate phosphorus removal (~17%) and significant reduction in chemical oxygen demand (COD). Foam formation and biofilm development on the electrodes were observed, although floc formation was limited. The digestate was pre-treated by centrifugation to simulate the liquid fraction, and key parameters such as pH, conductivity, current intensity, and temperature were monitored. The trials showed that EC can mobilize phosphorus and reduce organic load, but further optimization is needed to enhance flocculation and sedimentation.

**Practical implications and recommendations:**

Electrocoagulation offers a low-chemical, potentially cost-effective solution for improving digestate quality before discharge or reuse. It can be implemented with basic equipment (power supply, electrodes, reaction vessel) and adapted to different scales. The main costs are related to energy consumption and electrode replacement due to corrosion (sacrificial iron electrode). Benefits include reduced environmental impact, improved nutrient recovery, and compliance with discharge regulations. For better performance, practitioners are advised to optimize current density and reaction time. This approach supports circular economy goals by transforming waste into a resource and reducing pollution at farm and plant level.

**Additional dissemination and exploitation material(s)**

*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).*

*Combining electrocoagulation-flotation with anaerobic digestion for faecal sludge treatment: Micropollutant removal with simultaneous energy recovery.*

*This open-access publication presents an integrated approach combining electrocoagulation-flotation (ECF) and anaerobic digestion (AD) for faecal sludge treatment. It demonstrates high removal efficiencies for heavy metals and micropollutants, while significantly enhancing methane production. The study provides valuable insights into optimizing current density, residence time, and feedstock/inoculum ratios for energy recovery and pollutant control.*

***Full reference (APA style):****Dong, P., Parmentier, D., Zhang, T., & Van Hulle, S. W. H. (2025). Combining electrocoagulation-flotation with anaerobic digestion for faecal sludge treatment: Micropollutant removal with simultaneous energy recovery. Bioresource Technology, 435, 132939. https://doi.org/10.1016/j.biortech.2025.132939.*

**Geographical location**

- Please include the geographical location where the research and innovation activities took place.
- Drag to re-order selected items.

The innovation activities are being realized in AINIA's installations (Valencia, Spain).

**Additional information**

List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters)

Electrocoagulation is a simple and low-chemical method that can be easily implemented using basic equipment and sacrificial electrodes. Its potential to reduce phosphorus and organic load makes it attractive for farms and biogas plants.

However, further investigation is needed to optimize key parameters such as voltage, reaction time, and current density. In the preliminary trials, floc formation was limited and phosphorus removal moderate, suggesting that the process conditions must be fine-tuned to improve efficiency.

Future actions should focus on adjusting operational settings and evaluating long-term performance, including energy consumption and electrode durability. End-users are encouraged to consider EC as part of a digestate management strategy, with potential benefits in nutrient recovery and regulatory compliance.

| PRACTICE ABSTRACT #8 |
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| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| REDUCTION OF GREENHOUSE GAS (GHG) EMISSIONS THROUGH THE OPTIMIZATION OF THE OPERATION OF PARTIAL NITRITATION/ANAMMOX SYSTEMS FOR THE REMOVAL OF NITROGEN FROM PRE-DIGESTED SLURRY. |
| **Summary**<br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |
| The management of slurry in intensive livestock farming poses significant environmental challenges due to its high content of organic matter and nutrients like nitrogen and phosphorus compounds, or ammonia ($NH_3$) and GHG emissions. Traditional biological systems, such as Nitrification/Denitrification, require high energy consumption and contribute significantly to GHG emissions, particularly as nitrous oxide ($N_2O$). From this perspective, this investigation focuses on the study of Partial Nitritation/Anammox (PN/AMX) systems as the most effective technology for removing nitrogen from digestate in terms of effluent quality and GHG emissions.<br><br>PN/AMX for nitrogen removal involves an initial step of ammonium oxidation to nitrite, with an efficiency of approximately 50%, performed by ammonium-oxidizing bacteria in aerobic conditions, thereby reducing the energy demand compared to complete nitrification to nitrate. Then, anammox bacteria convert the remaining ammonium and nitrite into nitrogen gas under anoxic conditions. Since the PN/AMX process is completely autotrophic, all organic carbon can be anaerobically digested, allowing for maximum biogas production. Importantly, the PN step consumes alkalinity, lowering pH in the reactor and reducing $NH_3$ volatilization. This not only decreases ammonia emissions to the atmosphere but also mitigates odour problems associated with slurry treatment.<br><br>The research, carried out to date, focused on the identification of the most critical operational parameters that affect GHG emissions in the form of $N_2O$ in the (PN/AMX) process. For this purpose, two lab-scale reactors have been started up: one for partial nitritation and the other for the Anammox process. Both reactors were enriched to obtain biomass capable of treating high nitrogen loads, as required for livestock slurry treatment. At the same time, abiotic assays (without the presence of biomass) with nitrite in the liquid media were conducted to obtain information on $N_2O$ emissions non-related to biomass activity. |
| **Main findings**<br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?<br>This summary should at least contain the following information (max. 2000 characters):<br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users?<br>• Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies). |

- Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.

This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting research results in scientific language, which does not respond to real needs of the practitioners, should be avoided.

Slurry contains high levels of nitrogen that are difficult and costly to remove, while simultaneously releasing ammonia ($NH_3$), which causes odors and air pollution, and greenhouse gases (GHG) that harm the climate. Current treatment systems, such as nitrification/denitrification, consume a significant amount of energy, generate excess sludge for management, and reduce the potential for biogas recovery.

The Nutritive project aims to turn this problem into an opportunity by optimizing the partial nitritation/anammox (PN/AMX) process, carried out by a mixture of bacterial populations of natural origin, for the removal of nitrogen from livestock slurry.

In comparison with conventional biological processes of nitrification and denitrification processes applied to remove nitrogen from residual effluents, the application of PN/AMX process will diminish the energy consumption associated with aeration to a value of 40 %, the cost of solid waste management is reduced to 15 % and in addition, all the organic matter present in the manure can is transformed to methane that is a source of energy.

Results from NUTRITIVE will enable the development of PN/AMX technology to a further scale, approaching the final full-scale application. For this purpose, different slurry samples will be collected from various farms in the Autonomous Community of Galicia and tested in the process to evaluate the quality of the treated water generated and the production of $NH_3$ and GHG emissions. The best operational conditions and process design will be selected for assessment in terms of both economic and environmental impact.

The main benefits of adopting PN/AMX are lower treatment costs, higher biogas yields, reduced odour problems, and a smaller climate footprint. These advantages improve environmental compliance while creating economic opportunities linked to renewable energy generation.

**Additional dissemination and exploitation material(s)**

*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).*

Relevant websites where the project information is provided at the moment.

- Project website – Horizon Europe "NUTRITIVE"
  URL: https://nutritive.es
- Cross-disciplinary Research in Environmental Technologies (CRETUS-USC) website
  URL: https://cretus.usc.es

**Geographical location**

- Please include the geographical location where the research and innovation activities took place.
- Drag to re-order selected items.

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| Main research activities are conducted in the facilities corresponding to the Centre for Cross-disciplinary Research in Environmental Technologies (CRETUS) at the Universidade de Santiago de Compostela (USC), Spain.<br>Collection of livestock slurry is performed on farms located in the Autonomous Community of Galicia (Northwest of Spain), where the USC is based. |
| **Additional information**<br>List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters) |
| Research on the implementation of PN/AMX systems for slurry treatment presents both opportunities and challenges. Compared to the conventional biological treatment applied for nitrogen removal through nitrification-denitrification, the operational costs of the PN/AMX process are lower due to its lower oxygen demand, which reduces the energy consumption. Additionally, as it does not require organic matter, this can be used to increase biogas (methane) production and, consequently, the energy recovered.<br>In terms of implementing the technology, it is essential to note that the PN/AMX process is straightforward to implement after biogas-producing systems that are already in operation in the farms.<br>With respect to environmental aspects, the PN/AMX systems reduce the nitrogen released as ammonia, diminishing the problems of odours, produce less GHG emissions ($N_2O$), and reduce the potential for nitrogen pollution in the receiving bodies of the discharged wastewater.<br>These factors are expected to create an incentive for farmers and manure managers to adopt more sustainable treatment technologies.<br>However, some aspects require clarification before applying the technology. Among these are the assessment of the stable performance of bacterial populations under operational conditions for treating livestock slurry, the relatively slow start-up and adaptation of biological systems, and the need for trained staff. To overcome these barriers, pilot-scale demonstrations under real farm conditions are recommended.<br>Future research should focus on optimizing the PN/AMX system under variable conditions using real slurry, understanding the dynamics of long-term GHG emissions, and comparing the environmental and economic performance of this system with that of conventional systems. |

| PRACTICE ABSTRACT #9 |
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| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| RECOVERING AMMONIA FROM MANURE WITHOUT CHEMICALS: LOCAL FERTILISER PRODUCTION THROUGH AIR STRIPPING AND ZERO-CHEMICAL AMMONIA RECOVERY |
| **Summary**<br><br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |

Ammonia recovery from manure is essential to reduce nitrogen emissions and create local fertiliser alternatives. In this project, two technologies were tested to recover ammoniacal nitrogen from the liquid fraction of manure or digestate.

