Book of Abstracts

of the EAAP-ASAS Conference on Livestock farming and the environment: emissions and solutions

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Angra do Heroísmo – Terceira Island (Azores), Portugal
19-21 April, 2026

Welcome to the EAAP-ASAS Conference on Livestock farming and the environment: emissions and solutions

On behalf of the EAAP & ASAS Organizing Committee and the University of the Azores, it is our honor and pleasure to welcome you to the EAAP–ASAS Conference on Livestock Farming and the Environment: Emissions and Solutions, scheduled for April 19th to 21st, 2026, in Angra do Heroísmo – Terceira Island (Azores), Portugal.

This conference provides a unique opportunity to bring together scientists, researchers, and professionals from Europe, America, and beyond to discuss the pressing challenges of animal production and its environmental impact.

The scientific program will address key topics related to emission mitigation, sustainable resource use, and innovative strategies for reducing the environmental footprint of livestock systems. Sessions will explore advances in animal genetics, nutrition, and precision farming, highlighting how technology, management practices, and scientific breakthroughs can contribute to climate-smart animal agriculture. Special attention will be given to genomic and nutrigenomic approaches, feed efficiency, circular economy models, and policy frameworks supporting sustainability in the livestock sector.

Set in the heart of the Azores, a region renowned for its lush pastures, volcanic landscapes, and long-standing commitment to environmental stewardship, Angra do Heroísmo offers an inspiring backdrop for this international meeting. Participants will not only enjoy a dynamic and stimulating scientific exchange but will also have the opportunity to experience the islands' unique culture, history, and natural beauty.

We are confident that the EAAP–ASAS Conference on Livestock Farming and the Environment will be an engaging and memorable event, fostering collaboration, innovation, and shared solutions for a more sustainable future in animal agriculture. We look forward to welcoming you to Terceira Island for an unforgettable and productive experience.

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The main aims of the EAAP are to promote, by means of active co-operation between its members and other relevant international and national organisations, the advancement of scientific research, sustainable development and production systems; experimentation, application and extension; to improve the technical and economic conditions of the livestock sector; to promote the welfare of farm animals and the conservation of the rural environment; to control and optimise the use of natural resources in general and animal genetic resources in particular; to encourage the involvement of young scientists and technicians. More information on the organisation and its activities can be found at www.eaap.org.

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The European Federation of Animal Science (EAAP) has close established links with its sister organizations of American Society of Animal Science (ASAS), American Dairy Science Association (ADSAS), Canadian Society of Animal Science (CSAS) and Asociación Latinoamericana de Producción Animal (ALPA) and is also member of the World Association for Animal Production (WAAP).

The American Society of Animal Science fosters the discovery, sharing and application of scientific knowledge concerning the care and responsible use of animals to enhance animal and human health and well-being.

These core principles and beliefs are the foundation for ASAS and will guide the implementation of this 5-year strategic plan,

1. Animals are essential to human life and well-being.
2. The care and use of animals are held to the highest standards of integrity and professional ethics.
3. Research and scientific information are communicated in an open, transparent, and dynamic manner.
4. Career development for animal scientists, educators, and producers is essential to the viability of the allied and animal industries.
5. Animal science and the production of animal-sourced foods must continually evolve to meet the needs and values of society.

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The American Society of Animal Science is a committed partner to the European Federation of Animal Science in producing this joint meeting.

Scientific programme

Session 1. Opening session

Date: Sunday 19 April 2026; 18:00 - 19:15
Chair: Johnson / Kreuzer

Theatre Session 1

Poster Session 1

Session 2. Enteric methane - Supplementation (1)

Date: Monday 20 April 2026; 9:00 - 12:45
Chair: Azevedo / Niu

Theatre Session 2

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Session 3. Animal Systems (1)

Date: Monday 20 April 2026; 10:30 - 17:00
Chair: Boland / Kirwan / Johnson

Theatre Session 3

Poster Session 3

Session 4. Enteric & manure methane

Date: Monday 20 April 2026; 14:00 - 15:30
Chair: Foggi / Chaves

Theatre Session 4

Poster Session 4

Session 5. Enteric methane - Supplementation (2)

Date: Monday 20 April 2026; 16:00 - 16:45
Chair: Foggi / Chaves

Theatre Session 5

Poster Session 5

Session 6. Enteric methane - Grazing (1)

Date: Monday 20 April 2026; 16:45 - 17:45
Chair: Foggi / Chaves

Theatre Session 6

Poster Session 6

Session 7. Nitrogen in Animal Systems

Date: Tuesday 21 April 2026; 9:00 - 13:15
Chair: Wagner Riddle / Olivo

Theatre Session 7

Poster Session 7

Session 8. Enteric methane - Grazing (2)

Date: Tuesday 21 April 2026; 10:30 - 11:15
Chair: Terranova / Kreuzer

Theatre Session 8

Poster Session 8

Session 9. Enteric methane - Non-dietary Measures

Date: Tuesday 21 April 2026; 11:45 - 13:00
Chair: Terranova / Kreuzer

Theatre Session 9

Poster Session 9

Session 10. Animal Systems (2)

