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Oral Presentations

Parallel session 1

Wednesday · 10:45-12:15 · Mitigation Strategies and Technologies

Laboratory assessment of methane reduction potential by in-house slurry acidification in dairy cattle barns

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Dairy farming is a significant source of methane emissions, primarily from enteric fermentation and, to a lesser extent, manure management. In Denmark, dairy cattle housing systems are almost evenly split between barns with solid floors with daily manure removal, and those with slatted floors over continuous slurry channels, where slurry is regularly circulated by pumping. The latter, with channel lengths of several hundred meters and average slurry depths of 80 cm, contributes substantially to total methane emissions within the barn. While in-house slurry acidification, where the slurry in the dairy barn is adjusted daily to pH 5.5 by adding concentrated sulfuric acid, is primarily implemented to reduce ammonia emission, it is also known to impact methane emission strongly. Thus, this ongoing study investigates the effectiveness of in-house slurry acidification on methane emission as a mitigation strategy. Manure samples were collected four times over a year from eight barns—four with and four without in-house acidification - and incubated in the laboratory for three days. Incubations were performed in triplicate using 1-litre glass flasks filled with 500 ml of slurry, sealed with rubber stoppers, and maintained in a water bath at the same temperature as the slurry inside the barn. Methane and carbon dioxide production were quantified using gravimetric, manometric, and volumetric methods, with gas concentrations analysed via gas chromatography. We hypothesise that in-house acidification will reduce methane emissions from slurry by more than 90%.

Field acidification with acetic vs. sulfuric acid: effects on NH_3 and N_2O emissions from cattle and pig slurry applied to grassland

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Ammonia (NH_3) emissions from slurry application contribute to air pollution and ecosystem acidification, while nitrous oxide (N_2O) emissions contribute to global warming; both represent a loss of plant-available nitrogen. Field acidification is a strategy to reduce NH_3 emission, typically using sulfuric acid. However, safety concerns and sulphur accumulation in soil have increased interest in organic acids such as acetic acid. This study evaluated the effects of acidification with different amounts of sulfuric and acetic acid to have comparable pH on NH_3 and N_2O emission following application of cattle and pig slurry to grassland in Denmark. Two field experiments used cattle slurry and pig slurry separately. In both experiments a block design was used with three replicates for NH_3 and four replicates for N_2O. NH_3 emissions were measured using dynamic flux chambers connected to a cavity ring-down spectrometer, and N_2O emissions were measured using static chambers and mid-infrared spectroscopy. Cumulative emissions were analysed with a one-way ANOVA. Preliminary results showed that for both slurries acid treatments reduced cumulative NH_3 emissions compared with raw slurry, with no difference between acids. However, the reduction was only significant for cattle slurry. Cumulative N_2O emissions did not differ significantly among treatments for either slurry type; however, cattle slurry N_2O emissions were numerically higher following acidification. These results indicate that acetic acid can provide NH_3 mitigation comparable to sulfuric acid under field conditions without significantly increasing N_2O emissions, suggesting that acetic acid is an alternative where sulphur inputs are constrained.

Low-dose acidification effectively suppresses methanogenesis during manure storage: Evidence from a two-year field study

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As point sources of methane, liquid manure storages are targets for mitigation. Acidification with sulfuric acid at 6 kg m^{-3} can effectively reduce ammonia emissions, but pilot-scale studies show that methane emissions are suppressed even at 2 kg m^{-3}. We investigated if low-dose acidification could effectively reduce methanogenesis during practical storage despite the regular input of fresh slurry from barns.

Eight storages with, respectively, cattle and pig slurry were selected on farms in Western Denmark, 12 of which were acidified. In 2023-2024, three mixing strategies were evaluated: mixing only during acidification, two additional mixing events during the storage period, or monthly mixing. In 2024-2025, the slurry was only mixed during acidification. Acid doses were calculated to achieve a final concentration of 2 kg m^{-3} when tanks were full.

Slurry from all 16 storages was sampled three times at up to four depths for chemical analyses and (selected samples) measurement of methane production rates using a laboratory assay. In 2023-2024, all samples were incubated at 20°C to compare the methanogenic potential across sampling times and farms. In 2024-2025, a near-ambient incubation temperature was used to evaluate the potential emissions.

Acidification reduced average methane production rates in both cattle and pig slurry by 80–95% relative to untreated controls (p=0.004), with no differences between mixing strategies, indicating that a single acidification at an early stage can be effective for methane mitigation. However, pockets of unacidified slurry showing methanogenesis resumes when fresh slurry is added, and slurry spreading during summer complicates treatment.

Documentation of methane mitigation efficiency in a flaring system of methane-rich gases collected from covered slurry tanks – preliminary results

Simon Wilhelm Løvstrøm Granath[1], Anders Peter Adamsen[2]
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This study provides a preliminary evaluation of the in-field performance of a commercial on-farm flaring system designed to mitigate methane (CH_4) emissions from stored livestock slurry with sealed tent covers. The investigation, conducted at four separate farm locations with covered storage tanks with pig slurry (n=2) and cattle slurry (n=2), quantified both the flare's combustion efficiency and its gas collection efficiency under real-world operating conditions. Methane reduction was determined through continuous CH_4 concentration measurements before and after the flaring unit using Cavity Ring-Down Spectroscopy (CRDS) and Tunable Diode Laser Spectroscopy (TDLS). The system's gas collection efficiency was independently assessed using the tracer gas decay method to establish the total ventilation rate from the tank's headspace for estimation of recoveries of the produced methane. Six measuring campaigns are planned at each site over approximately a one-year period. The preliminary results from the first twelve measurement campaigns show that the combustion process is effective, achieving a methane reduction efficiency consistently > 99% for gases with > 5% methane. However, the tracer gas decay analysis revealed that the overall system effectiveness is limited by the physical gas capture, with collection efficiencies ranging from 77 to 92%. This discrepancy highlights that a significant fraction of gas may escape as fugitive emissions. The study concludes that while flaring is a highly efficient technology for methane combustion, its total environmental performance is critically dependent on optimizing gas collection from the slurry tank to realize the full mitigation potential.

Effect of SDS treatment on methane emissions from manure storage in pig and cattle barns

Herald Wilson Ambrose, Astrid Skifter Madsen, Frederik Rask Dalby, Michael Jørgen Hansen, Anders Feilberg
Aarhus University, Aarhus, Denmark

The study was conducted in two phases, namely barn and storage, simulating methane dynamics in pig and cattle production. In the barn phase, slurry was incubated at 22°C and 17.5°C for pig and cattle slurry, respectively. Reactors were initially filled with residual slurry, and three times per week feces and urine were added to mimic continuous manure production. SDS was applied at concentrations of 1, 2.5, and 5 g/kg slurry. After the barn phase, a portion of slurry was transferred to storage reactors, reflecting slurry flushing from barns to storage over a 21-week period. Storage experiments were conducted under summer (17.5°C) and winter (10°C) conditions to evaluate seasonal effects.

For the same SDS dosage, CH_4 mitigation efficiency differed between pig and cattle slurry. At 2.5 g/kg SDS treatment, CH_4 mitigation was higher in pig slurry (75%) than cattle slurry (31%) during the barn phase. In storage, SDS reduced CH_4 emissions by 60% in pig slurry and 30% in cattle slurry in summer, and by 35% and 9%, respectively, in winter. SDS redistributed dominant methanogens in cattle slurry but reduced several taxa while enriching *Methanogenium* in pig slurry. Furthermore, SDS treatment affected the pig and cattle slurry matrices differently, releasing higher amounts of proteins and carbohydrates into the liquid fraction of pig slurry compared with cattle slurry. These results indicate that SDS more effectively suppresses methanogenic activity in pig slurry, likely due to stronger disruption of methanogenic populations within the slurry matrix.

Effect of Manure Additives on Ammonia and Nitrogen Oxides Emissions during Storage

Elio Dinuccio, Kazi Rabeya Akther, Luca Rollè, Marta Maria Gulinelli
University of Turin, Turin, Italy

This study evaluated the potential of chemical, biological enzymatic, and physical additives to mitigate gaseous nitrogen emissions during storage of cattle manure under controlled laboratory conditions. Manure samples were collected from two cattle farms (Farm A and Farm B) and treated with sulfur powder (Chem_ADD), a biological enzymatic additive (Enz_ADD), and a physical additive (Phy_ADD), and compared with untreated controls. The experimental setup reproduced manure storage conditions at 20 °C. Gaseous emissions were monitored using a ventilated chamber system over different durations (16-46 days) depending on manure type, based on emission dynamics. NH_3 and N_2O concentrations were measured using an FTIR analyzer (ETG 9500), while NO, NO_2, and NO_x were quantified using a chemiluminescence analyzer (Teledyne, model T200).

Results showed that NH_3 emissions were reduced in treated manure compared with controls for both manure sources. For Farm A, reductions ranged from 42% to 54% and were statistically significant ($p < 0.05$), whereas for Farm B reductions were not statistically significant. Emissions of N_2O, NO, NO_2, and NO_x did not differ significantly among treatments for either manure source, as confirmed by both parametric (ANOVA) and non-parametric (Kruskal–Wallis) analyses.

These findings indicate that manure additives can reduce NH_3 emissions, although their effectiveness may depend on manure characteristics, while nitrogen oxides emissions remain unaffected. While promising, larger-scale or longer-term studies are needed to confirm their effectiveness in reducing nitrogen losses from livestock systems.

This work was carried out under the LIFE CLINMED-FARM project (LIFE20 CCM/ES/001751).

Parallel session 2

Wednesday · 10:45-12:15 · Inventories and Emission Factors

Establishment of methane conversion factors for different pig slurry management in buildings

Sandrine Espagnol ORCID iD, Annie Soulier, Nadine Guingand
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GEEP is a tool used by French pig farmers to assess their environmental performances including the carbon footprint. Methane is the main gas among GHG to be emitted on farm level and is modified by several practices (diet, technical performances, manure removal and biogas process). The methane conversion factors (MCF) Tier 2 of IPCC consider single dominant stage of manure management after excretion. The objective is to achieve greater precision by establishing specific MCF for buildings, depending on excretions and practices at this stage. The Excel-based model of IPCC (2019) which calculates annual MCF was adapted to a batch management in building with a daily time step. A daily hydrolysis rate constant (k) was used instead of a monthly k, using a k reference value for fresh pig slurry at 25°C from Dalby et al. (2023). The model was applied to estimate MCFs for different physiological stages and manure removal frequencies. For a 110-day fattening period on fully slatted floor, with 45 kg of VS excreted per pig and an average temperature of 24°C, the calculated MCF is 9% when slurry is removed only at the end of the fattening period. CH4 emissions obtained with the use of the estimated MCFs in GEEP were compared with average emissions factors from the ELFE database (Guingand, 2026), which compiles gaseous emissions measurements. This work enables GEEP to simulate CH4 emissions separately for buildings and storage (use of the initial model of IPCC) facilities and to consider specific practices for each.

Assessing Ammonia (NH_3) Emissions, Precursor Gas (SO_2, NO_x) Concentrations, and Source Contributions to Atmospheric $PM_{2.5}$ from a Commercial Manure Composting Facility

Sang-Ryong Lee ORCID iD
Dongguk University, Seoul, Republic of Korea

Increased ammonia (NH3) emissions from intensive agriculture negatively affect environmental and ecosystem health, contributing to formation of particulate matter (PM) and the potent greenhouse gas, N2O. Retarded generation of PM with a major constituent source of NH3 is a primary mechanism for evaluating the effects of agricultural contribution to PM. This study aimed to quantify NH3 emissions, examine the influence of environmental factors, and investigate the relationship between precursor gases (SO2, NOx, NH3) and PM2.5 at a modern manure composting facility in Paju, South Korea. Over 35 days, average internal concentrations of NH3, SO2, and NOx were significantly higher than external levels. NH3 concentrations reached 3.64 ± 0.06 mg m−3 at 3 m height and 2.43 ± 0.16 mg m−3 at ground level, while the total NH3 flux from the facility was 24.47 ± 1.39 NH3-N kg d−1. Internal PM2.5 concentrations (36.9 ± 2.6 µg m−3) were about 50% higher than external levels (23.7 ± 2 µg m−3), with a moderate correlation (r = 0.341) suggesting some contribution of external PM2.5 to internal levels. Despite large quantities of internal emissions, the facility's sealed design with a negative pressure ventilation system effectively minimized external emissions. These results suggest that while manure composting facilities are significant sources of NH3 and PM2.5, advanced systems like high-volume ventilation and scrubbing technologies can effectively reduce their impact on regional air pollution, contributing to better environmental management in agriculture.

Estimation of gaseous emissions from manure treatment facilities

Inge De Bo ORCID iD, Eveline Volcke ORCID iD
Ghent University, Gent, Belgium

Livestock manure is both a valuable nutrient source and a potential environmental burden, especially in regions with structural manure surpluses. To close nutrient loops and reduce reliance on mineral fertilizers, biological manure processing technologies are increasingly implemented. However, these treatment systems may emit ammonia (NH_3) and greenhouse gases (GHGs), while direct measurements are often impractical. Reliable estimation methods are therefore essential to assess environmental performance.

This study develops a process-scheme-based approach to estimate gaseous emissions from a typical biological manure treatment plant using pig slurry as feedstock. Literature-derived **conversion factors** and **emission factors** were compiled and harmonised to mass- and emission-balance formats suitable for inventory development. The methodology was applied to sequential unit operations, including raw manure storage, centrifugation, storage of liquid and solid fractions, biological treatment, biothermal drying, and acid air scrubbing.

The results highlight substantial variability and data gaps in reported emission factors, often stemming from inconsistent units and limited measurements for specific process units. Despite these uncertainties, clear emission patterns were identified: **storage and biothermal drying** represent major sources of **CH_4 and NH_3**, while **aerobic treatment steps** dominate **N_2O** formation. For a representative Flemish process configuration, **90% of the initial mass** remained within the system, whereas **7% of total nitrogen** was lost as gaseous emissions (NH_3, N_2O and NO_x).

This structured, process-scheme-based estimation framework supports the identification of effective mitigation strategies. Moreover, it highlights the need for harmonised emission factor reporting to reduce uncertainty in manure management assessments, based on sensitivity and scenario analysis.

A data-driven approach to new chemical odour emission factors

Emil Jakobsen
SEGES Innovation, Aarhus, Denmark

Current odour regulation in livestock production in Denmark relies on standard emission factors derived from legacy olfactometric measurements and simplified assumptions of odour as a single, stable entity. As chemical measurement techniques become standard and new housing systems emerge, more robust data structures are required to support future odour modelling and regulation.

The project "*New Odour Emission Factor*" develops a data-driven foundation for estimating odour emissions from chemical measurements, with data architecture as a core methodological focus. Existing odour-related datasets from pig and cattle housing systems collected since 2010 are consolidated, including PTR-MS–based concentration data and olfactometric measurements. These datasets originate from multiple projects and institutions and differ in sampling strategy, temporal resolution, and metadata availability.

To address this, a harmonised data architecture is developed, defining a common database schema with explicit handling of variables, units, temporal aggregation, and uncertainty. The architecture integrates detailed metadata on housing system, management practices, ventilation, measurement timing, and production stage, enabling transparent comparison across datasets and measurement types, including point and continuous measurements.

Building on this structured data foundation, statistical analyses are used to explore relationships between chemical composition and perceived odour, forming the basis for modelling a single aggregated odour value. The project demonstrates how robust data architecture is a prerequisite for translating complex chemical odour data into regulatory-relevant emission factors.

Temporal Variability of Methane Conversion Factors in Liquid Manure Storage and Implications for Future Refinements

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Methane emissions from liquid manure storage represent a significant source of agricultural greenhouse gases and are commonly quantified in national inventories using Methane Conversion Factors (MCF) according to IPCC Tier 2 guidelines. These default values are largely based on literature data, climatic classifications, and expert judgement, representing temporally averaged emission conditions for typical storage systems. However, farm-specific management practices, dynamic substrate processes, and seasonal variability are only partially reflected. Therefore, the objective of this study is to determine monthly and seasonally resolved MCFs for cattle liquid manure, to compare them with currently applied default factors, and to identify approaches for improving their representativeness.

Under farm-like, in vitro conditions, liquid manure storage was simulated, including continuous substrate feeding, periodic substrate removal, and realistic retention times. The maximum methane-producing potential (B0) was determined monthly to derive temporally resolved MCFs. Initial results reveal pronounced seasonal variations associated with changes in substrate composition, microbial activity, and temperature, thus exceeding the assumptions of constant Tier 2 default values.

Based on these findings, we propose that future MCFs should be derived using more process-based and temporally differentiated approaches. This includes the development of monthly or seasonal factors, the integration of real farm management practices, and the establishment of regional datasets with explicit uncertainty assessment. The results demonstrate that temporally explicit MCF approaches have strong potential to improve the accuracy of greenhouse gas inventories, support mitigation strategies, and optimize emission management in livestock production systems.

The emission factor paradox: N2O emissions from organic fertilizer exceed those from synthetic N fertilizers on Danish agricultural soils

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Nitrous oxide (N_2O) is a potent greenhouse gas and the most damaging ozone-depleting substance currently emitted, with agriculture as the dominant source. In Denmark, direct N_2O emissions from agricultural soils account for about 25% of agricultural GHG emissions, underscoring the need for accurate estimation. The Danish National Inventory Report applies the Tier 1 default emission factor (EF) of 1%, while a 2019 IPCC refinement proposes land-use-specific EFs of 1.6% for synthetic fertilizers and 0.6% for organic fertilizers.

From 2022 to 2024, we conducted 28 field trials across Denmark in spring barley and winter wheat to quantify N_2O emissions from synthetic and organic fertilizers. Cumulative emissions from synthetic fertilizers ranged from 0.12–1.05 kg N_2O-N ha^{-1} (spring barley) and 0.08–1.17 kg N_2O-N ha^{-1} (winter wheat). Organic fertilizers resulted in 0.95–1.41 kg N_2O-N ha^{-1} (spring barley) and 0.19–1.30 kg N_2O-N ha^{-1} (winter wheat). Across trials, emissions were consistently low. Mean EFs were 0.11–0.16% for synthetic fertilizers and 0.37–0.38% for organic fertilizers, contradicting both default and refined IPCC Tier 1 EFs.

In addition to growing-season emissions, supplementary trials revealed notable off-season N_2O peaks during key post-harvest events. Emission pulses occurred shortly after sowing oil radish as a cover crop, and in other cases later in autumn during crop termination. Although smaller than fertilizer-induced emissions, these off-season peaks contributed meaningfully to the annual N_2O budget.

Parallel session 3

Wednesday · 10:45-12:15 · Measurement Methods and Data Management

Field Exposure Effects on the Dynamic Response of Low-Cost NH_3 Sensors Used for Emission Measurements in Naturally Ventilated Barns

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Determining NH_3 emissions from naturally ventilated livestock barns is becoming increasingly important. Low-cost electrochemical sensors could be well suited to this purpose, given that conventional measurement approaches tend to be technically complex and costly. However, little is known about the effect of real barn exposure on the dynamic response of such sensors. This study investigates how low-cost NH_3 sensor deployment in naturally ventilated barns influences their response behaviour.

A total of 17 electrochemical NH_3 sensors from several 9–29 day field campaigns in naturally ventilated livestock barns were characterised in this study. For a subset of sensors, laboratory step-response measurements (0–10 ppm NH_3) were conducted before and after barn deployment to quantify changes in dynamic behaviour. Sensors with different cumulative exposure levels were also characterised in the laboratory. The experiments used a controlled gas mixing system and an FTIR spectrometer as reference. Typical NH_3 concentrations ranged from near-background levels up to approximately 5 ppm; temperature and relative humidity were recorded continuously.

The results revealed clear degradation of the dynamic response after barn exposure. While fresh sensors exhibited T_{50} response times of approximately 20–30 seconds, several sensors that had been exposed in the field showed response times of several minutes. Meanwhile, concentration measurements in the barn indicate that NH_3 levels can change within similar or shorter timeframes.

These findings suggest that response-time degradation may influence the representation of NH_3 concentration dynamics relevant for emission measurements. However, the magnitude of the resulting uncertainty in emission quantification still requires further investigation.

Applicability of the CO_2 balance method for ventilation rate estimation in a naturally ventilated buffalo barn

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Measuring gaseous emissions from naturally ventilated livestock buildings is a methodological challenge, mainly because emission estimates strongly depend on the accuracy of ventilation rate determination. Among the available approaches, the CO_2 balance method is one of the most widely used in research. It is also included in the international verification protocol - VERA protocol - for NVBs. However, its application to other livestock species remains uncertain, particularly when animal-related CO_2 production is derived from models developed for cattle.

This study evaluates and compares various methodologies to estimate the CO_2 production in dairy buffaloes and the resulting ventilation rates within naturally ventilated housing. The calculation framework adopted in the VERA protocol was used as a reference and compared with two more recent CO_2 production models. The aim was to assess the sensitivity of ventilation rate estimates to the selected CO_2 model and to discuss the implications of applying cattle-based parameterisations to buffalo housing systems.
Preliminary results show that the newer CO_2 models yield consistently higher ventilation rate estimates compared to the VERA approach, with differences of about 27-31%. These differences reflect the influence of assumed animal CO_2 production on the final ventilation rate and question the direct transferability of cattle-based models to buffaloes, whose physiology, body size and production characteristics differ from those of dairy cows.
The study highlights the need for species-specific parameterisation when applying the CO2 balance method in NVBs and provides a basis for improving emission measurement approaches in non-conventional livestock systems.