1. **Air ammonia stripping**

Using the Ammonia Mining Unit (AMU), manure liquid is treated in two steps: $CO_2$ is first stripped to raise the pH naturally, followed by heat-based ammonia stripping. The ammonia-rich air is then scrubbed with either sulfuric acid ($H_2SO_4$) or citric acid to produce ammonium sulfate or ammonium citrate. The system works in a closed loop with low emissions and can treat 1–5 m³/h. In Aalter (BE), 67% $NH_4$-N removal was achieved under real conditions.

2. **Zero-chemical ammonia recovery**

A second system uses an electrochemical membrane process that needs no added acids. It treats ~2 m³/day and produces organic nitrogen, suitable for organic farming. This method avoids SOx/$N_2O$ emissions and water use linked to acid production. It offers a higher-value product with a lower environmental footprint.

**Additional findings:**

- Performance tests with different ammonium sulfate sources showed:
    - Synthetic: 2.124 kg $NH_4$/day
    - Aalter: 2.855 kg $NH_4$/day
    - Hooglede: 0.432 kg $NH_4$/day

Based on this, **synthetic or Aalter** ammonium sulfate will be used in future trials.

**Why it matters:**

These solutions help farmers turn manure into a valuable fertiliser, reduce input costs, cut emissions, and lower dependence on imported synthetic fertilisers. The technologies are scalable, low in emissions, and support both conventional and organic farming systems.