Date: Tuesday 21 April 2026; 14:15 - 18:00
Chair: Leytem / Jackson

Theatre Session 10

Session 11. Enteric methane - Measurement methods

Date: Tuesday 21 April 2026; 15:00 - 17:00
Chair: Terranova / Kreuzer

Theatre Session 11

Poster Session 11

Accomplishments and latent potential in joint and complementary research efforts to reduce emissions in livestock systems

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Substantial advances in mitigating livestock-associated emissions have been achieved in recent decades, and further advances remain achievable. Research progress accelerated in five key areas: (1) refinement of measurement technologies and standardized protocols to quantify emissions under a wide range of production conditions; (2) characterization of variability in emission rates as influenced by management, environmental, and nutritional factors; (3) elucidation of mechanistic relationships between dietary composition, rumen function, emissions, and animal performance; (4) addressing the unit of interest and explanatory variables which reflects the determinants of the rate of the emission process, and (5) identification and evaluation of novel mitigation strategies. Over the past 15 years, coordinated international efforts among animal nutrition research groups enhanced understanding of mitigation mechanisms and promoted convergence in recommended practices, facilitated by the exchange and joint analysis of large-scale datasets and expertise. Recent developments, including the implementation of methane-inhibiting feed additives and low protein diets, can reduce enteric methane and nitrogenous emissions, potentially by tens of percent without compromising animal production. In contrast, in more extensive systems where protein deficiency commonly limits feed utilization, increasing protein supply may mitigate emissions by improving animal productivity and emissions per unit of product. Although disciplinary specialization remains indispensable, cross-disciplinary research is essential to quantify whole-system effects, including potential trade-offs and synergies across emission sources. The efficacy, feasibility, and adoption of mitigation strategies are highly dependent on production system context. Hence, interpretation and application of research findings, and assessing their mitigation efficacy must consider the structural, environmental, and management constraints inherent to diverse livestock systems.

Potential of plants and algae rich in secondary compounds on the mitigation of ruminant methane emissions

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Methane (CH_4) emissions from ruminants constitute a major greenhouse gas source and represent a loss of dietary energy, but are greatly dependent on dietary factors, such as feed ingredients. Fodder plants and agricultural by-products used in ruminant nutrition can differ widely in the composition of their secondary compound profiles and concentrations, and thus in their potential to modulate rumen metabolism and methanogenesis. We will review the evidence of the use of plants, including algae and agricultural by-products rich in secondary metabolites, as natural CH_4-mitigation strategies for ruminants. We will address the main secondary metabolite compound classes present in the most promising plants and in by-products including condensed tannins (CTs), phenolics, saponins, terpenoids, and, in the case of algae, the halogenated compounds, phlorotannin, and other related compounds, highlighting their individual potential efficacy and mechanisms, as well as the (in)consistency of the responses. Although for some feedstuffs the identified antimethanogenic potential can be attributed to a few specific secondary compounds, in many cases several classes of secondary compounds occur simultaneously. Moreover, even within each class (e.g., terpenoids), multiproduct enzymes that generate a wide diversity of molecular variants yield complex chemical patterns in a given plant species. The unpredictability and the synergistic effects of the multitarget properties of natural chemical cocktails must be considered to explain the large variability in responses observed when using these plants in ruminant feeding. Nevertheless, tropical and subtropical feed resources can provide regionally adapted, sustainable options, especially when using local forages and agro-industrial by-products. Challenges include compound standardization, palatability, toxicity, and practical feeding strategies and their integration into sustainable ruminant systems. detailed, though concerns about residue transfer, long-term safety, and practical implementation remain.

One size doesn't fit all: Challenges and opportunities in methane mitigation across diverse livestock systems around the world

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Livestock systems account for 30% of global anthropogenic CH_4 emissions, making them a key focus for near-term climate mitigation. Within the sector, CH_4 emissions are dominated by enteric fermentation, while manure management plays a smaller, system-dependent role. While technical options exist for both enteric and manure CH4 emissions, their feasibility and mitigation outcomes differ across production systems. In formal and input-intensive systems, interventions can deliver absolute CH_4 reductions. In contrast, in informal and low-input systems, options for absolute CH_4 reduction are limited and mitigation is more realistically achievable through reductions in emission intensity, driven by improvements in animal productivity. Overall, methane mitigation pathways must be compatible with food security, livelihoods, and resilience to climate change. Dietary shifts in countries, where consumption of animal-source foods exceeds nutritional recommendations, offer complementary mitigation potential. While the technical potential exists to reduce livestock CH_4 emissions by around 30% by 2030 under full adoption scenarios, implementation, adoption rates, and scaling remain key challenges. Mitigation progress requires economically viable mitigation options, context-appropriate extension systems, attention to trade-offs, and financing approaches, including carbon and results-based finance, that are compatible with emission-intensity metrics across diverse livestock systems.