Reduction in gaseous emissions from livestock buildings: A carbon and water mass balance approach to enhance accuracy

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Quantifying emission reductions presents significant challenges due to numerous factors influencing repeatability, such as environmental conditions, measurement methodologies, animal behavior, zootechnical performance and the spatial and temporal variability of emission sources. Despite the use of expensive experimental equipment, comparison of field measurements retains substantial uncertainties. To ensure scientifically robust evaluation and verification of measured emission reductions, the associated uncertainty should be lower than the value of the expected reduction.

In the present study, we used the dataset named GESTCO2 derived from a study performed in an experimental farm in Brittany in 2017. We calculated the CO_2 and CH_4 emissions based on the carbon concentrations, we listed uncertainty sources affecting the precision of the result and quantified them when possible. Then, we computed the carbon deficit and its associated uncertainty, using carbon and water mass balances. The mass balance calculations consider traceable data based on experimental information (number of animals, bedding and manure mass, feed efficiency, heating consumption, etc.) and robust coefficients based on literature (dry matter of feeding and bedding, organic matter in manure, etc.) and chemical composition (carbon ratio in poultry and feeding, etc.). Employing values provided by the mass balances allowed us to improve the trueness of the ventilation rate, which proved to be the most significant contributor to uncertainty of emissions.

This methodology, easy to implement, demonstrates the potential of improving the accuracy of greenhouse gases and ammonia emissions by using the traceable information available on a particular livestock production and with the use of adjusted coefficients.

Evaluation of models for prediction of CO_2 production rates from dairy cows in practice.

Carsten Schep ORCID iD[1], Cécile Levrault ORCID iD[1], Nico Ogink ORCID iD[2]
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Estimates of gaseous emissions from naturally ventilated dairy houses commonly rely on animal CO_2 production models. As emission policies shift to implementation of on-farm estimates, the reliability of these models are becoming increasingly important. Currently, the models published by CIGR (2002) and Kjeldsen (2024) are known to quantify animal CO_2 production. CO_2 production from slurry has only been briefly described by Pedersen et al. (2008).

This study evaluated the performance of CO_2 production models under practical conditions. Two groups of 16 lactating Holstein–Friesian cows were housed in mechanically ventilated dairy barns at the Dairy Campus research facility. During three three-week measurement periods in 2024, CO_2 production from animals and their in-house stored slurry was measured under varying outdoor temperatures and slurry volumes. For evaluation of the Kjeldsen models, feed quantity and quality was determined during the last two periods.

Measured and predicted animal CO_2 production showed strong correlations. However, the CIGR model consistently underestimated production rates with about 20%, whereas the Kjeldsen models provided more accurate predictions, but still showed an underprediction of 8%. In contrast, slurry CO_2 production showed no correlation with measured values. Additional analyses identified slurry volume, temperature, and pH as potential key predictors of slurry CO_2 production.

These findings confirm earlier studies and indicate that emission estimates based on the CIGR model carry a substantial risk of underestimation. Accuracy in CO_2 production at barn level and thus emission estimates is expected to be increased by an improved model for slurry CO_2 production.

How Precise is the CO2-Balance Method for Livestock Emission Estimates?: Quantifying Analytical Uncertainty by a Round-Robin Campaign

Harsh Sahu ORCID iD[1,2], Thomas Amon[1,2], Tariq Mehmood[1], Manfred Trimborn[3], Lars Broer[4], Diana Nett[3], Hergen Haase[4], Aditya Rawat[1], David Janke[1]

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The evaluation of emission mitigation strategies for naturally ventilated dairy barns depends heavily on the precision of the measurement method. This study examines the analytical limits of the common indirect CO_2-balance approach. To evaluate the uncertainty, five independent laboratories measured emissions simultaneously with three Cavity Ring-Down Spectroscopes (CRDS) and four Fourier-Transform Infrared (FTIR) spectroscopes under field conditions. A week long measurements by individual laboratories collected approximately 1100 hourly observations of CO_2, CH_4, and NH_3 concentrations. Emissions were calculated according to the VERA protocol and CIGR 2002 guidelines.

The research evaluates how instrumental and methodological performance influence the calculation of ventilation rate (Q) and emissions of ammonia (e_{NH3}) and methane (e_{CH4}). Our findings indicate that both CRDS and FTIR recorded diurnal emission dynamics with no significant differences, though CRDS demonstrates higher inherent precision. A pivotal result is that instrumental bias can be eliminated by employing a single analyzer for the gradient between indoor and background air. The study established precision levels of:

Q: ± 7,2 % (95 % CI: 1004–1160 m3 h^{-1} LU^{-1}),

e_{CH4}: ± 3,1 % (95 % CI: 7,17–7,63 g h^{-1} LU^{-1}),

e_{NH3}: ± 5,6 % (95 % CI: 0,67–0,75 g h^{-1} LU^{-1}).

The methodology proves robust against minor hardware variations, such as the sampling system (tube dimensions) and filtering aids (material and pore sizes). By establishing these precision benchmarks, the study advocates harmonized sampling protocols and single-analyzer configurations. At the conference, we will present a detailed analysis of inter-laboratory and inter-instrument variations across the measured parameters.

Comparing gaseous emissions of naturally ventilated dairy barns determined with a direct and indirect emission measuring method

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ILVO, Merelbeke-Melle, Belgium

Cattle farming exerts substantial environmental pressure, for example through ammonia emissions and as a major source of atmospheric methane. Precise quantification of emissions from cattle barns is therefore crucial.

The emission rate of a barn is determined by multiplying concentration differences and airflow rates. However, the assessment of airflow rates remains particularly challenging in naturally ventilated livestock barns. Two approaches were used in this study: an indirect tracergas–based method and a direct method that utilizes ultrasonic anemometry to measure airflow rates through barn openings.

Both methods were applied simultaneously in four dairy barns across Flanders. NH_3, CH_4 and CO_2 concentrations were measured at the barn openings (two lateral openings at the SW and NE side of the barn and one ridge) and at a central location inside the barn using either a multigas Picarro analyzer (Picarro Inc., Santa Clara, CA, USA) or Axetris sensors (LGD F200A: ; Kägiswil, Switzerland) combined with smartGAS CO_2 sensors (FLOW EVO; smartGAS Mikrosensorik GmbH, Heilbronn, Germany). For the indirect method, indoor CO_2 concentrations were paired with the CIGR CO_2 production models to estimate barn airflow rates. For the direct method, airflow was quantified using the vertical anemometer profiles.

Data were collected for at least one year at a resolution of one emission value per hour (direct method) or per day (indirect method). Initial results indicate that the indirect method produced lower emission estimates with reduced temporal variability compared to the direct method, primarily due to differences in ventilation characterization and calculation approaches.

Parallel session 4

Wednesday · 16:00-17:00 · Modeling and Emission Processes

Slurry temperature in different types of storage tanks

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Slurry temperature is a major driver for methane emissions from slurry storage. To date, ambient temperature is used as a surrogate for slurry temperature to model emissions. However, ambient temperatures may deviate from slurry temperatures and, therefore, modeled methane emissions from slurry storage may be biased. We conducted continuous slurry temperature measurements in two storage tanks: an underground tank with a perforated cover located below an unroofed exercise yard (U_per) and a circular aboveground tank with a tent cover (Si_te). Moreover, we carried out manual monthly temperature measurements at five and three different locations respectively, distributed over these two tanks. Accordingly, we conducted manual monthly temperature measurements at 17 tanks located on 11 farms. From these manual measurements, data were obtained from the following number and types of tanks: 5 U_per, 5 U_sol (underground tank with a solid cover), 3 P_sol (underground pit with a solid cover), 3 Si_un (aboveground circular tank, uncovered), 1 Si_te. The tank volumes ranged from 60 to 1200 m^3 and mainly contained cattle slurry. Continuous and manual measurements showed slurry temperatures in the order winter<spring<fall<summer. Air temperatures were substantially lower in winter and fall, similar in spring and higher in summer than slurry temperatures for all types of tanks except for Si_te where slurry temperatures were always higher than ambient temperatures. The mean slurry temperatures did not differ between the different types of tanks except for Si_te with higher values. Conclusions of these results related to methane emission modeling will be discussed.

Interpretable Machine Learning for Estimating Ammonia Concentrations in Naturally Ventilated Dairy Barns

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Machine learning (ML) shows promise for estimating hourly indoor ammonia (NH_3) in naturally ventilated dairy barns (NVDBs) using routinely available farm and weather variables. However, operational credibility requires not only predictive accuracy but also an understanding of key drivers, reliance on proxies, and robustness to sensor-like perturbations. This study evaluated four tree-based ensemble models (Random Forest, HistGradientBoosting, XGBoost, and CatBoost) to estimate NH_3 concentrations using 5,225 hourly observations collected between April 2025 and January 2026 in a NVDB, with 18 predictors representing climate conditions, management practices, and herd production state. Results showed that CatBoost achieved the highest accuracy (R^2 = 0.836, RMSE = 0.131, MAE = 0.090) under random split evaluation, but performance dropped substantially under temporally structured validation, highlighting the influence of temporal autocorrelation and seasonality in barn air-quality data. Interpretability analysis (SHAP, permutation importance, drop-one feature ablation, and cumulative R^2) revealed distributed contributions from management factors (especially cleaning), production-state variables (milk yield, fat, and temperature proxies), and indoor climate, rather than reliance on a single predictor. Feature-group ablation showed the largest performance decline when weather and ventilation variables were removed ($\Delta R^2 \approx -0.14$), followed by production related variables (≈ -0.09). Moreover, perturbation experiments showed gradual performance degradation under structured noise and temperature shifts, indicating robustness to moderate measurement disturbances. Overall, the results highlight both the interpretability and limitations of ML approaches for estimating NH_3 dynamics in temporally autocorrelated livestock housing systems, emphasizing the need for time-aware validation and robustness analysis to support reliable ML-based emission monitoring applications.

Modelling CO_2 Production of Fast- and Slow-growing Broilers and Quantifying Litter Contribution

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Determination of the ventilation rate (**VR**) is essential to quantify gaseous emissions from broiler houses. When direct measurements are unavailable, the CO_2 mass balance method is a common alternative. In practice, the CIGR model (published in 2002) is widely used for the estimation of the CO_2 production. However, due to the genetic evolvements of modern broilers, it remains a question if the CIGR model needs to be updated. This study aimed to validate the CIGR model and explore other alternatives. Respiration chambers were used to quantify the CO_2 production and litter contribution for fast-growing broilers (**FGB**, housed for 42 days) and slow-growing broilers (**SGB**, housed for 56 days) for two production rounds. FGB had a total CO_2 production of 3.36 g h^{-1} $bird^{-1}$, with litter accounting for 9.0% (0.28 g h^{-1} $bird^{-1}$). SGB had a total CO_2 production of 3.02 g h^{-1} $bird^{-1}$, with litter contributing 5.8% (0.23 g h^{-1} $bird^{-1}$). Friability and wetness scores of the litter were negatively correlated with litter CO_2 production for SGB. The CIGR model overestimated total CO_2 production by 6.2% for FGB and 19.9% for SGB, with Normalised Root Mean Squared Error (**NRMSE**) being 21.2% and 31.7%, respectively. To improve the accuracy of VR estimations, statistical Morgan–Mercer–Flodin (**MMF**) models for FGB and SGB, and physiological MMF models for both breeds were developed for total and bird CO_2 production. All MMF models had R^2 higher than 0.99, NRMSE lower than 5.3%, with random error accounting for more than 97.7% of the total error.

From manure to tailored fertilizers: A generic model to predict gaseous emissions during composting

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Composting is a cheap and flexible treatment to stabilize organic matter such as animal manure. Composting processes happen naturally during manure storage. These processes generate gaseous emissions. Predicting emissions for composting trajectories across highly diverse manure-based feedstocks using input information available on farm scale is knowingly challenging.

MEGASMOC is a model mixing empirical and process-based approaches. It simulates temperature dynamics, water evaporation, organic matter stabilization, and gaseous emissions (CO_2, CH_4, NH_3, N_2O, N_2) during naturally aerated windrow composting, using only basic manure characteristics and weather data. The model showed satisfactory performance in temperate regions but limitations with a particular substrate used as poultry litter in a tropical region. To enhance genericity, we propose to use a categorical approach to account for the diversity of composting materials when choosing the initial set of parameters. We consider several levels of precision depending on the information available for calibration.

Once developed and validated, the calibrated composting model will also allow further simulations with the soil-crop-atmosphere model STICS, therefore predicting emissions in the context of circular agriculture, including animal farming. This framework will ultimately support the inverse design of composting practices to produce tailored organic fertilizers with a prediction uncertainty of emissions and options of verification with data available on farm scale associated with low-cost gaseous measurements. We expect that these tools will be used to provide guidance in using available actionable practices (raw materials, duration, turning, etc.) to maximize agronomic benefits while decreasing gaseous emissions.

Parallel session 5

Wednesday · 16:00-17:00 · Manure and Fertilizer Management

Emission-optimized slurry application techniques and strategies in spring barley

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Slurry application strategy and techniques highly affect the risk of ammonia volatilization and nitrous oxide emission. In Denmark, approximately 40% of livestock manure is applied to spring crops before sowing where common practice is injecting slurry followed by ploughing.

The main objectives of the study were to investigate the effects of different slurry application techniques (injection with a traditional tine or a goosefoot tine), application strategies (injection before or after ploughing) and the addition of additives (Vizura or Eminex) on nitrous oxide emissions and the mineral fertilizer equivalent (MFE) of digestates and cattle slurry in spring barley.

Traditional injection using a narrow tine in 10 cm soil depth was compared to broad band injection using a goosefoot tine before and after ploughing. The injection techniques were examined with two slurry types (digestates and cattle slurry) with a low and a high dry matter content (results not shown here). Additionally, the effects of adding the additives Vizura or Eminex to digestants were explored.

Field experiments were conducted in 2024 and 2025, and the nitrous oxide emission was monitored after slurry application and sowing using static chambers during 20 campaigns.

Results from 2025 showed a tendency to lower emissions of nitrous oxide using a goosefoot tine compared to the traditional tine (not significant). There were no clear effect of ploughing before injection on nitrous oxide emissions compared to common practice after injection. Adding Vizura or Eminex to digestates before field application had a positive effect on nitrous oxide emission (some results significant).

Mitigation of Ammonia and Greenhouse Gas Emissions from Stored Cattle Slurry Using Floating Covers, Aeration, and Chemical Additive

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Effective livestock slurry management strategies are required to reduce ammonia (NH_3) and greenhouse gas (GHG) emissions from livestock production to support air-quality and net-zero targets. This study evaluated the effectiveness of several mitigation approaches for reducing gaseous emissions during cattle slurry storage. Treatments included: floating covers of biochar (2 cm) and light expanded clay aggregate (LECA, 10 cm), high-frequency aeration (HFA; slurry aerated for 3 min from the bottom of tanks every 6 h), low-frequency aeration (LFA; slurry aerated for 3 min every 12 h), and a hydrogen peroxide-based additive (GasAbate). Untreated cattle slurry was used as a control. Eighteen underground storage tanks were filled with 700 L of slurry and gas emissions were continuously measured using dynamic chambers over a 134-day storage period.

LECA achieved the greatest mitigation, reducing cumulative NH_3 emissions by 83%, while biochar reduced emissions by 40%. However, both treatments increased N_2O emissions by 57% and 215%, respectively. The GasAbate additive lowered NH_3 emissions by 18% and CH_4 emissions by 48% but resulted a 21% increase in N_2O emissions. The HFA reduced NH_3 and CH_4 emissions by 17% and 18%, respectively, while increased N_2O emissions by 14%. The LFA reduced NH_3 and CH_4 emissions by 8% and 9%, respectively, but increased N_2O emissions by 22%.

Overall, the results demonstrate that several treatments can effectively mitigate NH_3 and CH_4 emissions during slurry storage, although trade-offs with increased N_2O emissions must be considered when implementing these technologies at farm scale.

Simultaneous measurements of greenhouse gases and ammonia from cattle excreta under field conditions

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Cattle graze for up to six months annually in Denmark. Excess nitrogen and carbon are returned to the soil through excreta, becoming a source of greenhouse gases and ammonia emissions. This study simultaneously quantified ammonia, nitrous oxide, and methane losses from faeces, urine, and a mixture of both over six weeks. Emissions were measured using static chambers for methane and nitrous oxide and dynamic chambers for ammonia. Treatments included 1.5 kg of faeces and 0.75 L of urine separately and combined, each with five replicates, alongside background soil measurements. Ammonia concentrations were continuously monitored with a cavity ring-down spectroscopy analyser, while methane and nitrous oxide emissions were determined by measuring concentration increases during three to ten minutes in sealed chambers using a mid-infrared laser absorption spectroscopy analyser, with one or two measurements per day. Preliminary results showed that faeces were the sole source of methane with 65% of emissions occurring in the first day. Urine dominated nitrous oxide and ammonia emissions contributing 0.48 and 1.7 g m^2, respectively. Faeces contributed smaller amounts with 0.066 and 0.22 g m^2, respectively. Nitrous oxide emissions persisted for four weeks and were clearly influenced by rainfall. Ammonia was rapidly released from urine, whereas faeces provided a slower but more sustained source. No synergistic effects were observed when faeces and urine were combined. In conclusion, faeces were a rapid and short-lived source of methane, rainfall triggered nitrous oxide emissions, and ammonia was quickly release from urine and gradually from faeces.

Quantifying ammonia emissions from soil surfaces treated with organic fertilizers under controlled field-like conditions

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Ammonia (NH_3) volatilization from soil-applied organic fertilizers is a major pathway of nitrogen loss and environmental pollution. Livestock slurry used for biogas production generates digestate which can be applied to soils; however, this can cause substantial NH_3 losses that are challenging to quantify under variable field conditions, necessitating controlled systems to isolate mechanisms and compare treatments. This study presents a laboratory setup for measuring NH_3 volatilization from lab- and field-packed soils treated with organic fertilizers. A system of 20 dynamic flux chambers combined with cavity ring-down spectroscopy was developed and evaluated through multiple trials. Emissions were measured from unseparated and separated digestate fractions (semi-solid, solid, and liquid) applied to soil surfaces or containers without soil, and from acidified slurries applied to lab- and field-packed soils. A standardized ammonium bicarbonate-starch solution was used to verify system performance. Results showed no significant differences in NH_3 emissions among digestate fractions without soil, while soil application reduced emissions, highlighting the dominant role of soil-fertilizer interactions and revealing separation effects; differences among fractions may be explained by variations in total solids and rheological properties. For acidified slurries, field-packed soils showed higher evaporation rates; however, except for unacidified slurries, emissions did not differ between lab- and field-packed soils. Overall, the system enables assessment of relative trends in NH_3 emissions under controlled, field-simulating conditions and comparison of relative treatment effects; however, variability, especially for high-total-solids fractions, remains difficult to control due to sample heterogeneity, small application amounts, and inconsistent surface area.

Parallel session 6

Thursday · 11:00-12:30 · Mitigation Strategies and Technologies

Effects of under-slat slurry removal systems on air quality in pig production

Hajer Ben Alaya[1], Erika Yukari-Nakanishi[2], Marie-Aude Ricard[3], Jean-Gabriel Turgeon[3], Vicky Clouet-Côté[3], Valérie Létourneau[1], Mathilde Badin[1], Sébastien Turcotte[3], Caroline Duchaine[1], Sébastien Fournel[1], Stéphane Godbout ORCID iD[2]
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Automation and robotization in livestock production currently fulfill a wide range of functions, including milking, animal health monitoring, overall facility management, manure scraping, and barn cleaning. However, studies specifically addressing the impact of cleaning robots on gas emissions remain limited despite their potential to reduce methane emissions. To address this knowledge gap, this study aimed to evaluate the impact of automated and robotic slurry removal systems on gas and particulate emissions in pig production. An 8-week experiment was conducted in a swine research facility located in Quebec, Canada. Eight identical and independent chambers, each housing 10 finishing pigs, were used to replicate conditions representative of commercial swine production systems. Each chamber was instrumented to continuously monitor ambient conditions (temperature, relative humidity, and airflow rate). Four systems were evaluated: (i) control (slurry stored in the pit); (ii) conventional scraper (operated twice daily) with weekly emptying; (iii) intensive scraper (operated every 2 h) with daily emptying; and (iv) a cleaning robot (operated every 2 h) with continuous removal. In the scraper-based systems, slurry was collected in a reservoir located in the pit prior to emptying. Gas concentrations (NH_3, CH_4, N_2O, and CO_2) were continuously measured in each chamber using a photoacoustic gas analyzer. Particulate matter concentrations (PM_{10}, $PM_{2.5}$, and PM_1) were sampled weekly using a DustTrak™ DRX Aerosol Monitor. Slurry volume was assessed, and the slurry was analyzed for physicochemical properties. Data analysis is currently underway.