| **Main findings**<br><br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized? |
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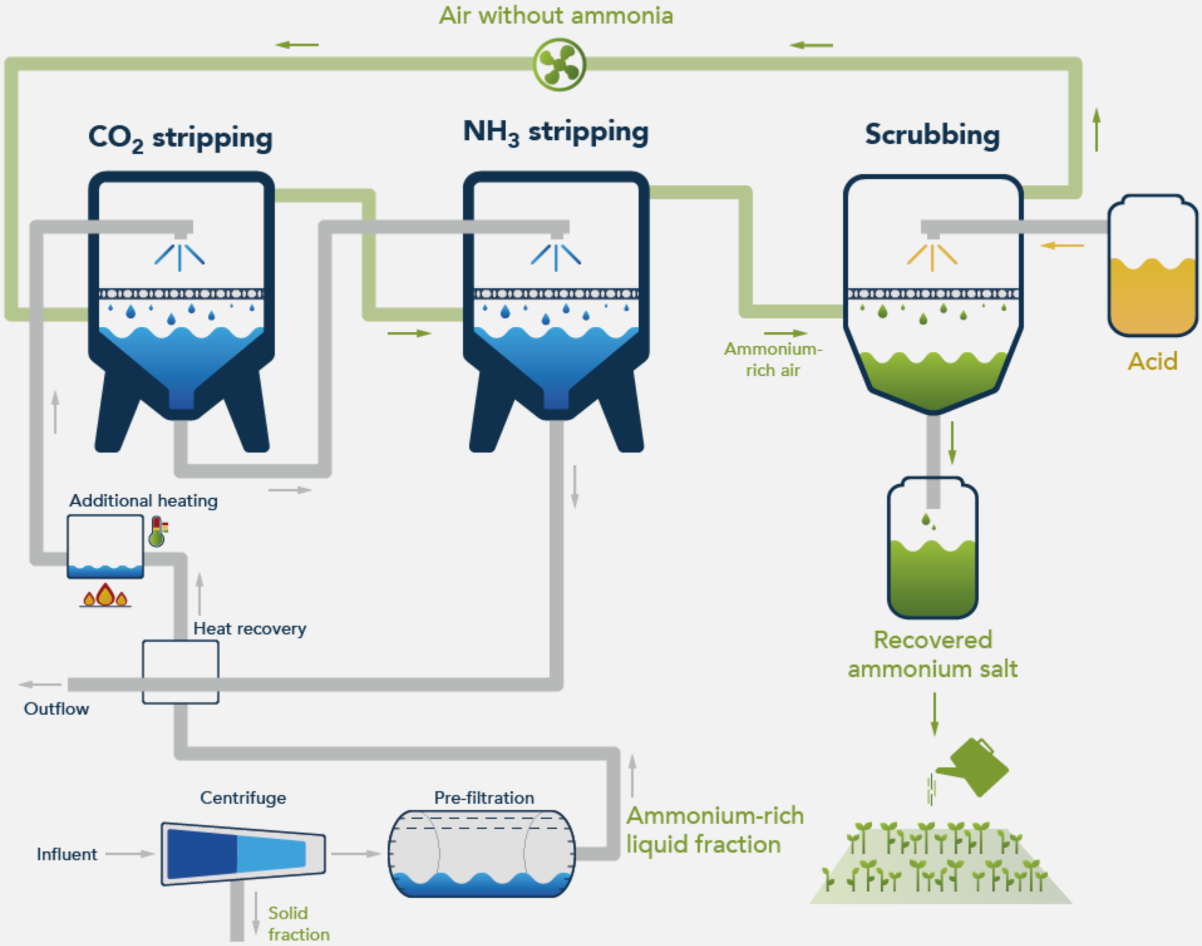
| This summary should at least contain the following information (max. 2000 characters):<br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users?<br>• Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies).<br>• Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.<br>This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting research results in scientific language, which does not respond to real needs of the practitioners, should be avoided. |
| Livestock farming produces vast amounts of manure, leading to high ammonia ($NH_3$) and greenhouse gas emissions. At the same time, synthetic nitrogen fertilisers—produced through the energy-intensive Haber-Bosch process—are widely used, despite their environmental and geopolitical impact. This project aims to recover ammoniacal nitrogen from manure and reuse it locally, offering both ecological and economic benefits.<br>Two innovative technologies were tested:<br>1. **Air ammonia stripping** using the Ammonia Mining Unit (AMU), combined with acid scrubbing ($H_2SO_4$ or citric acid).<br>2. **Zero-chemical ammonia recovery** using an electrochemical membrane system that internally recycles acid and produces organic nitrogen.<br><br>The AMU removed up to 67% of $NH_4$-N from the liquid fraction of manure under real conditions. Tests regarding zero-chemical ammonia recovery with synthetic ammonium sulfate showed the highest recovery (282 kg $NH_4$/day), followed by Aalter (3.12 kg/day) and Hooglede (0.432 kg/day). Further tests will use synthetic or Hooglede-based ammonium sulfate.<br>Zero-chemical recovery is more sustainable, requires no external acids, and produces a product suitable for **organic farming**. It avoids SOx and $N_2O$ emissions linked to acid use and allows recovery of **higher-value organic nitrogen**.<br><br>**Practical relevance:**Farmers can turn waste into value by producing local, fast-acting fertiliser. This reduces fertiliser costs, limits import dependency (especially from Russia), and supports strategic autonomy. Both systems operate in closed-loop setups with minimal emissions and are scalable for farm-level application. |
| **Additional dissemination and exploitation material(s)**<br>*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).* |
| Detricon's website: https://www.detricon.eu/<br>Detricon's linkedin: https://www.linkedin.com/company/detricon/<br>Detricon's youtube: https://www.youtube.com/@Detricon |

Detricon's Ammonia mining unit:


Detricon's stripping technology:



| **Geographical location**<br>• Please include the geographical location where the research and innovation activities took place.<br>• Drag to re-order selected items. |
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| The lab tests were carried out in Merelbeke (BE), pilot-scale testing is taking place in Hooglede (BE), Aalter (BE) and Merelbeke (BE), and the unit will be demonstrated on a model farm in Gistel (BE). |
| **Additional information**<br>List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters) |
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| PRACTICE ABSTRACT |
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| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| TRANSFORMATION OF PIG SLURRY IN VERMICOMPOST AND IRRIGATION WATER USING A SCALABLE AND LOW-COST MODULAR SYSTEM THAT REMOVES HEAVY METALS AND IMPROVES ORGANIC FERTILIZER MANAGEMENT. |
| **Summary**<br><br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |
| "Agropurín" is a modular, on-farm system that improves pig slurry management. The process starts with solid–liquid separation: the solid fraction is converted into vermicompost through vermi-management, and the liquid fraction is treated—first by biofiltration and then in macrophyte lagoons—to obtain water suitable for irrigation.<br><br>This process reduces heavy metals in the liquid phase and generates by-products that can be safely used as fertilisers, preventing pollution. Vermicompost can be marketed as a fertiliser with low transport costs, and the treated liquid can be used for irrigation, especially in regions with summer droughts where supplemental irrigation is important.<br><br>Recycling these by-products as solid fertiliser and irrigation water promotes the circular economy and contributes to the sustainability of the pig sector.<br><br>Authorities can propose, disseminate, and fund this technique to prevent heavy-metal accumulation in soils and water pollution from pig farming, especially in areas designated as vulnerable to nitrate contamination. |
| **Main findings**<br><br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?<br><br>This summary should at least contain the following information (max. 2000 characters):<br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users?<br>• Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies).<br>• Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.<br><br>This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting |

research results in scientific language, which does not respond to real needs of the practitioners, should be avoided.

Pig farms, unlike dairy farms which grow forage crops for cattle feed and use slurry as fertiliser, are typically intensive operations without agricultural land. Therefore, in some areas pig slurry accumulates and can cause environmental problems (water eutrophication, heavy-metal pollution, ammonia emissions, etc.). It is common practice to transport large quantities of slurry (a high-water-content material) over long distances for treatment, with high associated costs.

The process reduces heavy metals in the liquid fraction and yields by-products suitable for use as fertilisers, thereby avoiding pollution problems. Vermicompost can be marketed as a fertiliser with low transport costs, and the final liquid can be used as irrigation water, especially in regions with summer droughts where supplemental irrigation may be important.

Pig farmers can readily adopt this modular system because it is low-cost, scalable to each farm's needs, and requires minimal maintenance.

**Additional dissemination and exploitation material(s)**

*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).*

Description of Agropurín - Modular system for vermi-management of slurry for its valorisation as a fertiliser:

https://eu-cap-network.ec.europa.eu/good-practice/agropurin-modular-system-vermi-management-slurry-its-valorisation-fertiliser_en

https://intercambiom.org/practica-innovadora/agropurin-de-purin-a-vermicompost-y-agua-apta-para-riego-a-traves-de-filtros-biologicos/ (Spanish)

https://intercambiom.org/wp-content/uploads/2024/04/PR_13_FICHA_Filtros-biologicos-Agropurin-de-purin-a-vermicompost-y-riego_ECOCELTA-revision_v3.pdf (Spanish)

https://intercambiom.org/wp-content/uploads/2024/04/Ficha-Descripcion-AgroPurin.pdf (Spanish)

https://youtu.be/4uvFrDaC4Sg (Spanish and Galician with English subtitles).

https://youtu.be/1ezkl53CeSw (Spanish)

https://www.lavozdegalicia.es/noticia/somosagro/ganaderia/2024/06/24/buscan-formulas-liberar-purin-antibioticos-metales-pesados-rebajar-dependencia-fertilizantes-inorganicos/00031719232339173932705.htm (Spanish)

Characterizing and reusing by-products obtained by Agropurín system in forage crops:

Báez MD, García MI, 2023. Fertilizing value of fractions derived from pig slurry treatment using a modular vermi-management system and its agronomic application in corn.

Book of abstracts " 5ª Reunión Ibérica de Pastos y Forrajes," Huelva (Spain) and Loulé (Portugal), April 17-20. pp:. 72.

https://www.seepastos.es/wp-content/uploads/2025/04/libro-de-resumenes-red.pdf (Spanish)

Báez MD, García MI, 2025. Fertilization of ryegrass with fractions derived from the purification of pig slurry using a modular vermi-management system.