Effects of supplementing beef cattle with oil macerate of Asparagopsis taxiformis on methane emissions, growth performance, meat quality and carbon footprint.

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Asparagopsis taxiformis (AT) contains several anti-methanogenic compounds, the strongest being bromoform (CHBr3). Macerating AT in vegetable oil yields an oil containing CHBr3: Bromoil. We fed the Bromoil to beef cattle to evaluate its effects on growth and ruminal methane (CH4) emissions, meat quality, and carbon footprint. Twenty yearling crossbred Angus males were randomly allocated to four pens. The Control diet (C) consisted of a total mixed ration (TMR) diet, and the supplemented diet was the same TMR diet with added Bromoil supplying 25 mg CHBr3/kg of DM (Bro). Diets were prepared daily and the animals were kept on the trial for 2 months. Live weight and dry matter intake (DMI) were monitored. Individual CH4 and carbon dioxide emissions were measured using the Greenfeed® system. Animals were slaughtered in a commercial slaughterhouse. Meat, fat, liver, and rumen wall samples were then collected for quality analysis, CHBr3 detection, and rumen examination. The carbon footprint for both diets was calculated. Results showed no differences in average daily gain between C (1.35 ± 0.143 kg) and Bro (1.17 ± 0.143 kg). The DMI was higher for C (9.1 ± 0.13 kg/d) than for Bro (7.7 ± 0.13 kg/d). Animals fed Bro had lower CH4 emissions. There are no differences in meat quality traits. The addition of AT oil extract in beef cattle resulted in a 67% decrease in direct CH4 emissions without affecting growth rates or meat quality and left no traces of CHBr3 in the meat or liver. Further studies are necessary to confirm that Bromoil is safe and stable as an anti-methanogenic additive in animal production.

Bromine mass balance calculation for dairy cows fed bromoform-based feed additives

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Bromoform-based feed additives exhibit strong antimethanogenic potential. It is hypothesized that bromoform is dehalogenated in the rumen into multiple end products, including methane and bromine, yet little is known about subsequent bromine distribution and recovery in ruminants. This study aimed to establish a bromine mass balance in dairy cows fed a bromoform-based feed additive. The objectives were to quantify i) total bromine intake from the different sources, ii) bromine output in urine, faeces, and milk, iii) the unaccounted bromine fraction and potential loss pathways. Data were collated from four in vivo studies conducted at Ellinbank SmartFarm, Australia, where at least one treatment included a bromoform-based feed additive supplemented twice daily at milking to lactating Holstein-Friesian cows. Bromine intake was quantified via ICP/MS from water, grain, vetch hay, and the additive, with outputs measured in urine, faeces, and milk. Total bromine intake ranged from 399 to 944 mg/day, with vetch hay contributing the largest proportion. Urinary excretion was the primary elimination pathway (46% of measured output), followed by milk (44%), with faecal excretion lowest (10%). Bromine recovery accounted for only 32 to 61% of intake, leaving a substantial proportion unaccounted for, likely due to volatilization losses and deposition into tissues. The milk biotransfer factor averaged 0.007 d/kg, allowing prediction of milk bromine concentrations from dietary intake. Observed milk bromine concentrations remained within established food-safety thresholds. These findings highlight the significant contribution of basal feed sources, emphasizing the need to account for them when evaluating the fate of bromine in livestock. Further research into volatilization pathways and tissue distribution is recommended to strengthen the understanding of the fate of ingested bromine.

Bromoform-based additive to reduce enteric methane in finishing Nellore cattle

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Mitigating enteric methane (CH_4) from ruminants is a key challenge for reducing the environmental footprint of beef production, especially in tropical systems where Zebu cattle dominate and feedlots are rapidly expanding. Compounds capable of directly inhibiting ruminal methanogenesis, such as bromoform-based additives, have shown global potential, but evidence under Brazilian commercial conditions remains limited. This study evaluated the efficacy of a bromoform-based feed additive on CH_4 emissions of finishing Nellore bulls fed a high-concentrate diet. Eighty animals were housed in individual pens and allocated to either a control group or a treatment receiving the additive at 30 mg/kg DM. Animals were adapted for 30 days before methane measurements were performed using the GreenFeed® system following an intensive, standardized protocol to ensure robust emission estimates. The additive produced a consistent and biologically meaningful suppression of enteric CH_4 across all metrics. Treated animals exhibited reductions of ~55% in daily CH_4 production (63.8 vs. 141.1 g/day), ~56% in CH_4 yield (8.9 vs. 20.0 g/kg DMI), and ~54% in CH_4 intensity (6.1 vs. 13.3 g/kg ADG). In line with the known mechanism of halogenated compounds, hydrogen release increased markedly, confirming redirection of metabolic pathways due to inhibition of methanogenesis. Importantly, growth performance (ADG ≈1.52 kg/day) and feed intake were fully preserved, indicating that substantial CH_4 mitigation was achieved without compromising productivity—an essential requirement for adoption in commercial feedlots. Overall, these results demonstrate that bromoform-based additives are a highly effective CH_4 mitigation strategy for finishing Zebu cattle in tropical intensive systems, strengthening the alignment between productivity and environmental sustainability.