Simulation model for integrated floor cleaning strategy to reduce ammonia emissions in dairy houses

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Process-based ammonia emission models are widely used to evaluate mitigation techniques in dairy housing. However, the urease activity (UA) has typically been represented as a fixed and time-invariant parameter, without distinguishing between faeces and floor enzymatic activities, which limits the predictive reliability. To address this issue, a three-phase study was conducted to improve model representation of UA dynamics and evaluate integrated floor cleaning strategies. First, laboratory experiments were conducted to evaluate the effects of temperature (10, 20, and 30 °C) and urea solution–to–faeces ratios (20:1, 10:1, 5:1, and 2:1) on UA and pH in simulated urine puddles during 24 h. Based on the results, faecal UA dynamics were refined in the model. Second, a floor UA was introduced into the model, and the model was validated using barn measurements. Model performance improved substantially, with the coefficient of determination increasing from 0.30 to 0.75 (R^2) after optimization. Third, the improved model was applied to simulate integrated floor cleaning strategies with cost analysis, followed by barn validation. For a grooved solid floor with a manure scraper, simulations with the refined model showed optimal results when removing faeces four times daily and spraying a disinfectant, such as electrolyzed oxidizing water, once a day. Simulated ammonia reductions were 53% and 22% compared to scraping four and twelve times daily without disinfecting, respectively. Ongoing field validation confirmed these findings, with complete data to be presented at the conference. Overall, this study provides robust quantitative support for achieving source-based ammonia reductions through integrated cleaning.

Assessment of impacts of a vacuum robot on NH_3, CH_4, N_2O and odours emitted in pig finishing units

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The study was conducted in two finishing rooms of a commercial pig-production facility, both of identical and conventional design, each of which housed 100 pigs with a body weight of 25-120kg. In the control room, manure was stored in the pit beneath the fully slatted floor throughout the entire fattening period. The second room was equipped with a vacuum robot that removed manure six times daily between 0:00-20:00. Across two production batches under contrasted climatic conditions (winter 2024 and summer 2025), pig weight and feed intake were recorded to calculate pig performance. Slurry volume was quantified per room, and samples were collected for analysis. Ammonia, nitrous oxide and methane concentration were measured by photoacoustic analyser during monitoring campaigns that lasted 4-6 days, conducted biweekly throughout both fattening periods. The performance observed in the control room was consistent with French reference values for both pig performance (ADG: 927 g.d-1 - FCR: 2.5) and emission levels (respectively 2.8, 0.1 and 5 kg/place/year for ammonia, nitrous oxide and methane). No significant effect was observed on zootechnical performance. However, ammonia and methane emissions in the "robot" room were 28 and 37% lower, respectively, than those in the control room. Odour emissions, averaged across the two batches, decreased by 52%. In the context of strengthened ammonia emission reduction requirements under the revised Industrial Emission Directive (IED 2.0), the vacuum robot represents a technically adaptable mitigation strategy that can be implemented in a wide range of existing housing configurations.

Analysing the effect of early weaning and feed additive supplementation on enteric methane emissions in newborn beef calves

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The early life programming could be a promising strategy to mitigate enteric methane emissions from ruminants by altering the rumen characteristics in the early stage. The present study analysed the effects of early weaning (EW) alone and EW combined with a novel feed additive (EW+FA), which is a combination of medium-chain fatty acids, yeast extract, and fruits and herbs, on enteric CH_4 emissions in beef calves. A total of 57 beef calves of British Blue and Aberdeen Angus of 5.5 weeks old were allocated into three treatments: control (CON), EW, and EW+FA, and CH_4 emission was estimated daily by using a GreenFeed system from November 2024 to March 2025. Body weight (BW) was recorded biweekly to analyse growth performance. From the results, EW calves emitted significantly less CH_4 than both CON and EW+FA (−18 g d^{-1}, p= 0.004 vs C; −17 g d^{-1} vs EW+FA, p= 0.006). However, EW+FA did not show any difference compared to the control group (p = 0.91). Overall, there were not significant differences in CH_4 per kg BW and CH_4 per metabolic weight among treatments. Although EW reduced enteric CH_4 emissions during the first phase of the study, the effect did not persist from the second phase. The FA does not show any effect on CH_4 compared to the CON calves. These findings suggest that EW may temporarily influence CH_4 emissions during the early stage of calves, but the effect was not persistent.

Mitigation effects of tannin-rich diets on ammonia (NH_3) and methane (CH_4) emissions: measurements at housing level under naturally ventilated conditions

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As dairy farming contributes considerably to NH_3 and CH_4 emissions, mitigation measures are required. Feeding strategies start right at the beginning of the chain. The tanniferous legume sainfoin and *Acacia mearnsii*'s bark extract have shown potential to reduce urinary N excretion and enteric CH_4 at the individual animal level (Lazzari et al. 2023a, 2023b). To evaluate this under practical conditions in a case-control approach, in summer 2020 emission measurements were carried out in a naturally ventilated dairy housing consisting of two compartments (each for 20 lactating cows) using an external tracer-ratio method NH_3 and CH_4 concentrations were determined by CRDS, tracer gases by GC-ECD. The study used a two-period crossover design. One herd received a sequence of experimental diets (grass silage, sainfoin silage, sainfoin silage + acacia extract, grass silage) for at least four days each, while the other herd served as control (based on grass silage only). The treatments were then switched between the two herds. Diets with sainfoin silage and sainfoin silage + acacia extract reduced NH_3 emissions by 16–33% and 30–38%, respectively, with greater reductions at higher temperatures. CH_4 emissions were reduced with sainfoin (10%) and sainfoin+acacia (20%), less affected by temperature. After switching back to the grass silage diet, NH_3 emissions remained lower by between 7% and 13%, whereas CH_4 emissions returned to the baseline. Feeding sainfoin silage alone or in combination with acacia extract was effective in reducing both NH_3 and CH_4 emissions under practical housing conditions but also resulted in some performance losses.

Dietary characteristics affect enteric methane and odour formation in pigs: insights from colon digesta incubations and analysis of exhaled air

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Reducing gaseous emissions from pig production is important for mitigating environmental impact and improving barn-air quality. Fermentation processes in the large intestine contribute to emissions through microbial degradation of endogenous and unabsorbed dietary components, leading to the formation of gases such as CH_4 and odorous compounds. This study investigated how dietary protein, sulphur and fibre influence intestinal fermentation and associated gas production in pigs.

Thirty-six pigs were distributed over six dietary treatments in a 3x2 factorial design consisting of three protein-sulphur combinations (highP-highS, highP-lowS, lowP-lowS), each with and without fermentable (inulin) and insoluble fibre (oat hulls). Methane concentrations in exhaled air were measured in sedated pigs using FTIR spectroscopy. After euthanasia, proximal colon digesta samples were collected and incubated for 24h to quantify CH_4 and total gas production. After 24h, headspace samples were analysed for odorous compounds composition using GC-MS and GC-SCD.

Both total gas and CH_4 production (mL/g OM) were lower for high-fibre compared with low-fibre diets. Methane production was lower for highP-highS compared with lowP-lowS diets. Exhaled air CH_4 concentration was positively correlated with total CH_4 production during colon digesta incubation (r=0.693). Differences in odour-related compounds between treatments were relatively small.

These findings show that dietary fibre can influence colon fermentation processes linked to enteric CH_4 and odour formation, highlighting the potential of dietary strategies to mitigate emissions in pig production. The relationship between CH_4 in exhaled air and colon fermentation indicates that breath analysis may provide a promising tool to investigate enteric CH_4 formation in pigs.

Parallel session 7

Thursday · 11:00-12:30 · Livestock Facilities and Enteric Emission

Impacts of Starch, Fat, Nitrate, and 3-NOP Diet Supplementation on Methane Potential of Dairy Manure

Cristiane Romio, Henrik Møller
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Manipulating dairy cow diets has been widely explored to reduce methane emissions from enteric fermentation (EF). Increasing starch-rich forages as opposed to those rich in fibre, supplement of additives, such as nitrate (NO_3^-), 3-nitrooxypropanol (3-NOP), and fat are expected to impair EF due to the emergence of hydrogen sinks, inhibition of the methyl-coenzyme M reductase, or toxicity of long chain fatty acids. Reducing methane emissions from EF can result in higher emissions potential in manure, which can only be advantageous if methane is recovered as biogas during anaerobic digestion (AD), introducing a potential additional benefit of feed manipulation. As inhibitory effects may be extended, assessing dietary effects on the AD process is essential.

This study evaluated the impacts of various diets and additives on the ultimate methane yields (B_0) of the resulting manure. Manure originated from five experiments, three with 4-16 cows and two with 65-400 cows per group, with each group receiving each diet for three weeks. The diets included varying proportions of starch- and fibre-rich silages combined or not with fat supplementation in different proportions of unsaturated and saturated fats and 3-NOP and NO_3^- addition combined or not with fat supplementation.

Thermophilic batch AD showed that: a) starch-rich diets resulted in manure with higher B_0 than fibre-rich diets (confirmed in a continuous AD test), b) fat supplementation could increase B_0, where saturated fats proved to be the most beneficial, c) NO_3^- and 3-NOP did not alter B_0. Overall, the tested diets enhanced or did not impair AD performance.

Methane emission from lactating sow and growing-finishing pig housing with daily slurry removal

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Methane emission from animal housing can be reduced through practices that limit development of methanogenic communities. Farm management decisions, inventory reporting, and environmental policy need quantitative estimates of emission from low-emission slurry management systems. This contribution is focused on methane emission from pig houses.

Methane emission was measured from eight mechanically ventilated pig houses in Jutland, Denmark. Four houses had lactating sows and four had growing-finishing pigs. The sows and pigs were housed in pens with fully slatted floor. Slurry was removed daily by scraping of under-floor slurry channels to a collection pit at the end of the scraper channel and from there to a pump well outside.

All farms had forced mechanical ventilation. Methane concentration was measured in ventilation exhaust using cavity ring-down spectroscopy (CRDS, Picarro G2509), and anemometers were used for continuous air flow measurement. Emission from each farm was measured six times over a year. Each measuring period lasted for approx. one week.

Enteric methane emission was estimated from feed uptake using IPCC methodology and subtracted from measured emission to estimate the slurry contribution. The ABM model was applied for evaluation and to explore underlying mechanisms controlling emission. Additionally, the model was applied to outdoor storages with low-emission and conventional slurry systems to estimate farm-level emission.

This project is currently ongoing. Preliminary results show very low methane emission from one of the eight farms. Full results will be presented at the conference.

Optimizing Sensor Placement for Ventilation-Driven Emission Prediction in Naturally Ventilated Livestock Buildings

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Optimizing sensor placement in naturally ventilated livestock buildings (NVBs) is critical for reliable emission estimation under wind-driven and spatially heterogeneous airflow conditions. Conventional monitoring strategies remain largely heuristic and often fail to capture emission-relevant transport dynamics. This study presents a CFD-informed Sensor Placement Optimization (CISPO) framework that integrates experimentally validated CFD simulations, entropy-based informativeness analysis, and surrogate modelling to identify representative sensor locations for predicting ventilation-driven emission indicators. A NVB model was simulated for multiple wind directions and validated using boundary-layer wind tunnel measurements. The validated CFD fields served as ground-truth references for a large parametric dataset. Shannon entropy applied to discretized cross-sectional planes quantified variability in air velocity and turbulence kinetic energy, identifying direction-sensitive regions near openings and recirculation zones. Correlation analysis between grid-level velocity metrics and volume-averaged local mean age of air was used as a proxy for pollutant residence time, which identified 35 sentinel grids with high predictive relevance. A log–log surrogate model constructed from these sentinel grids achieved strong predictive performance with mean velocity emerging as the dominant predictor. Monte Carlo analyses showed that reducing the sensor set to 15–20 sentinel grids preserved approximately 95% of the predictive accuracy of the full 35-grid configuration. This indicates that substantial redundancy exists in dense measurement networks. The proposed CISPO framework provides a scalable and physically consistent methodology for emission-oriented monitoring design in NVBs, enabling robust estimation of ventilation-driven emission dynamics under varying wind conditions.

Effects of feeding triglycerides rich in C16:0 or C18:0 on enteric methane emissions and production in dairy cows

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In Denmark, dietary fat is considered to have the same methane reducing effect regardless of fat source and fatty acid (FA) composition, with a fixed reduction of 4% in methane yield (CH_4/kg dry matter (DM)) pr 10 g/kg DM added dietary FA.

This study investigated the effects of feeding triglycerides rich in C16:0 or C18:0 at different inclusion levels on enteric methane emissions, milk production, and metabolic indicators in 24 primiparous and 24 multiparous lactating Danish Holstein cows. Six dietary treatments were evaluated: control diet and low (L), medium (M), and high (H) inclusion levels of fat (1.43, 2.87, and 4.30% of DM) supplied as triglycerides rich in C18:0 (LS, MS, HS) or C16:0 (MP, HP). Feed intake increased linearly with increasing fat inclusion for both treatments ($p = 0.02$) excepted for primiparous on C16:0-based diets ($p=0.08$). Energy corrected milk (ECM) yield was highest for cows fed C16:0-based diets ($p < 0.001$). Daliy methane production (CH_4/day) was not significantly affected by dietary treatments ($p = 0.08$). Methane intensity (CH_4/ECM) was lowest for cows fed C16:0-based diets ($p < 0.001$), because of the increased ECM yield. Body weight change and plasma concentrations of β-hydroxybutyrate were not affected by treatments ($p = 0.2$ and $p = 0.34$, respectively). In multiparous cows, plasma concentrations of non-esterified fatty acids were highest for cows fed HP, likely reflecting the high dietary fat intake rather than a negative energy balance. Overall, triglycerides rich in C16:0 increased milk production. Saturated triglycerides showed limited potential to reduce methane emissions.

Farm-scale ammonia emissions from cattle housing and slurry storage in Switzerland

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Animal housings and slurry storages constitute half of ammonia emissions from livestock in Switzerland. Long-term emission measurements across all seasons are needed to appropriately capture factors such as meteorology, farm design, and management activities that contribute to considerable emissions variability. Measurements using methods that disrupt daily operations cannot be maintained for longer periods. The benefit of the inverse dispersion method (IDM) allows long-term monitoring of farm-scale emissions under representative conditions without affecting daily activities. Here we present initial results from ammonia emission measurements from a cattle housing with an open slurry storage tank using IDM in Switzerland over several seasons.

Ammonia concentrations were measured using miniDOAS instruments placed up- and downwind of a dairy farm to encompass all of the sources under predominant wind directions. Since the instruments need to be placed at a distance from the sources, the resulting depositional loss must be considered. Preliminary results show expected impacts of wind speed and temperature across seasons, as well as management activities on emission variability. The estimated emission corrections for short-range deposition indicate the likely overall impact size.

Methane and ammonia emissions from two types of floor and manure systems of naturally ventilated dairy barns in Denmark

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Dairy farming is a significant source of methane (CH_4) and ammonia (NH_3) emissions. Naturally ventilated dairy barns pose unique measurement challenges due to spatial gas distribution and the inability to directly measure ventilation rates, resulting in higher uncertainty compared to mechanically ventilated systems. This study investigates CH_4 and NH_3 emissions from naturally ventilated Danish dairy cubicle barns housing 200–300 cattle, featuring (i) slatted floors above continuous slurry channels, where slurry is frequently circulated by pumping or (ii) drained solid floors with daily manure removal and limited slurry storage capacity. Emissions were measured in four barns of each type, with six measurement campaigns per barn over one year, each lasting at least 72 hours. The tracer gas ratio method was employed, using estimated carbon dioxide production from animals and manure as a natural tracer gas. Gas concentrations were measured using Cavity Ring-Down Spectroscopy (Picarro G2509), with sampling lines positioned centrally along the barn length at approximately 4 m above ground. Preliminary results show that CH_4 emission are approximately 5% and NH_3 emission about 20% higher per livestock unit (LU) in barns with stirred slurry channels compared to those with drained solid floors. This difference is attributed to longer slurry storage and larger soiled surfaces in stirred systems, whereas manure is removed daily from drained solid floors to external storage. At the conference the final project results will be presented.

Parallel session 8

Thursday · 11:00-12:30 · Measurement Methods and Data Management

Field evaluation of path-integrated laser system for CH_4 and NH_3 emission quantification from livestock manure storage

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Livestock manure is a major source of anthropogenic methane (CH_4) and ammonia (NH_3) emissions, contributing significantly to climate change, air pollution and eutrophication. Yet, these emissions remain among the most uncertain components of national reporting inventories due to the limited facility-scale measurements. This gap constrains both emission estimates and mitigation strategies, highlighting the need for accurate, field-deployable measurement techniques.

Here, we present an open-path multi-gas sensor based on near-infrared tunable diode laser absorption spectroscopy, enabling simultaneous detection of CH_4, CO_2 and C_2H_2 alongside a novel open-path NH_3 analyser. Sensor performance was evaluated through controlled gas release experiments, where CH_4 and NH_3 emissions were quantified relative to a co-released tracer gas (C_2H_2) with known release rate. These experiments were conducted under varying source distances and emission magnitudes to validate accuracy and optimize measurement configurations.

The system was subsequently deployed at a cattle manure storage tank in Denmark. Tracer gas (C_2H_2) was released from the tank while simultaneous open-path laser measurements and the well-established tracer dispersion method (TDM) were performed.

Preliminary controlled-release results show that the open-path sensors accurately quantified CH_4 emissions (101% of release rates), while NH_3 emissions were recovered at approximately 79% of the release rates. Field measurements at the manure tank demonstrated good agreement between the open-path system and TDM for CH_4 emissions, confirming its robustness under real conditions. NH_3 emissions were below detection limits for both methods. These results highlight the potential of path-integrated laser sensing as a reliable tool for continuous monitoring of emissions from agricultural sources.

Satellite-Based Monitoring of Aerosol from Intensive Livestock Systems Using High-Resolution MAIAC AOD Retrievals

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Intensive livestock production is a significant source of atmospheric aerosols, emitting primary biogenic dust and secondary inorganic precursors that contribute to regional PM2.5. These systems act as emission hotspots for NH_3 and NO_x, enhancing secondary particle formation by up to 40-fold. Quantifying emissions at the facility scale remains challenging due to limited coverage of ground-based monitoring networks.

This study aims to develop an empirical modeling framework to investigate spatial patterns of aerosol loading associated with intensive livestock production in central Italy, using MAIAC-derived Aerosol Optical Depth (AOD) at 1 km resolution.

The methodology first considered a regional area where MAIAC observations were available and then focused on a subset including intensive livestock clusters, to evaluate localized aerosol loading and dust-related aerosol contribution. To further refine emission process characterization, the Ångström Exponent (AE) was employed to infer particle size distributions. A statistical analysis of local AE values was performed to differentiate emission sources. Where distinct patterns emerged, specific AE ranges were identified to evaluate the contribution of fine-mode secondary aerosols linked to livestock-derived chemical transformations and coarse-mode mechanical dust. These satellite-derived observations were subsequently integrated with in-situ Regional Environmental Protection Agency (ARPA) measurements to link column-integrated aerosol properties with ground-level particulate concentrations, providing a clearer understanding of local aerosol sources.

This framework provides a scalable tool to monitor spatial patterns of aerosol loading in broad areas with intensive livestock production and to identify surrounding areas potentially influenced by livestock-related emissions, where ARPA stations are absent, supporting environmental monitoring and mitigation planning.

Intercomparison of two open-path NH3 analyzers: Comparing measurements from the Airyx OPC-UV3-DL-301 with the Swiss miniDOAS instrument

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Ammonia (NH3) emissions from livestock and fertilized soils are critical for assessing air quality and nitrogen budgets. Open-path differential optical absorption spectroscopy (DOAS) combined with gas dispersion modeling enables non-invasive quantification of NH3 emissions. This study intercompares two open-path NH3 analyzers: the miniDOAS (Sintermann et al., 2014) and the Airyx OPC-UV3-DL-301 (Airyx GmbH). Both employ deuterium lamps. Whereas the miniDOAS records spectra at 190-230 nm, uses offline DOAS processing, and reports concentrations as enhancements above a user-defined reference spectrum, the Airyx covers a range of 190-310 nm, performs on-device processing, and provides absolute concentrations without requiring a user-defined reference.

Four intercomparison campaigns were conducted over approximately two months using single path lengths of 45 m, with concentrations derived from 1-minute averaged spectra. Campaign 1 captured variable NH3 from nearby farms; Campaign 2 monitored emissions downwind of a small slurry-spread area under warm, windy conditions; Campaign 3 was positioned within a larger slurry-spread field during very hot, calm conditions; and Campaign 4 rearranged the Airyx to a 90 m path with two serial miniDOAS units (~45 m each) in parallel during non-spreading background conditions.

In general, results demonstrated very good agreement between the two systems, with all dynamics in measured concentrations comparing
excellently.

Sintermann, et al.: A miniDOAS instrument optimised for ammonia field measurements, Atmos. Meas. Tech., 9, 2016

Can high-frequency monitoring identify emission dynamics that are overlooked by conventional sampling strategies?