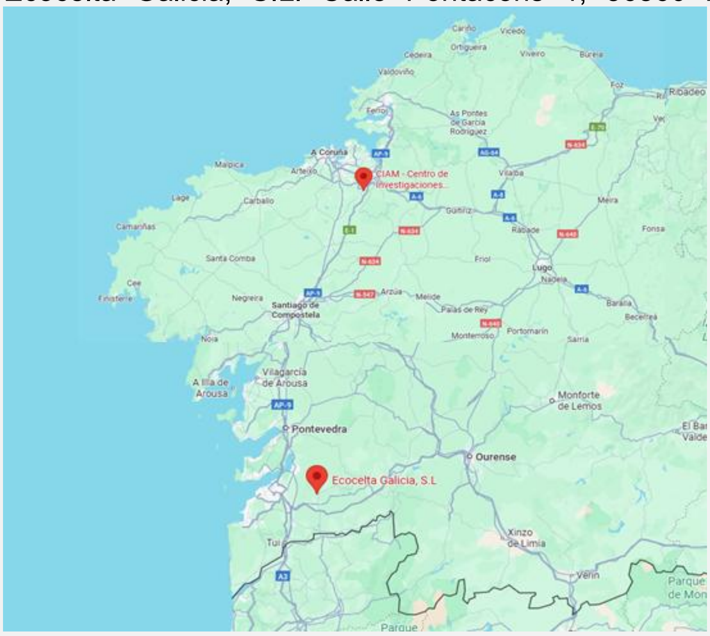
Proceedings "63ª Reunión Científica de la Sociedad Española de Pastos, SEP. "Los Pastos como elemento vertebrador de los Objetivos de Desarrollo Sostenible", Lugo (Spain), Sepembert 23-26, pp: 33-34.

https://www.seepastos.es/reuniones-cientificas-sociedad-espanola-de-pastos/ (Spanish, coming soon on the web).

**Geographical location**

- Please include the geographical location where the research and innovation activities took place.
- Drag to re-order selected items.

- Agricultural Research Center of Mabegondo (CIAM-AGACAL). AC-542, km 8. 15318 Abegondo (A Coruña)- Spain.
- Ecocelta Galicia, S.L. Calle Pontacons 1, 36860 Ponteareas (Pontevedra) - Spain




**Additional information**

List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters)

Facilitating elements:

- It is a technology that is easy to install on a farm.
- Minimal maintenance.
- High technological level of the farms.
- High degree of association in the pig sector.

Obstacles:

- Environmental/regulation risk factors.

Future actions/research:

- Authorities can propose, disseminate and fund this technique to prevent water pollution from the pig sector, especially in areas declared vulnerable to nitrate contamination.
- Agronomic field trials to test by-products and study the effects on production, nutrient assimilation by plants and the effects on soil (dosage, time of application, type of forage crops, other crops, etc).

## ANNEX 1 – EIP-AGRI PRACTICE ABSTRACTS TEMPLATE

| PRACTICE ABSTRACT |
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| **Title of the practice abstract**<br>*Provide a self-explanatory title that shortly summarises the challenge/opportunity and the project result(s) that addresse(s)/seize(s) it/them and are relevant for the practitioners (max. 255 characters.* |
| |
| **Summary**<br>*Summary for practitioners on the main finding(s)/innovative solution(s)) (max. 2000 characters.* |
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| **Main findings**<br><br>Shortly describe for practitioners the main finding(s)/innovative solution(s): how the challenges/opportunities can be solved/seized?<br><br>This summary should at least contain the following information (max. 2000 characters):<br><br>• Objective(s): what challenge(s)/opportunity(ies) does the project address/seize that are relevant for the practitioners/end-users?<br>• Result(s) of the project related to what new knowledge/innovative solution(s) have been developed that solve the challenge(s)/seize the opportunity(ies).<br>• Practical implications/recommendations: how can the practitioners make use of the results/outcomes in practice? What would be the main costs/benefits to the end-users if the generated new knowledge / innovative solution(s) is(are) implemented? etc.<br><br>This summary should be as interesting as possible for farmers/foresters/other end-users, using a direct and easy understandable language and pointing out entrepreneurial elements which are particularly relevant for practitioners (e.g. related to cost, benefits, productivity, etc.). Presenting research results in scientific language, which does not respond to real needs of the practitioners, should be avoided. |
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| **Additional dissemination and exploitation material(s)**<br>*Provide Title/Description and URL (this must be an external URL such as https://example.com). Provide Provide URL link to additional materials which are useful and attractive for practitioners (e.g., link to relevant websites, social media, videos, pictures, pdf files, other dissemination materials).* |
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| **Geographical location**<br>• Please include the geographical location where the research and innovation activities took place.<br>• Drag to re-order selected items. |
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| **Additional information**<br>List facilitating elements or obstacles for the implementation of the generated results, suggest future actions/research, and/or provide messages to end-users etc. (max. 2000 characters) |
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