Effects of leafy Brassica species on methane production and in vitro rumen fermentation characteristics

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This study evaluated the effects of five leafy Brassica species—bok choy (Brassica rapa subsp. chinensis), cabbage wombok (Brassica rapa subsp. pekinensis), Chinese broccoli (Brassica oleracea var. alboglabra), choy sum (Brassica rapa subsp. parachinensis), and watercress (Nasturtium officinale) on methane production and rumen fermentation using in vitro batch culture, when replacing grass hay at 0–100% of diet dry matter (DM). Substrates were incubated for 24h in rumen fluid from fistulated cattle, and gas, methane, volatile fatty acids (VFA), pH, and in vitro dry matter digestibility (DMD) were measured. Data were analysed with mixed models; species and inclusion level (e.g., dose) were fixed effects, incubation run (n=2) and run×dose×species was random. Significant species × dose interactions occurred for gas, methane, and DMD. Methane (% of gas, mL/g DM) declined sharply ($P<0.01$) with increasing Brassica inclusion, with 24–95% reductions at 25–75% and >95% at 100% replacement for most species. Chinese broccoli, choy sum, and bok choy showed the greatest mitigation; watercress had smaller but substantial effects. The DMD increased with Brassica inclusion ($P<0.05$). Species differences ($P<0.05$) were observed for pH, total VFA, acetate, butyrate (% of total VFA), and acetate:propionate ratio. Cabbage wombok had lower pH (5.95) than others (6.05–6.09; $P<0.01$). Total VFA concentration was highest for bok choy and cabbage wombok (~81–82 mM) and lowest for Chinese broccoli (58 mM). Acetate was highest for choy sum and Chinese broccoli (67–71%) and lowest for cabbage wombok (50%), whereas butyrate was highest in cabbage wombok (17.8%) and lowest in choy sum and Chinese broccoli (6–8%). The A/P ratio was highest for Chinese broccoli (4.01) and lowest for cabbage wombok (2.42). Brassica dose affected pH ($P=0.02$), propionate ($P=0.04$), and A/P ratio ($P<0.01$). These results indicate that leafy Brassicas markedly reduce methane while maintaining acceptable fermentation and increasing DMD. However, due to their low DM content (4.7–7.6% as-fed), they are most suitable as supplementary components in ruminant diets rather than as main feed, contributing to sustainable feeding strategies.

Mitigating Enteric Methane Through Forage Diversification: Effects of Greenleaf and Silverleaf Desmodium on Methane Yield and Intake of Dorper Sheep

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Adult Dorper rams (n = 36; 35.4 ± 5.2 kg) were used in a completely randomized block design with staggered entry (blocks of three sheep) to evaluate whether including Desmodium spp. legumes at 30% of total dietary dry matter decreases in vivo enteric methane (CH_4) emissions without compromising animal performance. The experimental period for each block was 20 days: 14 d for dietary adaptation with sheep housed in individual pens, followed by 6 d of sample collection during which the sheep were moved to individual crates. Three total mixed rations (forage: concentrate 85:15; 13% crude protein; 7.5 MJ/kg metabolizable energy) were formulated: T1, a grass-based control; T2, the control with 35% of forage part replaced by greenleaf Desmodium (D. intortum); and T3, the control with 35% replaced by silverleaf Desmodium (D. uncinatum). Sheep were housed in individual pens and fed the diets ad libitum, while dry matter intake (DMI) and fecal output were measured to determine apparent total-tract nutrient digestibility. Individual crates were placed in open circuit respiration chambers and remained there for the last 3 d of sample collection. Methane yield was calculated as grams of CH_4 per kilogram of DMI. Data were analyzed using one-way ANOVA, and treatment means were separated using Tukey's test at $P < 0.05$. Preliminary results from 21 rams indicate that legume inclusion increased DMI relative to control without affecting absolute total CH_4 emissions, but Desmodium-based diets lowered CH_4 yield emissions by up to 23%. Replacing 30% of total dietary dry matter from Rhodes grass hay with either D. intortum or D. uncinatum thus appears to reduce enteric CH_4 yield without detrimental effects on feed intake. This study forms part of the Low-Methane Forage Project (LMF), which evaluates locally available and climate-resilient forages in East African livestock systems. A complete analysis of enteric CH_4 emissions, animal performance, and nutrient utilization efficiency for the cohort of 36 sheep will be presented at the conference.