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Ammonia (NH_3) emissions from naturally ventilated dairy housing are commonly quantified using the indirect CO_2 balance method combined with NH_3 concentration monitoring. Measurement campaigns typically involve a limited number of sampling locations and intermittent scheduling of monitoring periods, reflecting the cost and labour demands of traditional instrumentation. Recent advances in low-cost gas sensors and IoT communication networks enable continuous high-frequency monitoring at multiple locations, potentially improving the representativeness of emission estimates.

A naturally ventilated dairy barn housing 80 *Holstein* cows was monitored from January to December 2025. Ammonia and CO_2 concentrations, temperature and relative humidity were monitored every 10 minutes using the NEIKER-kABE IoT monitoring system. Ten sampling points were established, 6 in the central barn line and 4 outside. A meteorological station was also installed outside the building. Ammonia emissions were calculated from NH_3 concentration differences between inside and outside the building, the CO_2 balance method and wind direction. To evaluate different temporal sampling strategies, the 10-minute dataset was resampled to simulate hourly, daily, weekly, monthly and quarterly sampling frequencies.

Mean NH_3 emission was 0.91 g h^{-1} LU^{-1}, and high-frequency monitoring captured short-term fluctuations associated with management and environmental dynamics not detected at lower frequencies. Average emissions estimated from daily sampling remained comparable to those from the 10-minute reference dataset.

These results demonstrated the value of high-frequency monitoring systems for characterising emission dynamics and supporting the early detection of emission peaks, while conventional approaches provided reliable estimation of mean emission values.

Quantifying Nitrogen Losses in Fast- and Slow-growing Broiler Production Systems

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Broiler production systems in northwest Europe are increasingly shifting from fast-growing broilers (**FGB**) to slow-growing broilers (**SGB**) to improve animal welfare, which may influence gaseous nitrogen (**N**) emissions. For broilers, the N losses have rarely been comprehensively quantified, and their partitioning remains uncertain. This highlights the need to reassess N losses. This study aimed to quantify N balance (inputs minus outputs) and partition N losses (ammonia NH_3, nitric oxide NO, nitrogen dioxide NO_2, nitrous oxide N_2O) for FGB (housed for 42 days) and SGB (housed for 56 days) over two production rounds in respiration chambers. The quantified N inputs included feed and bedding material, while outputs included retention in birds, accumulation in litter, and gaseous emissions. For FGB, the N balance was - 0.5% ± 1.8% (mean ± SEM). Of the total N output, 67.3% ± 0.8% was retained in the birds, 27.4% ± 0.8% accumulated in the litter, and 5.3% ± 0.6% was lost through gaseous emissions. NH_3 accounted for 97.0% ± 0.5% of N losses, while NO and NO_2 contributed 1.2% ± 0.2%, and N_2O 1.8% ± 0.4%. For SGB, the N balance was 3.9% ± 0.6%. N retention in birds accounted for 63.4% ± 0.4% of the output, 27.9% ± 0.7% accumulated in litter, and 8.7% ± 0.3% was lost via gaseous emission. Of the gaseous losses, 98.4% ± 0.1% was NH_3, 0.5% ± 0.1% was NO and NO_2, and 1.0% ± 0.2% was N_2O. The results showed that SGB had higher N losses (NH_3 emission) than FGB.

Equivalence of two gas analyzers for ammonia compared to the reference method (wet chemical)

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Ammonia emissions constitute a significant environmental concern in livestock production. To determine these emissions, both the ventilation rate and the ammonia concentration are required. Regarding the determination of ammonia concentrations, the wet chemical method is considered the standard reference method (SRM). However, this method is labor-intensive and very prone to errors, even when performed by experienced people, especially at lower NH3 concentrations. Furthermore, this method only provides an average concentration over the measurement period (ranging from 30 minutes to 24 hours). As a consequence, no insight can be gained into the evolution of concentrations over time. Gas analyzers are easier to use and can provide continuous measurements of ammonia concentrations, making it possible to monitor them over time. However, these gas analyzers must be verified to ensure they are equivalent to the SRM. In this study, two commercially available gas analyzers (one from PICARRO and one from Axetris) were validated as alternative methods to the SRM for measuring ammonia concentrations in livestock (pigs, poultry, and cattle) by using the EN 14793 standard. High correlations were found between the analyzers and the reference method. Equivalence to the wet-chemistry method was demonstrated for both analyzers in the range from 0 to 30 ppm when calibrated beforehand. Prior to the analysis, a two-sided Grubb's test was performed to identify outliers. Data points identified as outliers were examined in more detail to determine the reason for this deviation. Both the results of the equivalence tests and the assessment of the outliers will be presented.

Parallel session 9

Thursday · 15:00-16:00 · Measurement Methods and Data Management

How low can we go? Monitoring barn emissions with low- to mid-cost approaches

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Accurate estimation of ammonia (NH_3) and methane (CH_4) emissions from naturally ventilated dairy barns (NVDBs) is essential for their effective mitigation. High-end instruments such as cavity ring-down spectroscopy (CRDS) or Fourier-transform infrared (FTIR) analyzers are commonly used, offering high accuracy and temporal resolution. However, their high cost and the need for trained operators make measurement campaigns resource-intensive, limiting large-scale deployment and long-term monitoring.

In the ongoing EmiMod project, we assess the feasibility of mid-cost (<€20k) and low-cost (<€1k) sensors. A real-scale validation in a naturally ventilated dairy barn (NVDB) uses a CRDS-based reference system to continuously measure CH_4, CO_2, and NH_3 inside and outside the barn, enabling hourly emission estimates. Three custom systems are tested: two mid-cost solutions (NDIR/electrochemical and TDLAS, both measuring CH_4, CO_2, and NH_3) and one low-cost IoT-based system measuring CO_2 and NH_3.

Measurements began in November 2025 and will continue through the end of 2026. Initial results show deviations in daily emissions of 11% for CH_4 and 13% for NH_3 compared to the CRDS reference, and typical temporal daily patterns of CH_4 and NH_3 emissions could be captured. At the conference, we will present a detailed assessment of accuracy across seasons, as well as dynamic response, aging effects, and system robustness.

SAMBa: A low-cost sensor system for directly measuring airflow rates in naturally ventilated barns and exercise yards

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It is challenging to measure airflow in naturally ventilated livestock barns. This is mainly due to large side wall openings and rapidly changing flow directions caused by external wind conditions. Methods such as the CO_2 balance method combine averaged CO_2 concentrations with mathematical models of CO_2 production to estimate airflow. Since CO_2 concentrations are typically measured via a ring line, varying boundary conditions can only be represented to a limited extent.

To better estimate the volume flow through naturally ventilated barns, the Thünen Institute of Agricultural Technology has developed a low-cost sensor system. The Sensor Array Measuring Ball (SAMBa) uses three differential pressure sensors to determine the local wind vector. Thanks to the low-cost technology, many SAMBAs can be placed directly in the side wall openings. This allows for the continuous determination of the wind vector, accounting for local changes in airflow at each measurement point with high temporal resolution.

The wind vector determination was first validated in a wind tunnel. Subsequently, field tests were conducted in an open area without a barn. Comparisons with a 3D ultrasonic anemometer showed that the SAMBAs were able to capture temporal changes in wind. Initial measurements in a naturally ventilated pig barn and in the exercise yard of a dairy barn, conducted as part of the EmiMod project and using up to 27 SAMBAs, confirmed these results. Together with the also incorporated sensors for NH_3, CO_2, and particulate matter, the SAMBa can create a complete picture of the emission behavior of the barn.

IoT-Based Gas Monitoring and Emission Assessment in Monogastric Animal Farms: Insights from a Multi-Level Analysis

Andrea Costantino ORCID iD, Daniel Alexander Méndez ORCID iD, Juliana Serna Carrillo, Eliseo Gil Vidal, Marta Jarque Durán, Salvador Calvet Sanz ORCID iD
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Monitoring indoor environmental conditions in animal housing is essential to ensure animal welfare and reduce gaseous emissions. Advances in IoT technologies enable large-scale, automated monitoring of temperature, humidity, and gas concentrations. However, their effective use requires both reliable sensors and models capable of extracting meaningful information from the data. The Biotegania Project addresses these challenges across three complementary levels of analysis: device level, single-farm level, and multi-farm level.

At the device level, different NH_3 and CO_2 sensors were tested under controlled conditions to assess their technical performance through standardized procedures. Their on-farm performance was also evaluated through comparison with higher-accuracy reference instruments. At the single-farm level, high-resolution monitoring was performed in two case studies (poultry and pigs), including multiple measurement points and monitoring of the farm power use. These data support the development of AI models to predict gas concentrations and energy consumption. At the multi-farm level, 60 mechanically ventilated barns for monogastric production were equipped with a reduced set of low-cost sensors, with the final aim of assessing large-scale monitoring robustness and data generalizability.

The results show that commercial sensors exhibit significant variability in response time, making some devices more suitable for welfare assessment than for emission estimation, and highlighting the need for rigorous validation. Preliminary AI applications indicate that, due to the correlation between environmental variables and energy use, monitoring one of these parameters enables the estimation of the other through intelligent algorithms. This approach offers benefits for farm management and opens promising pathways toward integrated farm monitoring.

Evaluation of a High-end FTIR Analyser for Continuous Ammonia Monitoring in Livestock Barns

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Continuous and accurate measurement of ammonia (NH_3) concentrations in livestock housing is essential for emission assessment, model validation, and regulatory monitoring. This study evaluates the performance of a high-end Fourier Transform Infrared (FTIR) analyser (Gasmet DXseries) for long-term NH_3 monitoring in a fattening pig barn (0–50 ppm) and a broiler barn (0–15 ppm) over a 15–16 month period. The assessment focused on drift, interference from cooccurring gases and humidity, analytical accuracy, and comparison with the wet chemical standard reference method (SRM; EN 21877:2019).

Repeated calibrations with known NH_3/CO_2/CH_4/N_2O mixtures showed no measurable drift for the pig barn analyser, while the broiler barn analyser exhibited a slight increase in slope over time, but remained within expected uncertainty. Laboratory interference tests demonstrated no significant impact of CO_2, CH_4, or humidity on NH_3 readings. A statistically significant, but practically minor N_2O–NH_3 interaction was observed.

Accuracy assessments demonstrated that calibration substantially improved FTIR performance. When compared with wet chemical measurements, differences followed the expected pattern arising from methodological contrasts: wet chemical measurements provide a 24-hour time integrated average, whereas FTIR yields high temporal resolution measurements. Consequently, daily FTIR averages can differ from SRM values, particularly at low NH_3 levels. Despite this, paired datasets showed consistent relationships and fell largely within recognized acceptance criteria.

Overall, the FTIR analyser demonstrated robust stability, minimal cross-gas interference, and high accuracy after calibration, supporting its suitability as a continuous NH_3 monitoring tool in livestock barns, provided periodic validation is performed.

Parallel session 10

Thursday · 15:00-16:00 · Mitigation Strategies and Technologies

Methane Mitigation Outside the Cow: Field Demonstration of Gas-Phase Abatement of CH_4, NH_3, PM, and Odor in Dairy Barn Ventilation Air

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Livestock methane mitigation has largely focused on enteric interventions within the cow, including feed additives and breeding strategies. These approaches face limitations in scalability, cost, and farmer acceptance, and typically address only a fraction of total emissions. Here, we present a non-invasive alternative: mitigation after emissions leave the animal, through treatment of barn ventilation air. We introduce the Methane Eradication Photochemical System (MEPS), a gas-phase technology designed to treat dilute methane emissions (10–100 ppm) typical of dairy barns. MEPS uses UV-activated chlorine chemistry in a closed-loop system to oxidize methane while simultaneously removing co-pollutants including ammonia, particulate matter, and odor (H_2S etc.). Field tests at a dairy farm in Denmark show energy-efficient (<0.5 kWh/g(CH_4)) methane removal of ~40–80%, with co-removal of ammonia (>90%) and odor compounds (>70%). We present a path toward full-scale implementation through the PERMA projects funded by NextGenerationEU and the Innovation Fund Denmark via Food and BioCluster Denmark. The PERMA-BAO project focuses on improving barn airflow to increase methane capture while maintaining animal welfare and productivity. The PERMA-FS project aims to deploy and validate a system capable of removing 75–90% of methane emissions from a commercial dairy barn. MEPS is non-invasive, operates outside the cow and barn, and enables direct measurement and verification of emission reductions. It also addresses manure methane and simultaneously removes ammonia, odor and PM, providing immediate environmental and regulatory benefits. We argue that MEPS can play a critical role in achieving rapid, scalable reductions in agricultural methane emissions.

Mitigation of methane emission from covered manure tanks using a biofilter technology

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The agricultural sector is the largest contributor to methane (CH_4) emissions in the EU. In this study, we demonstrated a biofilter technology designed to mitigate CH_4 emissions from tent-covered manure tanks at three different pig farms. The first full-scale compost-based biofilter was operated from 2022 to 2025 (Falk et al., 2025; 2026), followed by two additional biofilters tested from 2025 to 2026. Each full-scale biofilter is 400 m^2 and consists of a gas distribution layer and a compost-based CH_4 oxidation layer. The biofilters were actively loaded with manure gas at a flowrate of 100 $m^3\ h^{-1}$.

Across the three farms, the average annual CH_4 load to the biofilters ranged from 0.5 to 4.6 kg $CH_4\ h^{-1}$, with observed variations from 0.0 to 12.9 kg $CH_4\ h^{-1}$. Seasonal patterns were evident; CH_4 loading was lowest in early spring when manure volumes were small and temperatures reduced, and highest during summer due to higher temperatures and increased volumes of stored manure. Biofilter performance was evaluated throughout a full annual cycle. Oxidation efficiencies ranged from 83% to 99%, with an average CH_4 removal efficiency of 93%. Considering that manure gas collection captured on average 75% of the CH_4 generated in the tanks, the resulting overall mitigation efficiency was 70%. The biofilter technology proved robust, stable across seasons, and easy to implement. Cost effectiveness varied depending on whether the manure tanks were high or low emitting.

Removal of trace gases in biofilters designed for reducing methane emissions from manure tanks

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Manure storage tanks contribute to global climate change through emissions of methane (CH_4), while also affecting local environmental quality due to the release of odorants and eutrophication related trace gases such as hydrogen sulfide (H_2S) and ammonia (NH_3). A compost based biofilter designed to mitigate CH_4 emissions from a covered manure storage tank has shown promising potential not only for CH_4 reduction but also for decreasing emissions of H_2S and NH_3 that are loaded to the biofilter with the manure gas. Across the measurement period, the biofilter significantly reduced H_2S and NH_3 emissions by an average of 86% and 84%, respectively, demonstrating that the technology provides substantial co-benefits beyond CH_4 mitigation. A potential concern with compost based biofilters is the unintended production of nitrous oxide (N_2O) within the compost. In this study, we quantified the N_2O generated and emitted from the biofilter surface to assess whether the N_2O emissions could hamper the climate benefit of the biofilter. The results showed that N_2O emissions were very low, corresponding to only 2.8% when expressed relative to the CH_4 removal in CO_2-equivalents (g CO_2-eq m^{-2} h^{-1}). This indicates that N_2O formation did not compromise the net mitigation effect of the biofilter. Overall, the findings demonstrate that compost based biofilters represent a robust and effective technology for reducing CH_4, H_2S, and NH_3 emissions from covered manure storage systems, while the climate impact of associated N_2O production remains minimal.

Ammonia recovery from ventilation air of livestock stables using in situ produced nitric acid generated by plasma technology: Results of a first pilot-scale set-up

Aline Vits ORCID iD[1], Robin De Winter ORCID iD[1], Lander Hollevoet ORCID iD[1], Yury Gorbanev ORCID iD[2,3], Annemie Bogaerts ORCID iD[2,3], Johan Martens ORCID iD[1]
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Indoor livestock farming is an important source of atmospheric ammonia emissions, threatening our environment and biodiversity. Besides being an emission, ammonia is also the key compound in mineral fertilizers, mainly produced through the Haber-Bosch process responsible for 1.3% of the global CO_2 emissions[1]. This results in the need for a remediation technology that is not only able to remove, but also recover the compound. Chemical air scrubbers usually use sulfuric acid to capture the basic ammonia resulting in a diluted ammonium sulphate solution with limited value as fertilizer.

In this work, a novel generation of air scrubbers is presented, using locally produced nitric acid to recover the ammonia in the form of a valuable ammonium nitrate fertilizer. Nitric acid is produced using warm plasma reactors that convert electricity and air into NO_x gasses, which upon absorption in water form nitric acid. Reaction conditions and procedures for NO_x conversion to nitric acid, minimizing nitrous acid co-product, are presented[2]. Subsequently, this acidic aqueous solution is used to scrub ammonia from air and the results are presented of the first pilot-scale set-up combining the production of plasma NO_x with NO_x scrubbing and ammonia scrubbing. Ammonia removal efficiencies of more than 90% are reached and reusable ammonium nitrate is produced. This research combines an environmental necessity with a decentralized and fully electrolyzed fertilizer production system.

[1] S. Mingolla and L. Rosa, *Nat. Food*, 2025, **6**, 610–621.

[2] A. Vits, R. De Winter, L. Hollevoet and J. Martens, Processes, 2025, 13, 3897.

Parallel session 11

Friday · 10:00-11:00 · Manure and Fertilizer Management

Effects of acidified slurry application on soil organisms, soil chemical properties, botanical composition and yield of a natural meadow in Switzerland

Thomas Kupper ORCID iD[1], Federico Ghione[1], Liv Kellermann ORCID iD[1], Johanna Mayerhofer ORCID iD[2], Jürg Enkerli ORCID iD[2], Stéphane Burgos[1], Beat Reidy ORCID iD[1]

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In house acidification of slurry using concentrated sulfuric acid is a technique to efficiently abate ammonia emissions from livestock housings, slurry storage and field application. However, the knowledge on the impacts of acidified slurry which is enriched with sulfur (S) and which exhibits a pH lower by approximately one unit on soil organisms, soil chemical properties and the crops is scarce. We present data obtained from an on-farm strip experiment in Neuenkirch, Switzerland, based on slurry obtained from an in-house acidification operation over five years with the following treatments: untreated slurry, acidified slurry without, and acidified slurry with additional liming with three replicates each. All slurries were a mixture of cattle and pig slurry. The application rates were based on the Swiss fertilizing norms for nitrogen and phosphorus. We investigated the impact of these treatments on soil organisms (earthworms, bacteria, fungi), soil chemical properties, namely pH and S content, and on the botanical composition and the yield of a natural meadow. We did not observe significant differences between the treatments related to the parameters investigated. However, there was a certain variability of the responses by the treatments between the three replicates. We will present the results of the experiments, discuss the limits of the experimental approach and draw conclusions regarding the impact of acidified slurry on soil organisms, soil chemical properties, botanical composition and yield in natural meadows.

Effect of adding calcium cyanamide (Eminex®) to dairy manure on the emission of methane and ammonia

N.L. Mhlongo ORCID iD[1], Hendrik Jan van Dooren ORCID iD[2], Sophie.E Veraa[1], Klaas Blanken[1], Hester.R Kamstra-Brouwer[3]

[1]Wageningen Livestock Research Institute, Wageningen, Netherlands. [2]Wageningen Livestock Research Institute, Wageningen, Netherlands. [3]Dairy Campus, Leeuwarden, Netherlands

Anaerobic microbial decomposition of organic matter in manure is an important source of methane, accounting for 20-25% of total methane emissions from dairy cows. By inhibiting this microbial process methane production can be reduced. Calcium cyanamide ($CaCN_2$) proved to be effective in laboratory studies, however, its effectiveness under real farm conditions had not been investigated. Therefore, this study aimed to assess the effect of adding Eminex®, (a $CaCN_2$ product from Alzchem, Germany) to dairy manure stored under practical conditions on methane and ammonia emissions. The emission measurements were carried out in the emission measurement facilities of Dairy Campus in Leeuwarden, The Netherlands in winter 2025. Thirty two lactating Holstein Friesian cows were kept under similar conditions in two identical units. After a pre-period Eminex® was added directly to the manure in one unit at a dose of 2 kg per m^3 and the other unit was untreated reference. Measurements were taken for 12 weeks, during each week animals were removed from both units for 48 hours to isolate manure emission. Corrected cumulative daily emissions were analysed using linear regression. Manure samples were taken to determine biochemical methane potential (BMP) and volatile fatty acid (VFA) concentrations. The results showed an average reduction of CH_4 emission from manure by 37.5% and an increase of NH_3 emission on unit level by 9,3% over the whole measurement period. An increase in VFA content and BMP was observed. It was concluded that use of Eminex® to reduce methane emission was also effective under farm conditions.

Effects of Manure Management Strategies on Methane and Ammonia Emissions: Field Tests in Pig Houses

Chenglong Wang, Guoqiang Zhang, Li Rong
Aarhus University, Aarhus C, Denmark

CH_4 is a potent greenhouse gas primarily generated from manure stored in pig housing systems. In addition, NH_3 emissions adversely affect both indoor and ambient air quality. Improving manure management practices is therefore essential for mitigating emissions from pig houses. Field experiments were conducted in two sections of a finishing pig house with identical flooring layouts consisting of one-third slatted floor and two-thirds solid floor. One section was equipped with a traditional pit, while the other used a funnel pit system. Measurements were carried out over four consecutive production batches. Each section contained 20 pens, with each pen measuring 4.8 m × 2.4 m. The slurry emptying frequency was once every seven days for the first two batches, representing the Danish regulatory reference, and once every three days for the final two batches. Pit ventilation was operated in the funnel pit section during the first and fourth batches, while all other operating conditions remained identical. Concentrations of CH_4 and NH_3, ventilation rate, and other environmental variables were monitored. With identical slurry emptying frequencies, the funnel pit exhibited approximately 30% lower CH_4 emission than the traditional pit. Increasing slurry emptying frequency from weekly to every three days further reduced CH_4 emissions. In contrast, no clear advantage of the funnel pit was observed for NH_3 emissions with current floor system. Pit ventilation contributed to both CH_4 and NH_3 emissions. It could be considered to empty slurry every three days rather than weekly to improve CH_4 emission mitigation if practice allows that.

Design of a new slurry storage facility for obtaining emission and mitigation estimates representative of farm conditions

Anders Feilberg[1], Michael Jørgen Hansen[1], Pia Brandt[2], Michael Holm[2], Frederik Dalby[1], Mads Skjærbæk[2], Sasha Daniel Hafner[1]
[1]Aarhus University, Aarhus, Denmark. [2]SEGES, Copenhagen, Denmark

Strategies for improved manure management and treatment hold a large potential for obtaining cost-effective reductions of methane emissions from agriculture. Frequent discharge of liquid manure from livestock houses reduces housing emissions and enables downstream treatment and utilization including anaerobic digestion. This puts more emphasis on emissions from long-term storage of both untreated and treated manure, including anaerobically co-digested manure. Measuring emissions and effects of manure management strategies at storage tank level in a representative way is, however, a significant challenge that hampers the inclusion of mitigation strategies in e.g. national emission inventories. For this reason, we present a new manure storage facility and experimental approach designed for obtaining realistic and representative emission data under controlled yet still dynamic conditions. The design is based on 12 ~99 m^3 concrete tanks with tent cover and mechanical ventilation of the headspace. We present model simulations that support the decision of tank size and dimensions. This includes temperature simulations and detailed methane bioproduction simulations. The combined simulations show that representative emission data requires a full-scale height (typically 4 meters), but not full-scale width. Full-scale height ensures realistic temperature dynamics and a realistic surface-to-volume ratio. In addition to the physical dimensions, a realistic filling and emptying pattern is also required, and examples are provided. With the suggested tanks, we can control content and hypothesize that realistic emissions can be achieved independent of production[FD1] . A methodology for detailed and robust emission data with relatively high time-resolution is presented. Shortcomings of alternative approaches will be discussed.

Parallel session 12

Friday · 10:00-11:00 · Mitigation Strategies and Technologies

Methane Mitigation Potential of Activated Sludge Recirculation in Swine Houses: Operational Effects and Microbial Mechanisms

Jin Mi Triolo[1], Ilho Bae[2], Woosung Kang[3], Hyeongyu An[2], So Young Park[4], Ju Hee Shin[5], Seung Gu Shin[6,3], Michael Jørgen Hansen[7], Sven G. Sommer[8]

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The recirculation of activated sludge (RAS) from aeration tanks in the forced aeration system to pig slurry pits in pig houses has recently gained attention as a CH_4 mitigation strategy. This study evaluates CH_4 mitigation of emissions in pig houses usin RAS conditions. CH_4 production potential (B_0) was determined across different growth stages, ranging from 341 ± 5.4 to 402 ± 21.8 mL CH_4/g VS.

A 2 L continuous reactor using fattening pig manure has been operated to represent a recirculation system. Under research farm conditions (99-fold recirculation; 1.38-day retention), preliminary results showed that CH_4 yield remained low (0.025 ± 0.003 kg CH_4/kg VS), corresponding to an apparent MCF of 0.010–0.012%, while N_2O emissions accounted for 0.0051% of input nitrogen as N_2O–N. Further experiments under varying recirculation conditions will be conducted.

Microbial 16S rRNA analysis showed that fresh manure contained no detectable archaea. In the recirculated sludge, the archaeal community was dominated by Methanospirillum (20.49%), a genus known for tolerance to oxygen stress, in contrast to Methanoculleus typically found in anaerobic digesters.

Despite the presence of the methanogens, CH_4 production remained limited, indicating that methane formation was not governed solely by microbial presence. The short retention time, combined with recirculation and oxygen exposure, likely limited both the establishment of adapted methanogens and their metabolic activit. These results suggest that CH_4 formation was suppressed through combined physical and kinetic limitations under RAS conditions.

Effect of spraying Magnesium Chloride ($MgCl_2$) on concrete slatted floors on the ammonia emission from dairy housing

Hendrik Jan van Dooren ORCID iD[1], Fedde de Jong[2]
[1]Wageningen Livestock Research, Wageningen, Netherlands. [2]Dairy Campus, Leeuwarden, Netherlands

Emission of ammonia from agriculture contributes significantly to nitrogen deposition beyond critical loads. Dairy farming is responsible for almost half of the national ammonia emission and housing contributes considerably, around 50% of dairy emissions. Reduction options available for existing dairy housing are needed. It was hypothesized that adding a magnesium chloride ($MgCL_2$) solution will enhance the production of struvite ($Mg(NH_4)PO_4.6(H_2O)$) from Mg^{2+}, NH_4^+ and PO_4^{3-} in dairy slurry and ammonia emission from available ammonium will be reduced. This study aimed to assess the effect of adding $MgCl_2$ frequently on the ammonia emission from dairy housing. Emission measurements were carried out in the emission measurement facilities of Dairy Campus in Leeuwarden, The Netherlands between July and October 2025. 32 lactating Holstein Friesian cows were kept under similar conditions in two identical mechanically ventilated units. Emission reduction was calculated from the difference between treatment unit and reference unit. After a pre-period of one week $MgCl_2$ was sprayed several times per day on a concrete slatted floor by a newly designed spraying system during three weeks in the treatment unit. Treatment and reference were switched between units and schedule was repeated afterwards. Emission in reference unit ranged between 13.3 and 18.3 kg NH_3 per animal per year. The results showed an average reduction of NH_3 emission by 39.7%. It was concluded that use of $MgCl_2$ could be an effective way to reduce ammonia emissions from dairy housing. Further research on effects during downstream storage and application of slurry is recommended.

Towards Climate- and Environment-Friendly Pig Housing: Results from Full-Scale Farm Measurements

Paria Sefeedpari ORCID iD, Noor Hertogh, Joost van Rooijen, Stefan Jannink, André Aarnink
Wageningen Livestock Research, Wageningen University and Research, Wageningen, Netherlands

Intensive livestock production areas, such as parts of the Netherlands, face major challenges in reducing emissions from pig housing systems, particularly ammonia (NH_3), methane (CH_4), nitrous oxide (N_2O) and odour. In close collaboration between research institutes and the pig industry, innovative low-emission housing systems have been developed using source-oriented mitigation techniques, with simultaneous improvement of indoor air quality and barn climate as a key objective. Emission reductions are achieved through frequent and complete manure removal (with or without urine–faeces separation), reduced emitting surface area, and improved floor cleanliness. Approximately 15 farms have implemented these systems, with full-scale measurements completed at two farms for weaned piglets.

The first system, a combi-scraper system, combining separated manure removal and disinfection of the scraping surface, achieved reductions for NH_3 (86%), CH_4 (95%), N_2O (81%), odour (32%), and particulate matter (PM) (63%) compared with emissions from traditional barns. The second system, a rooting system with frequent manure scraper and separation, showed similar reductions for NH_3 (63%), CH_4 (98%), and N_2O (98%), and odour (37%), while for PM an increase of -141% has been measured relative to the control barn.

Total greenhouse gas emissions decreased from 154.6 to 8.18 and 7.55 kg CO_2-eq per year for the combi-scraper and rooting system, respectively, representing an overall reduction in global warming potential of approximately 95% relative to the reference system. These results demonstrate that innovative housing designs can substantially reduce multiple emissions while improving animal welfare. Further results from the ongoing measurement campaign are anticipated in 2026.

Combined effect of frequent discharge of slurry and slurry cooling on methane emissions from pig houses

Michael Jørgen Hansen[1], Yijuan Xu[2], Michael Holm[2], Anders Feilberg[1]

[1]Aarhus University, Department of Biological and Chemical Engineering, Aarhus C, Denmark. [2]SEGES Innovation, Aarhus N, Denmark

In 2030 Denmark will introduce a CO_2-tax on methane from manure and enteric fermentation and there is an urgent need to develop and document methane-mitigation strategies. Slurry cooling is currently used in 5-10% of Danish pig production facilities, either as an ammonia-reduction technology or as a heat source. The aim of the present study was to document the combined effect of frequent discharge of slurry which has been mandatory in Denmark since May 2023 and slurry cooling on methane emissions from pig houses. The study was conducted in a commercial pig production system using four identical pig houses, each with 320 places for growing–finishing pigs, assigned to four treatments: 1) two slurry discharges per batch, 2) two slurry discharges per batch and slurry cooling (20 w m^{-2}), 3) frequent slurry discharge (weekly), and 4) frequent slurry discharge (weekly) and slurry cooling (20 w m^{-2}). Four batches of pigs were included. For each batch, methane emissions were measured 2–3 times over periods of at least one week. The results demonstrate that slurry cooling and frequent discharge both reduce methane emissions. Combining the two resulted in further emission reductions. The result of the study confirms that there is a combined effect of frequent discharge and slurry cooling on methane emissions from pig houses. The implications of the study and the integration of these results in the national emission inventory will be discussed.

Parallel session 13

Friday · 10:00-11:00 · Special session: Emission-Ceiling Permits for Dutch Livestock: Policy, Sensors, and Practice

Environmental and Nature 2000 permits for livestock housing based on emission ceilings and emission monitoring: a novel policy to resolve a legal deadlock in the Netherlands

Chris van Naarden[1], Suzanne de Vlieger[1], Rosa Staarink[2]

[1]Ministry of Agriculture, Fisheries, Food Security and Nature, The Hague, Netherlands. [2]Ministry of Infrastructure and Water Management, The Hague, Netherlands

The Netherlands is currently facing a nitrogen crisis, while additional regulations related to animal welfare and climate mitigation are also emerging. New livestock houses are needed to reduce ammonia and methane emissions and to improve living conditions for animals. However, obtaining permits for new livestock barns has become extremely difficult, mainly due to uncertainties regarding the actual performance of emission reduction measures (low-emission housing systems, add-on techniques, air cleaners, and management measures) in practice. In recent years, studies by Statistics Netherlands (CBS) and Wageningen University & Research (WUR) has shown that less nitrogen is found in manure samples from commercial farms with low-emission housing systems than can be expected based on source-oriented calculation methods using the nitrogen-phosphorus ratio as proxy for N-retention. Similar issues have been identified for (combined) biological air scrubbers, where removal performance in practice appears to be lower than included in Dutch legislation. Furthermore, granting permits based on a modelled nitrogen deposition using emission factors is legally regarded too uncertain, given the fact that emissions vary considerably across farms with identical housing systems. As a result of all this, permitting procedures have reached a legal deadlock in the Netherlands. Permits based on emission ceilings combined with continuous emission monitoring may provide a solution to this legal and ecological problem. In this presentation, the Dutch national programme on emission monitoring in livestock housing is presented, addressing the question of why the Netherlands is investing substantial effort and resources in emission ceiling permits with emission monitoring.

A new Dutch Belgian protocol for determination of gaseous and particulate emissions from livestock farms

Albert Winkel[1], Eva Brusselman[2], Arjan Hensen[3], Gert Otten[4], Loes Laanen[2], Julio Mosquera[1], Nico Ogink[1]

[1]Wageningen Livestock Research, Wageningen, Netherlands. [2]Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Merelbeke, Belgium. [3]The Netherlands Organisation for Applied Scientific Research (TNO), Petten, Netherlands. [4]Flemish Institute for Technological Research (VITO), Mol, Belgium

To reduce emissions from livestock barns and ensure that emission ceilings in permits are not exceeded, the government established an orchestration body in 2024 consisting of three national advisors specializing in legal, data, and technical aspects of emission ceiling permits and emission monitoring. The role of national advisor on technical aspects was assigned to Wageningen University and Research and includes the development of a protocol for measuring emissions from livestock barns. A working group of scientific experts from four knowledge institutions in the Netherlands and Belgium was formed. The protocol integrates previous Dutch substance-specific protocols into a single document, harmonizes them with existing protocols (including VERA), updates them to the current state of knowledge, and further elaborates topics previously described only broadly. The protocol consists of Parts A through F. Part A specifies how emission reductions from housing systems, additional techniques, and management measures must be measured for general recognition (i.e., emission factors in legislation). Part B describes measurement of the removal efficiency of air cleaning technologies, including air scrubbers, biobeds, drying filters, ionization systems, heat exchangers, and manure drying tunnels. Part C addresses emission monitoring on livestock farms operating under an emission ceiling permit. Parts D, E, and F define testing procedures and performance requirements for monitoring systems for gases, particulate matter, and odor, respectively. Version 3 of the protocol is currently being incorporated into Dutch legislation as the prescribed methodology. Based on Part C, monitoring agencies develop monitoring plans for livestock farms with an emission ceiling permit.

Development, lab testing, and field validation of continuous sensor systems for emission monitoring in from livestock farms

Jan Vonk, Kees Lokhorst, Albert Winkel
Wageningen Livestock Research, Wageningen, Netherlands

To reduce emissions from livestock barns and ensure that emission ceilings in permits are not exceeded, the government established an orchestration body in 2024 consisting of three national advisors specializing in legal, data, and technical aspects of emission ceiling permits and emission monitoring. The role of national advisor on technical aspects was assigned to Wageningen University and Research and includes a research programme focused on the development, characterization, laboratory testing, and field validation of continuous monitoring systems for gases (ammonia, methane, carbon dioxide) and particulate matter. Sensor assessment follows a structured four-step approach. First, an initial evaluation is conducted in consultation with manufacturers to review sensor specifications; this includes prototypes, market-ready sensors, and commercially available systems. Promising sensors are subsequently subjected to laboratory testing to determine limits of quantification, response time, calibration across a range of gas concentrations, repeatability, and instrument repeatability. In the third phase, sensors are deployed at three research farms representing dairy cows, pigs, and laying hens. Performance is evaluated under field conditions, including cross-sensitivity to other gases, signal drift, aging, pollution, and corrosion. During this phase, monthly sensor measurements are compared with 24-hour measurements using the standard reference method for the target gas. Sensors that meet performance criteria are then deployed at four commercial farms per animal species for field validation. Currently, more than ten sensors have entered the research phase, and two have completed field validation. Following successful validation, sensors can be applied at livestock farms with emission ceiling permits.

Continuous monitoring of ammonia emission in the first farms in the Netherlands with a novel emission ceiling permit

Roger Stoeltie, Frans Rozema, Alfred Gerrits
Tauw, Deventer, Netherlands

The Netherlands has recently introduced a novel emission ceiling permit that allows farms to operate within a predefined annual ammonia emission limit, supported by continuous monitoring. This presentation outlines the first practical implementation of this permit system in Dutch pig farms. Ammonia emissions are measured continuously using validated sensor technologies installed in commercial pig barns. Measurement quality is safeguarded through a multi-layered assurance approach, including sensor validation, routine calibration checks, automated data quality controls, and expert review of emission calculations. The monitoring system provides farmers with daily insight into their ammonia emissions, enabling timely management actions and increased awareness of emission performance. In parallel, the competent authority receives standardized and transparent reports that support supervision and compliance assessment. These first applications demonstrate how continuous, sensor-based monitoring can underpin a shift from prescriptive regulation towards goal-oriented emission control, while maintaining data reliability, regulatory confidence, and practical usability at farm level.

Plenary session

Friday · 11:30-12:50 · Plenary

Quantification of methane emissions from farm-scale pig manure storage tanks

Charlotte Scheutz ORCID iD, Nathalia T. Vechi ORCID iD
Technical University of Denmark, Kgs. Lyngby, Denmark

Methane (CH_4) emissions from outdoor manure storage tanks are complex because they are affected by operational and environmental factors. This study quantified methane emissions from 14 Danish pig manure storage tanks using a mobile tracer gas dispersion method (TDM). The TDM applies a tracer gas with a known release rate to simulate the target source emissions and simultaneous plume concentration measurements of the tracer and the target gas (Vechi et al., 2023). Quantifications (about 6 to 8 measurements per tank) were done covering an entire year. Of the 14 manure tanks, two tanks stored digested manure while the rest of the tanks stored untreated manure. Methane emissions from storage tanks with untreated manure varied from 0.01 to 14.3 kg h^{-1}, which when normalized by the amount of manure stored corresponded to annual average emissions in the range of 0.20 to 2.88 g m^{-3} h^{-1}, with an average of 1.46 ± 0.87 g m^{-3} h^{-1}. In general, seasonal variation patterns were clear and similar among the different tanks, with emissions peaking between July and September and being lower during winter. For storage tanks with untreated manure, manure temperature was thus a significant factor correlating with measured CH_4 emissions. Storage tanks with digested manure showed much lower emissions (on average 66%). There was a large variation among the untreated pig manure tanks, likely due to different management practices as frequency of manure removal from the tank, house practices, type of animal or other factors not yet well understood.

Research priorities to reduce nitrous oxide emissions from grazing ruminant urine patches to support the development of effective mitigation technologies – an international review

Tim Clough[1], Cecile de Klein ORCID iD[2], Kari Dunfield[3], Bo Elberling[4], Ramon Ganigué[5], Christoph-Martin Geilfus[6], Sara Hallin[7], Christoph Mueller[8], Jeanette Norton[9], Lisa Stein[10], Rod Venterea[11]
[1]Lincoln University, Lincoln, New Zealand. [2]Bioeconomy Science Institute, Mosgiel, New Zealand. [3]University of Guelph, Guelph, Canada. [4]University of Copenhagen, Copenhagen, Denmark. [5]Ghent University, Ghent, Belgium. [6]Hochschule Giesenheim University, Giesenheim, Germany. [7]Swedish University of Agricultural Sciences, Uppsala, Sweden. [8]Justus Liebig University, Giessen, Germany. [9]Utah State University, Logan, United States. [10]University of Albertax, Edmonton, Canada. [11]University of Minnesota Twin Cities, Minneapolis, United States

Globally, agriculture contributes around 52% of anthropogenic nitrous oxide (N_2O) emissions, with ruminant urine patches the largest N_2O source in grazed livestock systems. The development of practical solutions for farmers to reduce N_2O emissions from grazing ruminant urine patches are challenged by the inherent variability of N_2O emissions and the resulting variability in the efficacy of mitigation options. This review gathered expert global knowledge on the key research priorities and research approaches to support and accelerate the development of mitigation technologies for reducing N_2O emissions from ruminant urine patches. The objectives were to (1) comprehensively assess existing knowledge, discern knowledge gaps and challenges, (2) identify research needed to overcome barriers to the development of practical and cost-effective mitigation solutions and (3) provide a summary of N_2O emissions research priorities, targeted at reducing emissions from ruminant urine patches. The review addressed i) the key soil microbial, chemical and physical parameters affecting N transformations and N_2O emissions, ii) the role of plants and the plant rhizosphere on soil N cycling and iii) how deposition of ruminant urine influences the biological, chemical, physical controls and plant effects on N cycling and N_2O emissions.

Estimating Ammonia Emissions from the Floor in Pig Houses by Applying Computer Vision Techniques into Process-Based Modelling

Fei Xie[1], Jianchao Ci[1], Paria Sefeedpari[2], Peter Groot Koerkamp[1], André Aarnink[1,2]

[1]Agricultural Biosystems Engineering, Wageningen University, Wageningen, Netherlands. [2]Emissions & Manure Valorisation, Wageningen Livestock Research, Wageningen, Netherlands

Process-based modelling is an important method which simulates the physicochemical process of ammonia release from the floor surface and quantify ammonia emissions from livestock farming. A key factor in this model is determining the emitting areas contaminated by urine puddles. Current methods for quantifying emitting areas mainly rely on human observation, which is time-consuming, provides limited data and observer bias.

This study aimed to estimate the size of urine puddles by developing a method that combines deep learning model (DLM) with heat transfer modelling (HTM). Thermal images were acquired using a fixed thermal camera in fattening pig pens. A DLM was trained to detect visible puddle regions, while a heat transfer model HTM was used to predict the occluded puddle area based on heat dissipation patterns and the visible puddle regions. The predicted emitting areas were thereafter applied in the process-based model to estimate ammonia emissions from the floor.

The results showed that the DLM detected puddles with 99.2% precision, 91.9% recall, and 97.2% mAP50 (mean average precision at IoU0.50). The DLM achieved an average mean squared error （MSE） of 3.2×10^{-3} m^4 in estimating visible urine puddle area. The HTM also accurately estimated occluded areas with a low MSE. The combined HTM and DLM system succeeded in estimating the ammonia emissions based on the predicted temperatures and areas of occluding urine puddles in real-time.

This study integrates computer vision techniques into ammonia emission modelling, enabling more precise measurement and quantification of key variables used in gas emission models.