Reduction of enteric methane emissions in Belgian Blue bulls during the final growth stages by increasing fat supplementation

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Most studies on enteric methane reduction focus on dairy cattle. Beef cattle are less exposed, especially unique breeds such as Belgian Blue cattle. We hypothesized that increasing the fat level in the diet compared to a standard Flemish diet for growing and finishing Belgian Blue beef bulls from an age of 10 to 18 months (till slaughter) could reduce enteric methane emissions without negatively affecting weight gain. A crossover experiment was performed with 2 groups and 2 treatments during 4 periods of 3 adaptation weeks and 4 measurement weeks each. The treatment scheme was CTRL, TREAT, CTRL, TREAT for each group. For both treatments the diet consisted of 24 % pressed beet pulp, 36 % corn silage, 16 % mix silage of corn cob mix and fodder beet and 24 % concentrate feed on dry matter basis. The TREAT concentrate had a higher fat inclusion by incorporating the byproducts linseed cake and potato chips resulting in an increase in overall fat % from 4.8 % in CTRL to 9.5 % in TREAT. At the start of the experiment (first CTRL period), the first group (n = 14) was on average 11.9 months old with an average bodyweight of 477 kg, and the second group (n = 14) 10.4 months and with a bodyweight of 423 kg. The first CTRL period of the second group started 7 weeks after the start of the first period of the first group. Two GreenFeed systems were used to measure the methane emissions in both groups throughout the experiment, and the animals were weighed at the start and end of each measurement period. Statistical analysis was done at group level using a linear mixed model including treatment and age, using the animal and treatment period within the group as fixed effects. The absolute methane levels were 24.1 % lower in TREAT (145 g CH4/day) than CTRL (192 g CH4/day) with P = 0.0362. Daily weight gain was not different between CTRL (1.36 kg/day) and TREAT (1.46 kg/day) at P = 0.4166. We concluded that increasing the fat content of the diet reduces the methane emission of growing and finishing Belgian Blue bulls significantly without affecting daily weight gain.

In silico screening of food-derived compounds and in vitro rumen fermentation identifies Alliin as a potential methane inhibitor in dairy cows

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Enteric CH4 from ruminants is a major short-lived climate forcer and energy loss. Methyl-coenzyme M reductase (MCR) catalyses the terminal step of methanogenesis and is an attractive CH4 mitigation target. This study used in silico docking of natural molecules against MCR active site, ADMET filtering, and in vitro fermentation to identify CH4 inhibitors. The X-ray structure of MCR from Methanothermobacter marburgensis (PDB 5A0Y) with coenzyme M (CoM) as a reference ligand defined the catalytic F430 pocket. About 140,000 compounds from FooDB database were docked using the ICM platform, and a weighted score of −25 kcal/mol (CoM: −28 kcal/mol) was used as threshold, yielding 56 primary hits. Predicted ADMET properties, commercial availability, and literature evidence reduced it to 20 candidates with an untreated control and positive controls 3-nitrooxypropanol (3-NOP) and rosmarinic acid for in vitro testing. They were incubated at 1% of substrate organic matter (OM) in a 24-h Hohenheim Gas Test with rumen fluid from three dairy cows (duplicates per cow; n = 6). Gas production and concentration (CH4, H2, and CO2), pH, ammonia-N, VFA, in vitro OM digestibility (IVOMD), and dissolved gas concentration were measured and then analysed using mixed-effect models with donor cow as a random effect. Planned contrasts (compound vs. control) were used to assess compound effects. Positive control 3-NOP reduced CH4 yield (mL/g degraded OM) by 99%, dissolved CH4 concentration by 99%, and IVOMD by 5%, while Alliin reduced them by 51%, 50%, and 8%, respectively ($P < 0.01$). Both increased H2 accumulation ($P < 0.01$), indicating substantial inhibition at the terminal step of methanogenesis. Tiglic acid, glutaric acid, and allantoic acid caused reductions of 42%, 38%, and 35% in dissolved CH4 concentration, respectively ($P < 0.05$). This pipeline shows that large-scale docking of food-derived compounds targeting MCR, combined with ADMET filtering and in vitro validation, can identify natural candidates like Alliin. Further in vivo evaluations are required.

Tannin Supplementation in cow-calf pairs grazing a grass monoculture

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Cow-calf pairs grazing rangelands rely on grass-based diets that decline in quality over the season, reducing nitrogen (N) use efficiency and increasing enteric methane (CH_4) emissions. Grass monocultures also lack plant secondary compounds, such as tannins, which may improve nutrition and reduce environmental impacts. Twenty-four Angus cow-calf pairs grazed six 3.6-ha meadow bromegrass paddocks (4 pairs/paddock) over two consecutive years. All cows received 1 kg/cow/day of DDGs (Control; n=3 paddocks), while tannin-supplemented cows (TT; n=3) additionally received a quebracho-chestnut extract included at 0.5% dietary DM. After a basal period, cattle grazed three consecutive 14-d treatment periods. Mixed models included treatment, period, and their interaction as fixed effects; and year, paddock, and animal as random effects; and baseline values as covariate. Biomass removal did not differ between treatments ($P > 0.05$), though TT paddocks had greater ADF in Periods 2–3 ($P<0.05$). TT cows had lower BUN and fecal ADF ($P < 0.05$) and tendencies for lower urinary N ($P = 0.11$), and greater fecal N ($P = 0.12$). Methane production showed no treatment effects for daily emissions, yield, or intensity ($P>0.05$). Daily CH4 emissions and CH4 yield peaked in Period 2 and declined in Periods 3–4 for TT cows ($P<0.05$), with a smaller decline for Control animals over the same periods ($P<0.05$). Methane intensity was also lower for TT cows by Period 4 ($P = 0.041$). Across periods, TT cows consistently exhibited numerically lower CH4 emissions, reaching a 20% reduction by Period 4. Fecal fiber, N, and CH_4 outcomes aligned with bodyweight patterns: TT cows maintained BW while Controls declined 5%, and calf BW increased 37% in TT vs. 34% in Controls, although these differences were not significant ($P>0.05$). Thus, moderate tannin inclusion promoted selection of a higher-quality diet (lower fecal fiber and more fiber remaining in the grazed pasture), improved N-use efficiency, and reduced enteric CH4 emissions by up to 20%, supporting their potential as a strategy to enhance nutrient retention and mitigate environmental impacts in grass-based beef systems.