Soil type and application method interact to control NH_3 and N_2O emission following slurry application to grassland

Johanna Pedersen ORCID iD[1], Maarit Mäenpää ORCID iD[2], Sasha Daniel Hafner ORCID iD[1], Flavia Dela Pierre ORCID iD[1], Jorge F. Miranda-Vélez ORCID iD[2], Søren O. Petersen ORCID iD[2]

[1]Department of Biological and Chemical Engineering, Aarhus University, Aarhus, Denmark. [2]Department of Agroecology, Aarhus University, Aarhus, Denmark

Application of liquid animal manure (slurry) to grassland is a major source of reactive nitrogen losses, particularly NH_3 and N_2O. These losses are known to vary with soil properties and application method, yet quantitative information suitable for farm-level emission inventories remains limited, partly due to low comparability between individual experiments due to confounding effects.

We conducted a controlled study to isolate the effects of soil type and application method on NH_3 and N_2O emissions following cattle slurry application. Experiments were carried out at a facility using intact soil monoliths representing three soil types (coarse sand, loamy sand, sandy loam). Slurry was applied in May and July using trailing hose and open slot injection. N_2O flux from all soils was measured using static chambers, while NH_3 emission was quantified using dynamic flux chambers on coarse sand and sandy loam only. Non-amended control plots were included to account for background N_2O fluxes.

Preliminary results indicate strong soil type dependence and significant interactions between soil type and application method, as well as differences between sampling times for both NH_3 and N_2O emissions. Open slot injection consistently reduced NH_3 emissions relative to trailing hose application, but increased N_2O emissions. However, the magnitude and direction of these trade-offs varied across soil types and experimental runs.

These findings highlight the importance of accounting for soil-specific responses and management interactions when estimating emissions and designing mitigation strategies. The results suggest that generalized emission factors may obscure critical trade-offs between NH_3 and N_2O mitigation in grassland systems.

Poster Presentations

Manure and fertilizer management

#1. Bio-Slurry as a Sustainable Fertiliser: Impacts on Forage Production and Greenhouse Gas Mitigation Compared with Synthetic Fertilisers and Farmyard Manure (+ flash talk)

Zenebe Amele Sahile[1], Akiber Chufo Wachemo[2], Daniel Mulat[3], Chris Jhones[3]
[1]Arba Minch University, Arba Minch, Ethiopia. [2]Wolaita Sodo University, Wolaita Sodo, Ethiopia. [3]International LIvestock Research Institute (ILRI), Nairobi, Kenya

Livestock production is a cornerstone of food security and livelihoods in Sub-Saharan Africa. Still, it is constrained by seasonal shortages of forage and associated greenhouse gas (GHG) emissions. This study evaluated bio-slurry (BS), a nutrient-rich digestate of biogas co-product, against synthetic fertiliser (NPK), farmyard manure (FYM), and their combinations for Napier grass (*Cenchrus purpureus*) production and GHG emissions.

A randomised complete block design trial was conducted at the International Livestock Research Institute farm in Nairobi, Kenya. Control, BS, FYM, NPK, 50% BS + 50% NPK, 50% FYM + 50% NPK treatments applied at 100 kg N ha^{-1}, total N basis; replicated four times. Agronomic performance, forage quality, and soil fluxes (CH_4, N_2O, CO_2) were collected.

Results show that (50% BS + 50% NPK) was an effective strategy, achieving the highest dry matter yield of 3.84 t ha^{-1}, outperforming the control (69%), NPK (42%), and BS (14%). Most significantly, it recorded a crude protein yield (CPY) of 603.62 kg ha^{-1}, an 89% increase over the control and surpassing NPK by 32%, while maintaining CP 16.95%. Sole BS application led to high N_2O fluxes (0.48 kg N_2O-N ha^{-1}), but BS + NPK reduced N_2O emissions by over 50% and acted as a net methane sink (–0.01 kg CH_4-C ha^{-1}, $p < 0.05$).

In conclusion, BS + NPK is an agronomically commendable, climate-smart strategy that supports a circular bioeconomy in tropical smallholder systems. Future research should consider upstream bio-slurry and fertiliser production, farmyard manure storage, and downstream animal feeding impacts to get full picture of sustainability.

#2. Dual-phase additive application for reducing GHG and ammonia emissions in dairy manure management (+ flash talk)

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Manure management is a major source of greenhouse gas (GHG) emissions in dairy production, but it also presents opportunities for nutrient recovery if optimized effectively. Storage pits and composting units emit CH_4, CO_2, N_2O, and NH_3 via distinct microbial pathways: anaerobic storage favors methanogenesis and ammonification, while composting environments foster aerobic-anaerobic transitions, stimulating nitrification, denitrification, and N_2O release. Although composting stabilizes manure and reduces CH_4 emissions, it can result in significant carbon and nitrogen losses. Mineral additives are a promising mitigation strategy, but their effectiveness depends on the timing and placement of application within the manure management chain.

This study investigates the use of $MgSO_4$ and $MgSO_4$ + $FeCl_3$, applied at different stages of manure management at CAETEC Experimental Agricultural Center (Querétaro, Mexico). It consisted of a randomized factorial design with nine treatments, applying additives in the manure collection pit (363 m^3), composting piles, or both, across three composting cycles. Physicochemical properties and GHG (CH_4, CO_2, N_2O) and NH_3 emissions were monitored throughout the 132-day trial.

Preliminary data from the storage phase show both additives significantly reduced emissions, with CH_4 lowered by 60% and NH_3 by up to 75% versus the control. Manure properties changed, including >60% reductions in TOC and C/N ratio, and >50% increases in NO_3^-. These changes decrease key precursors for emissions during storage. Emission analyses for the composting phase are ongoing and will contribute to a comprehensive evaluation of additive performance across the entire manure management system.

#3. Use of Alfam2 model as online monitoring of ammonia emission during slurry spreading (+ flash talk)

Morten Toft
BioCover, Vejen, Denmark

Acidification in combination with monitoring of ammonia emission during application of slurry, enables mapping of NPA – **N**itrogen **P**lant **A**vailability – from application of organic fertilizer - slurry. This further enables calculation of accurate **V**ariable **A**plication **R**ate - **VAR** SHAPE files for accurate dosage of mineral N - nitrogen.

A Danish farm of 729 ha demonstrated an average of 78 % NPA with acidified slurry and a re-distribution of surplus N of 1.1 ton from areas with +80 % efficiency, to areas with a deficit of 1.8 ton N or -80 % efficiency - to achieve a homogeneous N application. This resulted in an increase in yield and significant reduction in total use of mineral N fertilizer.

#4. Evaluating Ammonia Volatilization from Buffalo Digestate: A Methodological Comparison of Measurement Techniques (+ flash talk)

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This study is part of the LiMiT-DGGAS project, which investigates innovative strategies for sustainable digestate management to reduce ammonia (NH_3) and greenhouse gas (GHG) emissions while enhancing nutrient recovery. This study evaluates NH_3 volatilisation dynamics following the field application of liquid and solid digestate fractions, under real agronomic conditions, using a low-emission trailing shoe system for the liquid fraction, and a conventional manure spreader for the solid fraction. Both fractions were sourced from full-scale anaerobic digestion of buffalo manure. Furthermore, two distinct monitoring approaches were evaluated: the open chamber and the micrometeorological backward Lagrangian Stochastic (bLS) method. The results show that NH_3 emission rates are strongly influenced by environmental variables, with daily peaks occurring at the times of maximum average wind speeds and temperatures. Volatilisation was most intense immediately after application, with 60–70% of total NH_3 losses occurring within the first 37 hours across all treatments. Emission fluxes typically subsided within 100 hours post-application. When quantified via the chamber method, both fractions exhibited comparable absolute emissions. In contrast, the bLS method revealed absolute emissions that were 26% higher for the liquid fraction than for the solid one. Despite these methodological differences in absolute quantification, both protocols consistently identified the solid fraction as the primary source of volatilisation when normalised against the total ammoniacal nitrogen (TAN) applied. These findings emphasise the critical role of digestate fraction characteristics in nitrogen loss and highlight how the choice of monitoring scale can influence the interpretation of emission dynamics.

#5. Effects of slurry digestion, acidification and plasma treatment on nitrous oxide and ammonia emissions (+ flash talk)

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With animal slurry, readily available nitrogen and carbon are added simultaneously to the soil, which together promote the formation of nitrous oxide. However, how pre-treatments of the slurry such as anaerobic digestion, slurry acidification and plasma treatment affect the nitrous oxide emissions, is poorly studied. In this project, nitrous oxide emissions and ammonia losses were measured in two field experiments with slurry application to winter cereals in southwest Sweden in April 2025. Treatments included were anaerobically digested cattle slurry, with and without the addition of sulfuric acid, nitric acid or the combination of nitric acid and nitrite (to mimic plasma treatment), and untreated cattle slurry. Nitrous oxide emissions were measured with 1–2-week intervals over an entire year using a portable gas analyser (Aeris Mira Ultra). Ammonia emissions were measured during the first week after manure application using dynamic flux chambers connected to a cavity ring-down spectrometer. For nitrous oxide, preliminary results show extremely high initial emissions from the treatment with nitrite-containing digestate. For the remaining treatments, results indicate somewhat higher emission peaks for untreated cattle slurry than for digestates during the first months after application, while there were no clear differences between the slurry treatments during the rest of the year. Ammonia emissions were similar for untreated and digested cattle slurry, and acidification of the digestate by 0.8-1.0 pH units reduced the emissions by 45-55% with both sulphuric acid and nitric acid.

#6. Ammonia Emissions from Field Applied Manure of Different Dairy Housing Systems

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Ammonia (NH_3) is a volatile, water soluble compound mainly produced by microbial hydrolysis of urea, with volatilization influenced by pH, temperature, and aeration. Its atmospheric emissions contribute to fine particulate matter, soil acidification, and eutrophication, threatening air quality and ecosystems. In Europe, livestock production accounts for up to 90% of agricultural NH_3 emissions; in Spain, agriculture represented 96.9% in 2022, primarily from manure and fertilizer use. This study aimed to compare NH_3 emissions from field applications of compost-bedded pack (CBP) manure and cubicle (CUB) slurry from dairy systems with mineral fertilizer (ammonium sulfate) and an unfertilized control on wheat plots. A randomized complete block design was implemented on eight 1.2 × 27 m plots, with equivalent N rates (100 kg N ha^{-1}) applied across treatments. NH_3 fluxes were monitored using portable flow chambers and acid impingers over 15 days after fertilization. Data were analyzed by mixed model ANOVA with Tukey's test. NH_3 emissions varied significantly by treatment and day, but not by block or interaction. Mineral fertilizer (8.15 mg m^{-2} h^{-1}) produced the highest emissions, followed by CBP manure (4.38), control (1.08), and CUB slurry, which showed the lowest and occasionally negative fluxes, suggesting net N retention via surface crusting or microbial immobilization. Emission peaks occurred on day 1 (14.04 mg m^{-2} h^{-1}) and declined sharply after rainfall events. Although mineral fertilizer enhanced immediate N availability, liquid slurry proved most sustainable, minimizing NH_3 volatilization and environmental impact.

#7. Minimizing the environmental impact of cattle slurry in Galicia (Spain) using a smart system for estimating nutrients in slurry tanks from electrical conductivity and density measurements.

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Slurry composition is variable. Using a system to estimate the actual slurry nutrient content at the time of application allows for adjusting the amount applied to the needs of the crops, minimizing emissions to the atmosphere (N_2O and NH_3) and losses due to leaching (NO_3^-).

A total of 101 slurry samples were collected during 2018 and 2019 from 19 dairy cattle farms representative of the different feeding systems in Galicia. Sampling was carried out after agitation in the slurry tanks using a tubular probe. The slurry samples were analyzed (dry matter, nitrogen, phosphorus, potassium, and ammonia nitrogen). Electrical conductivity (mS cm^{-1}) was measured using a conductivity meter (Orion Star A122), and density (kg dm^{-3}) by weighing 100 mL of the slurry with a graduated cylinder.

From these data, multiple linear regression equations between the fertilizer value of the slurry (kg of nitrogen, ammoniacal nitrogen, P_2O_5 and K_2O per cubic meter) and density (D) and electrical conductivity (EC) were established.

N (kg m^{-3})=0.22EC+ 3.99D-3.80. R^2 =0.76 ***.

Ammoniacal N (kg m^{-3})=0.13EC+1.61D-1.84. R^2 =0.82 ***.

P_2O_5 (kg m^{-3})=0.07EC+3.43D-3.11. R^2= 0.43 ***.

K_2O (kg m^{-3})=0.24EC-4.63D+4.71. R^2= 0.58 ***.

*** P<0.001

The regression equations obtained were good for nitrogen (N) and ammoniacal nitrogen (N), acceptable for potassium (K_2O), and poor for phosphorus (P_2O_5).

These equations have been incorporated into a smart system installing sensors of electrical conductivity and density in the slurry tank for knowing the nutrient content of slurries (project FEADER 2023/053B).

#8. Ammonia Emissions from Nitrified and Separated Pig Slurry under Controlled Storage Conditions

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Ammonia (NH3) emissions from livestock slurry storage contribute to atmospheric nitrogen pollution and fertilizer loss. Nitrification of separated slurry liquid fraction may reduce emissions while retaining plant-available nitrogen. This study investigates NH3 emission dynamics from conventional and nitrified pig slurry using dynamic flux chambers.

Emissions were quantified using 60-L barrels (n=3) with 50 L slurry and 10 L headspace. Treatments: (i) reference slurry (SL; TAN = 1.3 g L-1) and (ii) nitrified separated fraction (NS; TAN = 0.3 g L-1). Sealed barrels (6-mm ports) received ambient air at 0.1 L min-1 (exchange rate 0.01 min-1). Exhaust was captured in sodium acetate buffer (pH 4; Häni et al., 2016) using 250-mL (1-week) or 25-mL (12-hour) impingers.

NS emissions were lower than SL on an absolute basis but comparable relative to TAN. Initial rates (post-agitation) were ~100 ng s-1 (SL) and ~15 ng s-1 (NS) over 12 hours, or ~20 and ~4 ng s-1 weekly. Both treatments declined ~one order of magnitude per week for 3-4 weeks. Replicates showed strong consistency. Absolute rates were lower than uncovered storage values (Kupper et al., 2020), suggesting the setup simulates covered storage.

Nitrification reduces storage emissions proportionally to TAN. Following open questions remain for ongoing research: 1) applicability to real covered storage, 2) mechanisms behind the observed low emissions, and 3) minimization of nitrogen loss during nitrification.

#9. Estimation of the fertilizer value and potential emissions of pig slurry from Galician commercial farms

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Pig slurry is a valuable fertilizer for forage crop production in Galicia (NW Spain) and compositional variability is an important constraint on their efficient use. In 2024, 210 slurry samples were collected from commercial farms of six animal categories (fattening, weaned piglets, mixed-cycle farms, farrowing to finishing farms, sows with piglets up to 6 kg and sows with piglets up to 20 kg) and analyzed for total nitrogen, ammoniacal nitrogen, total potassium, total phosphorus content, density, pH, electrical conductivity (EC), dry matter, and organic matter. Data analysis included an analysis of nutritional content of slurries, correlations among variables and estimation of gaseous emissions using predictive models (Antezana et al., 2016). Animal category affected some physico-chemical parameters and significant relationships were found among slurry characteristics expressed in fresh basis. Quick measurements in situ as density and EC will allow farmers to adjust the dose of slurry applied.

Antezana, W., De Blas, P., García-Rebollar, P., Rodríguez, C., Beccaccia, A., Ferrer, P, Cerisuelo, A, Moset V, Estelles F., Cambra-López, M., Calvet, S., 2016. Composition, potential emissions and agricultural value of pig slurry from Spanish commercial farms. Nutr Cycl Agroecosyst. 104. 159-173. https://doi.org/10.1007/s10705-016-9764-3

#10. Storage emptying efficiency and effect of inoculum removal on storage methane emission

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Methane emitted from manure in animal houses and outside storages amount to ca 25% of total Danish agricultural GHG emission. Frequent removal of slurry from the slurry system in pig houses and transfer to outside storages has proven to be an effective and straightforward strategy to reduce slurry related house emission of methane and is now mandatory in Denmark. Abatement technologies for storages and stored manure represent a large potential to reduce methane emission from the slurry management chain even further. Strategic removal of methanogenic residual slurry prior to subsequent re-filling of storages has been suggested as an efficient tool to reduce methane emitted from storages similar to what has also been demonstrated for the effect of removal of residual slurry in pits for house emission. A full-scale storage has been designed where it is possible to empty the storage efficiently with a minimum amount of residual slurry left as methanogenic inoculum prior to subsequent re-filling and storage period enabling the technology to be implemented on an operational level on farms. Implementation and results on efficiency for inoculum removal in full scale storages are presented. The effect on storage emissions of efficient inoculum removal prior to subsequent storage periods is modelled using the Anaerobic Biodegradation Modelling (ABM) and results are presented. The simulated effect of inoculum removal on methane emission is discussed and compared to previous methane measurements from pilot scale storages without inoculum.

Livestock facilities and enteric emission

#11. Effects of Agolin Naturu® on enteric methane emissions, milk yield and emission intensity in organic Brown Swiss cows (+ flash talk)

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This study evaluated the effects of Agolin Naturu (AN; Alltech Inc., US), a blend of essential oils, on enteric CH_4 emissions (g/day), milk yield and CH_4 emission intensity (g/kg milk) in organic Brown Swiss cows. The research is part of the project activities of the startup Ecolivestock, funded by the Autonomous Province of Trento (n. C69J23001360008). The trial lasted 15 weeks: 3-weeks control period, followed by 9 weeks of AN supplementation, and 3-weeks washout. The first 6 weeks of supplementation were intended for rumen adaptation, and AN effect was evaluated during the final 3 weeks. Twenty-eight lactating cows (milk yield: 14±5.3 kg/day; days in milk: 176±136; parity: 2.3±1.8) were enrolled. Animals received a total mixed ration throughout the trial with additional concentrate supplied via the automatic milking system (AMS; DairyRobot R9500, GEA, DE). AN was included in the pelleted concentrate at a dose of 1 g per cow/day and delivered through the AMS. CH_4 emissions were monitored using a sniffer system (MooLogger, Tecnosens, IT) installed in the AMS. Preliminary results indicate no significant differences in CH_4 emissions between control, AN supplementation, and washout periods. Milk yield increased significantly by about 17% during AN supplementation and washout periods compared with control, resulting in a 14% reduction in CH_4 emission intensity. These results provide preliminary evidence in organic Brown Swiss cows that AN supplementation may improve productive performance and reduce CH_4 emissions per unit of milk; although, further research is needed to confirm these effects.

#12. Effects of fiber type and particle size on enteric methane production in finishing pigs

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Four experimental diets were formulated to evaluate the effects of particle size and dietary fiber (DF) source, differing in solubility, on enteric methane emissions in finishing pigs. The diets included: high-soluble DF diets based on sugar beet pulp milled to 3 mm (SBP) or 2.5 mm (SBPR); high-insoluble DF diets based on oat bran milled to 3 mm (OB) or 2.5 mm (OBR). The experiment was conducted as a repeated 4 × 2 factorial design, using 16 female pigs (initial body weight 50.2 ± 3.2 kg). Each period lasted 16 days, comprising 10 days of dietary adaptation followed by 6 days of fecal collection to determine apparent total tract digestibility. Animals were placed in respiration chambers for 72 hours to measure gas exchange. Pigs were fed a daily allowance of 3 kg.

Dietary treatments did not affect dry matter intake ($P = 0.93$). Apparent total tract digestibility of organic matter was influenced by DF source ($P < 0.001$), with lower values for high-insoluble DF-based than high-soluble DF-based diets. Reducing particle size did not alter digestibility within either fiber source. Enteric methane emissions per DM intake differed among diets ($P < 0.03$), being lowest for OB (0.91 L kg^{-1} DM intake), intermediate for OBR and SBPR (2.27 and 2.33 L kg^{-1} DM intake, respectively), and highest for SBP (2.53 L/kg DM intake). These results indicate that reducing particle size may have a greater effect on increasing enteric methane emissions from insoluble than soluble DF sources.

#13. Climate-smart housing for dairy sheep and goats to reduce heat stress and ammonia emissions

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Climate change is increasing the frequency and intensity of heat waves in southern Europe, creating new challenges for the management of livestock buildings. In the France–Spain cross-border area, small ruminant production systems are increasingly exposed to irregular seasonal patterns, including extreme weather events occurring outside their seasonal periods. These conditions increase the risk of heat stress in animals while simultaneously affecting the dynamics of ammonia (NH_3) emissions within livestock housing.

Under warmer conditions, ventilation management becomes a critical factor, as it directly determines both thermal comfort and the accumulation and dispersion of NH_3. Insufficient ventilation, combined with high temperatures and increasingly variable climatic conditions throughout the year, can lead to the accumulation of ammonia inside the barns, negatively affecting air quality, animal welfare and productivity.