Nutritional Assessment and Enteric Methane Mitigation Potential of the Invasive Alga Rugulopteryx okamurae

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The proliferation of the invasive macroalga Rugulopteryx okamurae (R. okamurae) in the waters of the Azores presents a significant ecological challenge, requiring effective biomass management and valorisation strategies. This study evaluated the nutritional composition of R. okamurae and its effects on ruminal fermentation and enteric methane mitigation through in vitro assays. In vitro trials demonstrated that the inclusion of 5% R. okamurae (on a dry matter basis) in the diet led to a 98% reduction ($p<0.05$) in cumulative methane production after 24 hours of incubation, whereas a 1% inclusion resulted in a 38% reduction. Nonetheless, total gas production decreased significantly by 57.02% and 73.5% for the 1% and 5% inclusion levels, respectively, indicating a potential toxic effect at higher inclusion rates. The in vitro fermentation system was supplied with a basal diet representative of the conventional feeding regimen adopted for dairy cattle in the Azores. This diet comprised 50% local pasture—characterized floristically by approximately 80% Lolium perenne and 20% Trifolium repens—in addition to 25% corn silage, 20% grass silage, and 5% concentrate, yielding a forage-to-concentrate ratio of 95:5 on a dry matter basis. Nutritional analysis of R. okamurae revealed a crude protein content of 18.68%, neutral detergent fibre (NDF) content of 55.71%, and an elevated ash content of 31.86%. These results suggest that R. okamurae may serve as a functional feed additive for enteric methane mitigation in ruminants, provided it is administered at low inclusion rates. Further investigations are warranted to elucidate its toxicity profile and ensure its safety for practical application in ruminant nutrition.

Evaluation of seaweed-based feed additive on enteric methane emissions of grazing heifers on pasture

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Objective: This study evaluated the impact of a seaweed-based feed additive (SBFA) on enteric methane emissions in grazing heifers. Materials and Methods: Two groups of heifers (n = 11 per group) were maintained on tame pasture under identical conditions. The trial consisted of three phases: a two-week baseline period, a two-week adaptation period, and a seven-week full-dose period. During adaptation, the treatment group received seaweed-based feed additive (SBFA) once daily with increasing dose. The SBFA was then administered at full dose throughout the final phase, although individual intake varied. Enteric emissions of methane were continuously monitored using the GreenFeed Emission Monitoring system. And data were evaluated using a commercial software program (rStudio Team 2025, Boston, MA). During the baseline period, gas emissions was not different between the groups (P = 0.75); however, during the adaptation (P = 0.08) tended to be lower in the SBFA group compared to the control, and during the full-dose period methane emissions in the SBFA treatment group were significantly (P < 0.01) lower than in the control group (P < 0.01), averaging 53.7 g/d versus 203.2 g/d, corresponding to a 73.6% reduction in methane. Additionally, a prolonged suppression effect was observed, with methane emissions in the treatment group remaining low for up to 4 days (P = 0.08) post-supplementation. Implications and Applications: These findings indicate that SBFA, when administered once daily, has significant potential for mitigating enteric methane emissions in grazing cattle.

Effects of a bromoform-based feed additive on the fermentation profile and methane production in an in vitro batch culture system

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Bromoform inhibits methanogenesis and shows promise for methane mitigation, however, its chemical instability limits practical application. This study evaluated how an investigational veterinary product, bromoform stabilized in oil (Rumin8 Pty Ltd, West Perth, Australia) included at 1% of the incubation substrate DM, affects in vitro ruminal fermentation parameters. The incubation substrate was comprised of 70% cracked corn, 20% corn gluten feed, and 10% ground bermudagrass hay (DM basis). In each of the three incubation days (replicates), a representative sample of digesta was collected from two ruminally cannulated steers. The two treatments tested were control (substrate only) or substrate plus the bromoform stabilized in oil mixture at 1% of the substrate DM. Data was analyzed as a randomized complete block design using Proc Mixed from SAS. Bromoform stabilized in oil reduced CH_4 production (g of CH4 per g of incubated DM and per g of fermented OM) compared with control (P = 0.002 and 0.006, respectively). Final pH, total volatile fatty acids (VFA) and in vitro organic matter digestibility were not affected (P > 0.05) by the inclusion of the bromoform stabilized in oil. Acetate molar proportion (MP) was greater in the control (P = 0.02) whereas butyrate MP propionate MP, and valerate MP were greater in the oil (P = 0.002, 0.03, 0.03 respectively). Acetate propionate ratio was higher in control (P = 0.02). Bromoform stabilized in oil reduced methane production by 93%, changing fermentation profile, decreasing acetate and increasing propionate without negatively affecting digestibility or other in vitro fermentation parameters. Overall, these findings indicate that bromoform stabilized in oil may be a promising choice as a feed additive to mitigate methane emissions in cattle. However, in vivo studies are necessary to evaluate the full response in cattle and its impact on animal health and performance.