In this context, the FRESHEEP&GOAT project aims to strengthen the resilience of sheep and goat farms in the POCTEFA region by improving the management of livestock buildings. The project is based on close collaboration between scientific institutions, technical organizations and farmers. Approximately 30 sheep and goat farms located on both sides of the French–Spanish border will be monitored. Data on production performance, building design and environmental parameters (temperature, humidity, ventilation and gas concentrations) will be collected to better understand the relationship between housing conditions and animal responses to heat stress and NH_3 emission dynamics.

These combined efforts will generate robust benchmarks and practical recommendations, facilitating the transferability of effective adaptation strategies for small ruminant farming systems.

Modeling and emission processes

#14. ALFAM2 update and perspectives (+ flash talk)

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The ALFAM2 model is a mature tool for estimating ammonia emission from field-applied animal slurry. The related ALFAM2 database is a public collection of detailed emission measurements. This contribution will present some recent developments in both, along with perspectives and current challenges. Some of these topics are summarized here in this abstract.

The relatively simple yet semi-mechanistic nature of the ALFAM2 model, its simple inputs, and public availability of two software implementations (http://alfam.dk) have all probably contributed to its use for research and inventory purposes. The newest parameter set for the model (4), under development in early 2026, incorporates information from measurements made with wind tunnels or other dynamic chambers on hundreds of plots in addition to micrometeorological measurements. Preliminary results show similar sensitivity as in earlier micrometeorological-only parameter sets, and an improvement in uncertainty. Inclusion of soil effects and interactions between soil and application methods is still an unmet challenge.

The ALFAM2 database now includes > 3000 field plots. A long-term approach for efficiency in expansion, maintenance, and reproducibility in now built into in the public database repository (https://github.com/AU-BCE-EE/ALFAM2-data). Separate submission sets are frozen after 2-4 years of submission with all submitted data and scripts. A single active submission set uses streamlined code and new approaches for building and checking the database. The database demonstrates the increase in the value of experimental data when organized and included in a public collection.

#15. Optimizing and dimensioning acid scrubbers for ammonia removal from barn ventilation air

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Ammonia is a common airborne contaminant from livestock, which contributes to eutrophication, acidification, particulate matter and greenhouse gas emission. A range of mitigation strategies are already being developed and implemented. We focus on improving wet acid scrubbers, a well-established technology for ammonia mitigation. A major challenge in acid scrubbers is the environmental and financial cost of constructing and maintaining the scrubber, which means that the size and operational parameters are important. However, a tool for estimating these parameters in random packed trickle bed reactors is not currently available. Therefore, an open-source model has been written in python with the dual purpose of estimating the correct size of future scrubbers to avoid unnecessary construction costs and of exploring a wide range of operational parameters for optimization of the reactor. Here pH and EBRT have been evaluated at different values to create a 3D scatter plot of both the acid consumption and the ammonia removal efficiency. This tool has been used on different hypothetical reactor setup scenarios, with the long-term goal of improving the accuracy and predictive power of the model for a range of different ammonia scrubbers, so that each farm can make an educated decision on what the best filter for their specific needs is.

#16. Residual manure following discharge is enriched in organic matter that negates methane reductions from frequent discharge practice

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Frequent discharge of manure from pig houses has become standard practice due to its potential to substantially reduce methane emissions. Recent measurements indicate emission reductions 35–54% (CI95). The large confidence interval is likely linked to the methane production potential of the residual slurry remaining after discharge. Particulate matter in manure tends to settle at the bottom of slurry pits, leading to the accumulation of organic matter and particle-associated microorganisms in the residual fraction.

In this study, residual slurry samples were collected from several pig houses following vacuum flushing and compared with corresponding bulk manure samples. The results revealed substantial variation in organic matter content of residual slurry, ranging from no enrichment to 200% enrichment for certain components. Crude proteins were generally less enriched in the residual slurry, whereas lignocellulose and lipids showed higher degrees of enrichment. Furthermore, enrichment was more pronounced in slurry from farrowing sows than from finishing pigs.

These findings indicate that residual slurry can have a significantly higher methane production potential than bulk manure. Current Danish national emission models do not account for this enrichment, which may lead to an overestimation of the mitigation effect of frequent manure discharge. Simulations using the Anaerobic Biodegradation Model illustrate how enrichment of organic matter can influence methane emissions and highlight discrepancies compared to simpler models used in emission inventories and climate mitigation catalogues.

Measurement methods and data management

#17. Evaluating nitrogen emissions in fattening pigs using open circuit chambers and manure containers (+ flash talk)

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Open circuit chambers are commonly used in research on enteric methane in ruminants, but may also provide valuable information on emission research in other animal species. We investigated the use of these chambers to assess nitrogen emissions in fattening pigs, and linked the emissions on chamber level to the emissions on manure level. Pigs were fed two contrasting diets to include variation in ammonia emissions, which was tested in a cross-over design with six climate controlled open circuit chambers. Each chamber housed five fattening pigs. The chambers were equipped with a solid floor lying area (rubber, ± 3.64 m^2), and a slatted floor area (± 1.68 m^2). Throughout the housing period, urine and feces were collected in a collection tray located below the slatted floor area. Two periods of three weeks in the chamber were used, with one week of cleaning in between. This allowed us to assess how the length of the housing period and animal weight affected the ammonia emission level response on different diets. After the end of each period, manure samples were taken and put in continuously ventilated containers from which ammonia emissions were measured for ten days. The effect of using fresh manure versus manure that was kept in a fridge for 16 days on emissions from manure containers was assessed.

#18. Continuous digital pig smell measurements in the project EmiMod in Germany

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Continuous, digital odour measurements in outdoor conditions remain a challenging and active area of research, especially considering agricultural odour emissions. One of the objectives of the EmiMod project, currently underway in Germany, is to measure and characterise odours from pig housing facilities with natural ventilation and exercise yards. Besides the use of established, discontinuous, non-digital methods, the project investigates the use of two digital measurement technologies: ion mobility spectrometry (IMS) and electronic noses (eNose).

While IMS systems have been established for other smell-related tasks, the eNoses investigated in this project are based on a novel sensor array composed of 62 metal oxide nano fibre sub-sensors that are not specific to individual gas components, but rather produce more general smell patterns in the data.

The project includes an extensive field measurement campaign focused on the odour emissions of a small, free-ventilated pig housing. A total of 10 eNoses were placed at different distances around the pig housing. The IMS device was installed next to a eNose located 10 m from the pig housing.

A randomised field inspection plan was carried out in order to provide human smell annotation to the digital datasets. The field inspection plan involved 10 certified smellers that annotated their smell impressions via a web app at two sensor locations roughly every 4 days during the course of 13 months.

Based on the extensive datasets being created, the project aims to enable the training and testing of AI models for digital, continuous on-site pig smell recognition.

#19. Sampling strategy and chamber configuration effects on nitrous oxide emissions after slurry application under diurnal temperature variation

Flavia Dela Pierre, Johanna Pedersen, Søren O. Petersen
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Land application of slurry is a major source of greenhouse gas emissions, with nitrous oxide (N_2O) as a key contributor.

Emissions are commonly quantified using non-flow-through static chambers with discrete sampling and subsequent gas chromatography (GC) analysis. Sampling is often conducted at a time assumed to represent the daily mean temperature. However, the extent to which this captures the true daily N_2O flux remains uncertain, particularly under conditions with pronounced diurnal temperature variation.

This study evaluates how diurnal variability, sampling strategy, and chamber configuration influence estimated N_2O fluxes following slurry application. A field experiment will be conducted in spring–summer 2026 on permanent grassland and bare soil. Fluxes will be measured using static chambers with GC and chambers coupled to a portable mid-infrared laser absorption spectroscopy (LAS) analyzer. A 24-hour intensive campaign will quantify diurnal emission patterns. Subsequently, repeated campaigns will be conducted over several weeks using the LAS system, with sequential flux measurements at multiple times of day.

In addition, the effect of internal chamber fan speed on measured N_2O fluxes will be assessed using LAS across two soil types, to test whether mixing intensity interacts with soil conditions to influence flux estimates.

The study addresses the trade-off between measurement precision and temporal representativeness, as well as potential methodological artefacts related to chamber operation. The results are expected to inform optimal sampling strategies and chamber configurations, and to support improved comparability and interpretation of chamber-based N_2O emission data.

#20. Effect of drone flight direction on gas concentration measurements: wind-tunnel test in a barn environment

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Open-air emission measurements of entire farms or manure storage systems have received increasing attention in recent years, creating a need for new measurement techniques to better characterize these complex sources. One promising approach is the use of drone flights to measure concentrations around the target system. However, several methodological challenges remain, including the potential influence of flight direction on measured concentrations.

In this study, a Sniffer4D Mini2 (AIRINS, Singapore) was used to quantify NH_3, CH_4 and CO_2 concentrations in a dairy barn. To simulate drone operation, the sensor was placed inside a wind tunnel (35 cm diameter, 3.7 m length) on a rotating platform positioned at the tunnel's center. The wind tunnel was deployed inside a dairy barn, and barn air was directed through the tunnel at different wind speeds, while the rotating platform allowed controlled variation in the angle between the Sniffer4D's inlet and the airflow. Four orientations were studied: air blowing on the front, back, left and right sides of the device. Because barn concentrations changed over time, Sniffer4D measurements were compared with those from a Picarro G2508 (Picarro Inc., USA), which sampled air at the same location.

For all studied orientations and flow rates, the Sniffer4D and Picarro G2508 showed similar concentration trends for NH_3, CH_4 and CO_2. These results indicate that the effect of flight direction on Sniffer4D measurements is minor, supporting the feasibility of drone-based concentration and emission monitoring. A next step is to account for the turbulence generated by the drone itself.

#21. Standardised measurement of CH4 and N2O emissions from deep litter systems in cattle barns

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Emissions of methane (CH_4) and nitrous oxide (N_2O) from deep litter systems in cattle barns are poorly quantified, and current inventories rely on generic emission factors that do not capture variation in bedding material, manure residence time, and in situ environmental conditions. This limits the accuracy of national greenhouse gas reporting and the evaluation of mitigation strategies.
This study presents a measurement framework for quantifying CH_4 and N_2O emissions from deep litter under commercial Danish farming conditions. Emissions will be measured using static chamber techniques applied directly on the litter surface in cattle barns. The methodological work includes optimisation of chamber design and spatial distribution to obtain representative emission estimates under heterogeneous conditions. To interpret emission dynamics, oxygen and temperature profiles will be measured within the litter matrix, allowing linkage between gas fluxes and aerobic or anaerobic conditions. In parallel, deep litter will be characterised for key physical and chemical properties to support interpretation of emission variability.
The project aims to develop standardised measurement methods for barn-scale emissions from deep litter systems and to generate high-quality datasets suitable for deriving improved emission factors. By linking emissions to measurable physical drivers, the approach supports reduced uncertainty in emission estimates and provides a robust basis for integration into national greenhouse gas inventories. The resulting datasets will further support the development and validation of process-based and empirical models for improved prediction of emissions under varying management conditions.

#22. Separating building-related and animal-related greenhouse gas and ammonia emissions in pasture-based dairy systems using continuous barn measurements

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Accurate quantification of greenhouse gas (GHG) and ammonia (NH_3) emissions from dairy production remains challenging, particularly when attempting to distinguish emissions originating from animals from those associated with housing infrastructure and soiled surfaces. Most studies report whole-barn emissions with animals present, and few approaches allow isolation of building-only contributions, limiting refinement of emission factors and mitigation strategies.

This study, conducted within the Canadian Carbon-Neutral Milk Living Laboratory, focuses on continuous gas measurements in three commercial Holstein dairy barns practicing summer pasture. Measurements were performed over 8–12 consecutive days per farm, enabling comparison between periods when animals were absent (pasture grazing) and present indoors (milking and/or overnight housing). This design allows estimation of building-only emissions and, by difference, animal-related contributions.

Preliminary results indicate that building-only emissions accounted for approximately 8% of CO_2, 9% of CH_4, and 57% of N_2O at the barn scale. Animal presence dominated CO_2 (92%) and CH_4 (91%) emissions. For NH_3, emissions were substantial during periods without animals, representing about 57% of total emissions, highlighting the role of soiled surfaces and residual manure. In CO_2-equivalents, building-only emissions represented about 11% of total barn emissions. When expressed per unit of production, building-only emissions corresponded to approximately 0.15 kg CO_2-eq per liter of milk, or about 15% of the average carbon footprint of milk Quebec.

These preliminary findings demonstrate that a non-negligible share of emissions originates from housing infrastructure. Ongoing analyses will refine these results, with final outcomes to be presented at the conference.

#23. Vertical stratification of physicochemical properties in livestock slurry storage tanks: Implications for representative sampling

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Accurate characterisation of livestock slurry is essential for nutrient management, emission estimation, manure valorisation, and reliable model inputs. However, sedimentation and stratification may affect sample representativeness within storage tanks. This study assessed vertical, horizontal, and between-tank physicochemical variability in commercial pig slurry storage tanks. A total of 144 samples were collected at multiple vertical positions, together with vertically integrated samples collected without prior mixing. Samples were analysed for dry matter (DM), volatile solids (VS), pH, total ammoniacal nitrogen (TAN), total nitrogen (TN), volatile fatty acids (VFA), total VFA (TVFA), lipids, and temperature. Sampling positions were normalised to slurry height. Linear mixed-effects models included relative vertical position and sampling opening relative to the slurry inlet as fixed effects, and tank and sampling date as random effects. Principal component analysis (PCA) explored multivariate compositional patterns. Relative vertical position primarily influenced particle-associated properties. From the bottom towards the slurry surface, DM and VS decreased by an estimated 2.18 and 10.0 percentage points, respectively. In contrast, pH, TAN, TN, VFA, TVFA, and lipids showed no significant vertical effect. PCA indicated substantial between-tank variability relative to vertical position. Differences among sampling openings were limited overall, although DM and TN varied between some sampling positions. Overall, vertical stratification mainly affected particle-associated properties, whereas solute-related properties showed no consistent vertical trend. These findings support improved representative sampling strategies for commercial slurry storage tanks.

Inventories and emission factors

#24. Preliminary ammonia concentration measurements in a covered outdoor runs (wintergarten) of mechanically ventilated broiler houses (+ flash talk)

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Covered outdoor runs (verandas; “wintergartens”) are increasingly used in Dutch poultry housing and are mandatory in Beter Leven 1-star broiler systems. However, validated methods to quantify their contribution to total ammonia emissions are currently lacking. This study explores initial measurement approaches and presents first indicative concentration data from a mechanically ventilated broiler house operated under negative pressure.

Ammonia (NH_3) concentrations were measured simultaneously inside the barn and in the covered outdoor run. Sampling lines were positioned near the access openings, at the interface between barn and run. Preliminary measurements showed very low NH_3 concentrations in the covered outdoor run (approximately 0–1.5 ppm), whereas barn concentrations increased over the production cycle, with typical average concentrations ranging from 3 to 15 ppm. These findings might suggest that, under negative-pressure ventilation[JH1] the run contributes only marginally to total NH_3 emissions compared to the barn. In addition, an indicative pattern/trend was observed where barn NH_3 concentrations decreased when the run was accessible and increased when access was closed. This pattern, however, requires confirmation across multiple flocks and under various conditions, such as wind direction, wind speed, and usage of the run).

Future work/research will focus on quantifying spatial and temporal variability of emitting surfaces through flux chamber (box) measurements in both barn and covered run, as well as improving partitioning of emissions between barn and the outdoor run.

#25. Livestock unit as an indicator in the assessment of agricultural activity in Latvia

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Since the beginning of the 20th century, efforts have been made to apply a single equivalent for assessing the number and density of livestock of various agricultural species, starting with the USA, later in Europe and elsewhere in the world. Various calculation methods have been developed for the livestock unit (LU) equivalent, which are used in legislative acts, at the national and international levels. The aim of project is to analyze the livestock unit calculation methodology used in Latvia and to develop recommendations for its renewal. Like many European countries, Latvia uses different LU coefficients for statistics, environmental impact assessments, and national support payment calculations. Different LU coefficients create a situation where the number of LU calculated for the same farm may be different - in environmental requirements it is calculated according to the total annual load (considering animal cycles and potential pollution), while the payment system uses simplified coefficients that reflect the number of animals at a specific time. In Latvia, in 1999, the guidelines were prepared, which defined the LU, indicating that it is an animal that produces 100 kg of nitrogen in manure per year after its storage, re-editing in 2008. It is necessary to conduct a study on whether the coefficients applied in Latvia are appropriate to the current situation, considering the increase in productivity of farm animals and the use of new breeding technologies and to facilitate the acquisition of reliable data on the breeds used, live weight, productivity, feeding, nutrient digestibility, manure production and composition.

#26. A novel approach to a farm gate accounts for carbon fluxes in pig production

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Understanding the partitioning of dietary carbon (C) - specifically its distribution among excretion, gaseous losses, and retention in the animal tissues is important for integrating C into established nutrient accounting systems. The Danish manure normative system currently regulates nutrient application via mass balance calculations for nitrogen, phosphorus, and potassium; however, C turnover is not yet included. Integrating C fluxes into this system would enable more accurate and transparent estimation of enteric methane (CH_4) and carbon dioxide (CO_2) emissions from pig production, thereby improving the assessment of on-farm nutrient flows and associated greenhouse gas emissions. The present work, therefore, is aimed at establishing a theoretical foundation for a comprehensive on-farm C mass balance. To enable the integration of C, models were developed for weaned pigs, grower-finisher pigs, and sows, using established prediction equations to estimate dietary C intake and its partitioning among excreta, gaseous emissions, and retention in animal tissues. Model outputs were generally broadly consistent with published experimental results, particularly for grower–finisher pigs, demonstrating that converting nutrient flows to carbon equivalents and applying established predictive relationships can effectively represent most production stages. Validation using an experimental dataset showed strong agreement for C intake and respiratory C losses, whereas predictions of fecal, urinary, and enteric CH_4 outputs were less accurate and require further improvement. Overall, the modelling framework provides a basis for integrating carbon dynamics into broader nutrient accounting systems.

#27. Estimation of greenhouse gas emissions from livestock in Morocco from 2000 to 2023

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This study estimates greenhouse gas emissions from the livestock sector in Morocco over the period 2000 to 2023, with a particular focus on methane (CH_4) and nitrous oxide (N_2O) emissions associated with enteric fermentation and manure management. The analysis is based on the Intergovernmental Panel on Climate Change Tier 1 methodology, following the 2019 Refinement to the 2006 Guidelines, and uses species-specific livestock population data at national and provincial scales. Livestock categories considered include dairy and non-dairy cattle, sheep, goats, camelids, equids, and poultry. Results indicate that methane emissions dominate the overall greenhouse gas profile, largely driven by enteric fermentation processes. Ruminant species, particularly cattle and sheep, represent the main contributors to total emissions, while nitrous oxide emissions from manure management remain comparatively lower but non-negligible. Total greenhouse gas emissions increased steadily from 2000 until the late 2010s, reflecting growth in livestock populations and structural changes in production systems. A decline in emissions has been observed in recent years, associated with reductions in ruminant populations. Spatial analysis reveals significant variability across provinces, with higher emission levels concentrated in regions characterized by intensive livestock activity and higher animal densities. The findings highlight the strong dependence of emissions on livestock population dynamics and production systems rather than on technological mitigation. The predominance of methane emissions underscores the importance of targeting enteric fermentation in mitigation strategies. This study contributes to improving the transparency and consistency of national greenhouse gas inventories and provides a scientific basis for developing climate-smart livestock policies in Morocco.

Mitigation strategies and technologies

#28. Characterizing the volatile compound fingerprints and removal efficiency of a dual-stage scrubbing process in multi-floor swine buildings via GC-IMS (+ flash talk)

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With the increasing scarcity of land resources, multi-story swine production has emerged as a significant trend in China. However, the high stocking density associated with these facilities has intensified concerns regarding odor emissions, and effective mitigation strategies are still being explored. This study evaluated the performance of a cost-effective dual-stage scrubbing system (acidic scrubbing followed by sodium hypochlorite oxidation) for treating exhaust air from a multi-story swine building. Ammonia (NH_3) concentrations, total odor levels, and volatile compound profiles were characterized using infrared photoacoustic spectroscopy, olfactometry, and Gas Chromatography-Ion Mobility Spectrometry (GC-IMS), respectively. The results showed that the odor emitted from multi-story swine buildings exhibits high concentrations. The average concentrations of NH_3 and odor in the exhaust air were 16.468 ±7.265 mg/m³ and 1204 ± 601 (dimensionless), respectively. GC-IMS effectively tracked the evolution of volatile profiles, revealing that while the system successfully removed NH_3, organic acids (acetic acid, propanoic acid, butanoic acid, and 2-methylpropanoic acids), and short-chain ketones (1-hydroxy-2-propanone and 3-hydroxy-2-butanone), it simultaneously triggered the formation of secondary by-products. These included alcohols (2-propanol, butanol), aldehydes (heptanal, nonanal), acetic acid ethyl ester, and hazardous species such as thiophene, dimethyl sulfide, and acrylonitrile (a Group 1 carcinogen). This study provides a robust methodology for evaluating swine odor and suggests that future research must integrate sensory and chemical assessments to optimize removal efficiency while minimizing the generation of hazardous secondary pollutants to ensure environmental safety.