How long does it take to low levels of quebracho and chestnut tannin extract supplementation to grazing dairy cattle affect methane production?

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Enteric methane mitigation in grazing dairy systems is challenging because dietary additives must remain effective under fluctuating rumen and pasture conditions. Plant-derived tannins are promising natural options, yet the time required for rumen adaptation and the persistence of their effects remain unclear. This study evaluated the impact of long-term, low-dose supplementation with a quebracho–chestnut tannin extract (0.125% of estimated herbage DMI) on rumen fermentation, methane production, nitrogen metabolism, milk composition and udder health in grazing dairy cows. Five rumen-cannulated late-lactation Friesian × Jersey cows grazed perennial ryegrass for 70 days. Four 72-h in vitro fermentation assays were performed at −1, 24, 36 and 60 days, plus a post-supplementation sampling at +14 days. Milk yield and composition, urinary urea nitrogen (UUN), somatic cell count (SCC) and rumen parameters (gas, CH_4, VFA, NH_3) were repeatedly measured and analysed through nonlinear and mixed-effect models. Tannin effects emerged progressively: early changes were minimal, while clear reductions in gas and methane production appeared after 24–36 days, reaching ~34% lower CH_4 and substantially less total gas by day 60. Rumen NH_3 declined by ~25% and UUN by ~17%, indicating improved nitrogen use efficiency. Despite reduced in vitro degradability, no negative impacts on milk yield or milk solids were observed; instead, milk protein concentration increased during dosing. SCC and milk conductivity also decreased from day 24, although these benefits diminished once supplementation ceased. Overall, grazing cows required three to four weeks of continuous tannin exposure before full effects on fermentation and methane suppression were observed. Sustained supplementation is therefore essential for practical mitigation.

Hazel leaves: a means to reduce methane emissions and concomitantly improve the fatty acid profile of bovine milk?

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A variety of phenolic compounds, including tannins, have been shown to mitigate ruminal methane emission and to partially inhibit ruminal biohydrogenation. The latter mechanism may help preserve a portion of α-linolenic acid and enhance the proportion of conjugated linoleic acids in bovine milk fat, both of which are of particular importance for human nutrition. Certain phenols can also be transferred to milk, potentially offering additional health benefits to consumers. Compared to other phenol-rich feeds, hazel leaves have proved palatable to dairy cows and could represent a viable alternative if they indeed have anti-methanogenic effects and concomitantly enhance milk fat quality. Although a preceding short 3-day trial did not support the anticipated effects on milk fatty acids, longer-term exposure might yield different outcomes. Consequently, we compared our findings on methane emission to those on milk fatty acid profiles and phenol levels in a dose-response experiment. Over a 22-day period, 20 cows were offered diets containing incremental amounts of hazel leaves, ranging from 0 – 41% dietary dry matter (equivalent to 0.5 – 8.6% total phenols and 0.03 – 4.93% condensed tannins). Despite a clear dose-response relationship between hazel leaf proportion in the diet and methane mitigation, the fatty acid profile and total phenol content in milk were unaffected. Therefore, even though hazel leaves may offer environmental benefits, through reduced methane emissions, they do not appear to be an effective strategy for improving these distinct criteria in milk quality. However, as the inclusion of hazel leaves in the present diet diluted the α-linolenic acid proportion of total dietary lipids to a certain extent, they still seem to have exhibited a protective function in the rumen which could be strategically applied to diets supplemented with feeds rich in α-linolenic acid.

Influence of plant secondary metabolite-producing forb inclusion on digestive capabilities and greenhouse gas emission potential of beef steers