#29. Scaling a Methane Eradication Photochemical System for Agricultural Applications (+ flash talk)

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Mitigation of anthropogenic low concentration methane (CH_4) emissions requires technologies that are both chemically efficient and industrially scalable. Learning from a field-scale prototype of the Methane Eradication Photochemical System, we are utilising the results in our development towards commercialization. New lab-scale prototypes have been produced to test more effective full-scale designs. CFD and light simulations are used to inform reactor design decisions on gas mixing, uniform air residence time and light utilization. These efforts aim to enhance energy efficiency, maximize the volume of air treated and screen candidate materials for reactor construction. All improvements are aimed at better understanding operational limits and expanding the system's capabilities before scale-up.

The field prototype utilized a 5.5 m^3 photochemical chamber within a shipping container. Air drawn from a cattle barn was mixed with Cl_2 and subjected to UV-induced photolysis. This process generates chlorine radicals that drive the oxidative degradation of CH_4 into CO and CO_2.

System scalability was evaluated at airflow rates of 250-1200 m^3/h at varying CH_4 concentrations. Key results included apparent quantum yield (AQY) of 5.68% at 89 ppm CH_4 (0.33 kWh/gCH_4) and a specific power of 0.53 kWh/gCH_4 at 44 ppm CH_4 (AQY 2.3%).

An updated swirl reactor design will allow for light panels covering the end, which in turn allows for a more uniform air-residence-time distribution. Laboratory measurements validate CFD-modeled residence-time uniformity. In addition, optical simulations predict approximately fourfold photon utilization in a full scale prototype compared to the field prototype.

#30. Integrated assessment of best available techniques for mitigating ammonia emissions from pig manure storage under Mediterranean climatic conditions (+ flash talk)

Esther Vega ORCID iD
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The transition toward more sustainable production systems is one of the main challenges facing the pig sector. In this context, livestock farms are increasingly implementing strategies to reduce ammonia and greenhouse gas emissions from their facilities. To address the environmental impacts associated with NH_3 deposition, European policies have promoted emission reduction programmes based on the mandatory application of Best Available Techniques (BAT), as defined in the European reference document. These techniques have been proven to reduce pollutant emissions and resource consumption while remaining technically and economically viable. However, their performance under Mediterranean climatic conditions has not yet been fully assessed.

The BATPORC project aimed to evaluate the effectiveness of several BATs, individually or in combination, to mitigate NH_3 emissions from pig slurry storage systems under Mediterranean conditions. Slurry from fattening and sow farms was stored at pilot-scale tanks, where seven strategies were tested and compared with a control tanks. The evaluated techniques included natural crust formation, floating devices , expansive clays, flexible covers, slurry acidification, and combinations of acidification with floating materials or clays. Ammonia emissions were monitored to determine emission rates and cumulative emissions.

Preliminary results from the first summer campaign showed that slurry acidification achieved mitigation efficiencies above 98%, regardless of combination with other techniques. Floating materials achieved moderate reductions (55-66%), while clays showed limited effectiveness for sow slurry (<10%) but higher mitigation for fattening slurry (≈70%). Further winter evaluations and subsequent industrial-scale validation will support evidence-based decisions for NH_3 mitigation in the Catalan pig sector.

#31. Reducing methane emissions from finishing pig houses through daily slurry acidification: Results from four commercial farms (+ flash talk)

Yijuan Xu, Mads Skjærbæk
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Manure acidification is a well-established environmental technology used in pig housing to reduce ammonia emissions, with documented reductions of approximately 64%. In addition to ammonia mitigation, recent studies indicate that slurry acidification may also significantly influence methane (CH_4) emissions from pig production systems. To quantify this potential effect under commercial conditions, experimental trials were conducted in four commercial finishing pig farms.

In all herds, slurry was acidified daily to pH 5.5 using an in-house acidification system supplied by InFarm Solutions. Methane emissions were measured periodically over a one-year period in each herd to capture seasonal variation and operational differences. Alongside methane concentrations, key parameters influencing emissions were continuously monitored or recorded, including ventilation rate, indoor temperature, feed consumption, animal numbers, and production performance.

Preliminary results indicate that daily slurry acidification substantially reduced methane emissions from the pig houses. Across the monitored farms, methane emissions were consistently lower than values typically reported for conventional finishing pig housing systems. Initial estimates suggest methane reductions exceeding 60%, although final data processing and statistical analyses are still ongoing.

These results contribute to improving the understanding of manure acidification as a potential climate mitigation strategy.

#32. Effect of calcium cyanamide on greenhouse gas and ammonia emissions during manure storage (+ flash talk)

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Manure additives have been proposed as a mitigation strategy to reduce greenhouse gas and ammonia emissions from livestock manure. Therefore, the effect of calcium cyanamide ($CaCN_2$) on methane (CH_4), ammonia (NH_3) and nitrous oxide (N_2O) emissions from stored cattle slurry were evaluated. Emissions were continuously measured from six pilot-scale tanks using a dynamic measuring chamber with controlled air outlet. Gas concentrations in exhaust and ambient air were sequentially measured with a gas analyzer. The experiment took place in spring (April-June 2025, 61 days) and in autumn/winter (October 2025-January 2026, 81 days). Two tanks received slurry treated with $CaCN_2$ in an experimental farm (treatment A), two received the same slurry with an additional dose (treatment B) and two received untreated slurry from the same farm (reference). Average emission rates from the reference slurry were 14 and 33 g CH_4 $m^{-3}day^{-1}$, 5.5 and 8.7 g NH_3 $m^{-2}day^{-1}$ and 0.09 and 0.20 g N_2O $m^{-2}day^{-1}$ in autumn/winter and spring respectively. Based on these rates, CH_4 emissions were substantially reduced, with treatment A and B achieving reductions of respectively 96% and 99% in autumn/winter, and 74% and 85% in spring. NH_3 emissions initially increased, but overall reductions were respectively 12% and 22% in autumn/winter, and 11% and 17% in spring. N_2O emissions were reduced in spring (treatment A 40% and treatment B 52%), but not in autumn/winter. In conclusion, $CaCN_2$ effectively reduced CH_4 emissions. Also total NH_3 emissions were slightly reduced and N_2O emission reduction only occurred in spring.

#33. Effects of 3-nitrooxypropanol on enteric methane production, feed intake and weight gain of Holstein Friesian heifers (+ flash talk)

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Evaluating the methane mitigating potential of feed strategies in vivo is essential to implement new strategies to reduce enteric methane emissions from cattle. However, there is currently a dearth of studies addressing such strategies for youngstock, and more specifically for a broad age group of youngstock. The aim of this study is to evaluate the effectiveness of the feed additive 3-nitrooxypropanol (3-NOP) in mitigating methane emissions from Holstein Friesian heifers aged 4 to 24 months. The youngstock are divided into three groups (4–12, 13-18, 19-24 months of age), based on the age-specific nutritional requirements, with group-specific 3-NOP doses of 150, 150, and 60-80 mg/kg DM, respectively. Treatments (placebo and 3-NOP) are included in the diet fed to the animals at pen level. Our methodology is therefore based on a replication over time of a nested crossover design within each of the 3 groups, in which pen (n = 2) is nested within treatment period, and animal is nested within pen. We hypothesize that methane emissions from each group, measured using the GreenFeed system, will be reduced by 20-30 %. A mixed model-oriented power simulation resulted in the need for three eight-week crossover experiments per group, of which the first are currently being carried out. This approach, which aims to examine different age groups of youngstock, could also be applied in other efficacy studies, leading to a more comprehensive assessment and therefore to a broader implementation of mitigating strategies for youngstock, whose individual feed intake often cannot be measured.

#34. Methane mitigation via photo-Oxidation: Scaling up photo-chemical processes to barn scale, process optimization and challenges in minimizing resource use towards economical and climate positive solutions. (+ flash talk)

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Methane Oxidation using chlorine radicals is a promising and cutting edge technology for the large-scale treatment of dilute methane emissions from agricultural and other sources. Using chlorine gas and UV light to produce chlorine radicals, methane can be oxidized to CO and CO_2 even at very low concentrations. However, scaling up gas phase photo-chemistry in highly oxidative environments introduces unique challenges which need to be overcome to effectively scale the process towards barn scale installations capable of processing large air flows. As with all climate mitigation technologies, this process also must be economical and be net climate positive for it to ever be commercially viable.

In this work we present Ambient Carbon's efforts to scale up this technology, and our approach to reducing resource use and improving process economics. As well, we present challenges to scale up the technology, and propose some solutions towards full scale treatment systems for cattle barns. Here we present specific efforts to minimize both chemical and energy requirements through process optimization and chemical recycle systems which can be integrated into necessary pollution control equipment already employed in the process. We will report on modeling and experimental results from both lab and field tests reducing chlorine loads and energy use, and for recycling of scrubber liquids for chlorine production. These approaches, combined with effective process control can make photo-chemical methane oxidation a scalable and effective technology for methane emissions mitigation, and we will show paths forward for the development of the technology.

#35. Design and development of innovative business models to foster sustainable management across the livestock manure value chain (+ flash talk)

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Livestock manure management is a major source of ammonia (NH_3) emissions and contributes indirectly to nitrous oxide (N_2O), a potent greenhouse gas. In Mediterranean pig production systems, high summer temperatures intensify NH_3 volatilisation and reduce nitrogen-use efficiency. The MITIGA-FERT project evaluates Best Available Techniques (BAT)—slurry acidification and urease inhibitors—to enhance nitrogen retention and mitigate emissions under real commercial conditions in Catalonia.

Pilot trials were conducted in two commercial pig farms with different ventilation systems: passive (Agrocat) and active (bonÀrea). Treatments were applied directly in the barns during summer, combining in-situ slurry acidification with urease inhibitors. Continuous environmental monitoring stations measured NH_3, CO_2, temperature and relative humidity, while treated and untreated slurry samples were analysed for physicochemical properties including pH, electrical conductivity, total solids, total nitrogen and ammoniacal nitrogen.

Acidification significantly reduced slurry pH and promoted the stabilisation of nitrogen in the ammonium (NH_4^+) form, enhancing nitrogen retention and slurry homogeneity. Sensor-based monitoring showed substantial reductions in NH_3 emissions, ranging from 40% to 81% compared with untreated controls. Emission mitigation was strongly linked to pH reduction, with values below approximately 5.5 favouring NH_4^+ stabilisation and limiting NH_3 volatilisation.

These findings demonstrate the effectiveness of combining slurry acidification and urease inhibitors to mitigate emissions in commercial pig production systems. Beyond reducing atmospheric losses, the treatments improve the fertiliser value of slurry and support circular nutrient management, contributing to more climate-resilient livestock production.

Keywords: ammonia emissions; slurry acidification; urease inhibitors; nitrogen retention; pig production.

#36. Field slurry application practices towards reduced GHG and NH3 emissions in China

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Field slurry application is globally applied as a part of sustainable recyling economy with however increased concern of gas emissmions. This study compared NH3 and GHG emissions during pig slurry application practices with selected treatments (in total 34 plots) in two locations of China (North and South). The treatments included various ratios of slurry and mineral fertilizers, acidified and non-acidified, sprinkler and drip irrigation, nitrification inhibitor addition and combined effects. The results showed that acidified pig slurry (pH=6) could reduce 38.0-42.6% NH3 emissions, while 30% pig slurry application gave 60.4% lower NH3 emission and 62% lower GHG emissions in average compared to 100% slurry application. Drip irrigation showed 38.9-42.6% lower NH3 emission and 12.4-18.6% lower N2O emission than sprinkler irrigation. However, the accidifcation may slightly increase the emission of N2O, while the nitrification inhibitor (DCD) addition could significantly reduce N2O emission up to 70%, and the mixed effects from accidification and DCD (AD group) gave similar or even higher reduction of N2O emissions. Meanwhile, AD group also showed 29.5-34.5% lower NH3 emissions. Overall, 30% partially pig slurry application, accidification especially combined with DCD could significantly reduce the emissions of NH3 and GHG emissions during slurry application in practice in China.

#37. Development of advanced oxidation scrubber technology for mitigating odour emissions from piggeries assisted by mass-spectrometry odour analysis

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Odour hindrance by ammonia and other odorant emissions from livestock facilities are of growing concern in regions with both high population and livestock densities, such as Flanders, Netherlands and Denmark. While mitigation strategies for ammonia have been optimized to reach reductions up to 95%, current best available technologies for mitigating odorous emissions only achieve reductions of 30 – 40%, which is often insufficient to meet local odour emission regulations.

This research aims to develop the scientific basis for an odour abatement technology based on advanced oxidation processes (AOPs), specifically targeting key odorants emitted from piggeries, including carboxylic acids, reduced sulphur compounds, amines, indoles, and phenols. The oxidation reactions of these odorants are investigated both individually and in mixtures, enabling the identification of competitive reaction kinetics and interferential effects. Based on these results, a predictive kinetic model is designed to estimate the reaction time of the odorants in the air scrubber needed for their elimination. Odour abatement is estimated using a chemo-analytical method, in which odorant concentrations are measured upstream and downstream of the air scrubber using mass-spectrometry-based methods, and subsequently converted into odour concentrations using the SOAV method.

Ultimately, this AOP-based module will be implemented as a downstream module in existing chemical air scrubbers optimized for ammonia removal, thereby enabling the simultaneous removal of both types of emissions within a dual scrubber installation.

#38. Holistic Perspective on the Manure Management Chain: Impact of Calcium Cyanamide (Eminex®)

Dominik Reiter, Benedikt Kappelsberger
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Manure management in agriculture is a major source of environmentally and climate-relevant emissions, including ammonia (NH_3), hydrogen sulfide (H_2S) and the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Numerous mitigation strategies have been developed to reduce these emissions and associated nutrient losses. However, measures targeting single process steps may lead to unintended effects, such as pollution swapping or emission shifts along the manure management chain. Therefore, emission abatement strategies require a holistic, life-cycle-based evaluation.

In recent years, a liquid manure additive based on calcium cyanamide ($CaCN_2$), formulated as Eminex® , has been identified as an effective measure for reducing gaseous emissions during manure storage. To assess its overall impact, research extended beyond storage to include downstream processes across the entire manure lifecycle. Extensive investigations—particularly within the EMeRGE research project—generated new insights into effects on biogas production, field application and microbiological processes.

The results demonstrate that $CaCN_2$ addition significantly reduces greenhouse gas emissions during storage while preserving nutrients for subsequent use. This nutrient conservation can enhance methane yields during anaerobic digestion and improve crop yields following field application, while simultaneously reducing soil-borne N_2O emissions. Microbial dynamics play a key role in these effects.

Overall, $CaCN_2$ represents an efficient manure additive with multiple positive effects along the manure management chain. Its application supports emission mitigation without compromising, and potentially improving, resource efficiency, thereby contributing to a reduction of the climate impact of both livestock and crop production.

#39. Nitrate scrubbers: A new generation of NH_3 scrubbers for livestock housing produced by Circlair

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In answer to the European nitrogen crisis, a new type of air scrubbers has been developed and brought to the market by the KU Leuven spin-off, Circlair.

Air scrubbers are no new technology and already exist either as biological scrubber, using micro-organisms or as a chemical scrubber using H_2SO_4 as acidic compound in order to capture the basic NH_3. Both scrubber types are left with discharge water with a low nitrogen concentration and therefore a rather low economic value.

This is what the new type of air scrubbers offer a solution for. Instead of H_2SO_4, HNO_3 used to capture and recover the NH_3 in the form of a concentrated and valuable ammonium nitrate (NH_4NO_3) fertilizer, without jeopardizing safety or NH_3 removal efficiency.

Results of a full scale set-up, treating air from around 1000 animals are presented. The new air scrubbers reach a NH_3 removal efficiency of 94%. Implementation of smart process control allowed water consumption to be reduced by a factor 5-10, while producing a NH_4NO_3 solution containing nitrogen in the concentration ranges of commercial, mineral fertilizers.

This technology offers a strong end-of-pipe remediation method as well as a circular use of valuable nitrogen molecules in a way that is sustainable for both environment and agriculture.

#40. Effects of two commercial additives on nitrogen and carbon losses from dairy cow manure

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CH_4 and NH_3 emissions from dairy manure contribute substantially to the environmental impact of livestock production. During slurry storage, relevant N-losses and C-losses may occur due to pollutant emissions. This in vitro study evaluated the effects of a mineral additive mainly based on calcium sulphate (MIN) and a microbial additive (MA) on the mass balance of N and C after 90 days of slurry storage. Treatments included unsupplemented manure (CTR), MIN and MA, applied at the manufacturers' recommended doses, with biweekly additions of fresh feces–urine mixture. Total N losses calculated by mass balance averaged about 70% of the initial and added N, with no significant differences among treatments. However, NH_3-N losses accounted for a greater proportion of total N in MA compared with CTR and MIN (59.94 vs 53.49 vs 50.94%) ($P = 0.01$), while MIN showed the lowest percentage of N lost as NH_3. Unaccounted N-losses were detected in all treatments, ranging from 11% to 19% of initial N ($P = 0.01$). C-losses determined by mass balance averaged approximately 33% of the initial and added C and differed among treatments ($P = 0.02$), being higher in MA and lower in MIN (34.76 vs 31.54%). However, gaseous C-losses ($CO_2 + CH_4$) were significantly lower in MA ($P < 0.01$). An unaccounted C-loss was observed in all treatments, particularly in MA (59.74%, $P < 0.01$). These findings highlight relevant unaccounted N and C-losses during slurry storage and show differences in emissions caused by different mineral and microbial treatments.

#41. Effect of manure removal frequency on air quality in dairy barns

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The experiment was conducted at the *Centre de recherche en sciences animales de Deschambault* (CRSAD), located in Quebec, Canada. A total of 24 heifers were included in the study. Two scraping frequency treatments were evaluated: conventional scraping (three times per day) and increased scraping (ten times per day). Each trial lasted three weeks and was repeated three times. Gas concentrations (CO_2, CH_4, N_2O, and NH_3), as well as airborne particles and bioaerosols, were measured at specific time points during two sampling periods (morning and afternoon), starting from the second week after treatment implementation. In addition, manure was analyzed for physicochemical properties. The results showed no significant differences in CO_2, CH_4, and NH_3 emissions between treatments ($p>0.05$). However, CH_4 emissions were numerically higher under conventional scraping, whereas NH_3 concentrations were numerically higher under increased scraping. A significant interaction between treatment and sampling period was observed for N_2O emissions ($p<0.05$). In the morning, conventional scraping resulted in significantly higher N_2O emissions compared with increased scraping. In addition, particulate matter concentrations were lower under the increased scraping treatment. Moreover, a slight variation was observed in the nitrogen composition of manure: conventional scraping showed numerically higher ammonium ($N–NH_4^+$) concentrations, whereas increased scraping exhibited higher nitrite ($N–NO_2^-$) and nitrate ($N–NO_3^-$) concentrations. In conclusion, increasing the frequency of manure removal may improve air quality in dairy barns. Additional trials (with more cows and longer time) should be carried out to confirm the trend.

#42. A modular biofiltration system for sustainable pig slurry valorisation

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This study evaluates Agropurin® technology, developed by ECOCELTA, an integrated, low-cost system for pig slurry management combining solid–liquid separation with sequential biofiltration. The system aims to enhance nutrient recovery, reduce environmental impacts, and support circular economy practices. Raw sow slurry was processed through a three-stage biofiltration system consisting of a mussel shell compost filter, a vermifilter and an aquatic macrophyte unit. The treatment demonstrated high efficiency in contaminant removal and effluent stabilization, with heavy metals such as zinc and copper reduced by ~90%. Macronutrient dynamics revealed substantial nitrogen and phosphorus reductions, whereas potassium remained largely available in the final effluent. The combined action of physicochemical filtration, microbial and earthworm activity, and plant uptake ensured system robustness and adaptability to varying influent characteristics. The resulting products, including organic liming amendments, vermicompost and treated effluent, show strong potential for agricultural reuse highlighting a sustainable and efficient approach to livestock waste valorisation.

#43. Prediction of the ammonia emission potential based on the ALFAM2 model and meteorological conditions for slurry spreading

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Field application of slurry is a major source of ammonia emissions from livestock production. Besides low emission techniques, timing applications to reduce emissions is a promising option. We established a web-based tool which is easy to use for farmers to identify time periods for field application of slurry with a low emission potential for any location in Switzerland (aero.meteotest.ch).

The tool consists of a Swiss map. To estimate emissions, we used the ALFAM2 model. NH_3 emissions are calculated for each 1 km^2 grid in Switzerland based on actual meteorological projections from MOS (Multi-Model-Output-Statistics) for air temperature, wind speed and precipitation. The emission calculation over 48h is conducted at a time resolution of one hour over the next five consecutive days. It updates hourly based on the most recent weather projection. The calculated emission data are then classified: the lowest 65% of emission values are assigned to a green symbol, the 15% highest values to a red one. The remaining 20% in between the green and red values are assigned orange. When tipping onto the map of the web surface at the location where the slurry application will occur, the symbols green, orange and red are displayed for each 1h interval over the next 5 days.

Model calculations based on meteorological data 1999-2022 suggest an emission reduction potential ranging from approximately 2% to 11% of the total agricultural emissions by using the model. The costs which vary between approximately 0.02 and 0.20 Euro per kg NH_3-N reduced are moderate.