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Livestock production is implicated with contributing approximately 12% of global greenhouse gas emissions, with enteric fermentation from ruminant animals representing a significant proportion of this contribution. However, alterations in forage species, especially inclusion of those producing plant secondary metabolites [PSM]) are known to influence rumen microbial activity, potentially shifting patterns in digestive efficiency and, therefore, methane production. This study evaluated the effect of warm-season forb inclusion into forage-based diets on in vivo and in vitro digestibility and methane production. We conducted an in vivo metabolism experiment in a 4 × 4 Latin square design. Dietary treatments consisted of a 70:30 ratio of bahiagrass (Paspalum notatum Flueggé) and either lablab (Lablab purpureus [L.] Sweet; LAB), soybean (Glycine max [L.] Merr.; SOY), or sunn hemp (Crotalaria juncea L.; SUN). A grass-only treatment served as the control (CON). This metabolism experiment was used to determine intake and digestibility as well as estimate CH4 emissions via the IPCC Tier 2 calculations. Rumen fluid collected from the in vivo experiment was used to incubate duplicate flasks to assess potential activity of methane production (PAMP). Contrary to the study design, steers did not consume the targeted amount of their prescribed forb (LAB = 3.1%; SOY = 3.7%; SUN = 7.6%). There was no effect of diet on intake ($P = 0.90$) or in vivo digestibility ($P = 0.17$) of DM. Therefore, there was no effect of diet ($P = 0.98$) on estimated daily CH4 emissions. There was, however, an effect of diet on PAMP ($P = 0.01$). Methane production potential was greatest ($P < 0.05$) from CON (1.8 g/kg DM) and least ($P < 0.05$) from SUN (0.2 g/kg DM), with LAB (1.5 g/kg DM) and SOY (0.8 g/kg DM) intermediate. Results are interpreted to mean that selection and strategic incorporation of PSM-producing forbs may influence CH4 emission contributions of ruminant livestock, but intake will be a pivotal factor in successful deployment of this management strategy.

Evaluating the methane mitigation potential of Canadian oilseed co-products using in vitro ruminal batch culture

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The objective of this study was to evaluate the in vitro ruminal fermentation of hay diets supplemented with increasing inclusion of Canadian oilseed co-products. In a completely randomized design, the in vitro ruminal batch culture was conducted with a control (bromegrass hay) and six oilseed co-products (camelina hulls; CH, camelina meal; CM, yellow mustard bran; YMB, yellow mustard seed; YMS, oriental mustard bran; OMB, and oriental mustard seed; OMS) at increasing inclusion rates (0%, 2.5%, 5%, 10%, and 100% DM). Dry matter (DM) and fiber disappearance, cumulative gas (GP) and methane (CH4) production, and volatile fatty acid (VFA) concentrations were evaluated. Statistical analysis was performed using PROC MIXED with treatment and dose as fixed effects, with batch (n = 3) and replicate (n = 3) within batch as random effects. There was no effect ($P \geq 0.84$) of the co-products included at up to 10% on DM or fiber disappearance. There was a quadratic response ($P < 0.01$) of CH on GP without affecting CH4 production or VFA proportions, in which GP was decreased at 2 and 5% inclusion. Increasing inclusion of Oriental mustard co-products up to 10% linearly reduced ($P < 0.01$) CH4 production by up to 20% compared to the control. Increasing inclusion of CM linearly increased ($P < 0.01$) the proportion of iso-valerate and increasing inclusion of YMB linearly decreased ($P < 0.01$) acetate. The YMS linearly decreased ($P < 0.01$) acetate and the acetate to propionate ratio (A:P), and linearly increased ($P < 0.01$) iso-valerate with increasing inclusions up to 10%. Total VFA and A:P ratios decreased linearly ($P < 0.01$) when either OMB or OMS were included at doses up to 10%. All six co-products reduced ($P < 0.001$) GP and CH4 when incubated alone (100% inclusion) compared to bromegrass hay. The disappearance of DM was lesser for the CH and greater for all mustard co-products when incubated alone compared to the control ($P < 0.001$). The results of this experiment indicate that including Canadian camelina and mustard co-products at up to 10% in a high-forage diet reduces overall gas production without affecting nutrient disappearance.

Evaluation of Rumen-Protected Lysine Supplementation on Performance and Greenhouse Gas Emissions in Nellore Beef Cattle Finished in Feedlot

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This study investigated the impact of rumen-protected lysine (RPL; AjiPro®-L, Ajinomoto Health & Nutrition North America, Inc., USA; 25 g/d) supplementation on performance and GHG emissions in Nellore beef cattle during a feedlot period. 120 non-castrated Nellore cattle were allocated to either a control group (CON; n = 60) or a treatment group (LYS; n = 60) supplemented with RPL, housed in 12 pens (10 animals/pen). Initial and final body weights (IBW, FBW) were measured after 16 h of fasting on day 0 and at the end of the trial. Carcass gain was calculated as the difference between final and initial carcass weights (IBW × 50%). Dry matter intake (DMI) was recorded at the pen level. Methane emissions were quantified by the sulfur hexafluoride tracer technique in 30 animals per group during days 50–67 and 100–107. Feed related GHG emissions were estimated according to FAO LEAP (2020), while manure-related GHG emissions were calculated by the IPCC 2019. Data were analyzed using generalized linear mixed models in R (ver. 4.2.2). No significant differences were found between groups for IBW (CON: 270.0 kg; LYS: 270.3 kg; P = 0.86), FBW (CON: 455.7 kg; LYS: 457.2 kg; P = 0.82), or carcass gain (CON: 119.8 kg; LYS: 120.8 kg; P = 0.78). Average DMI was lower in the LYS (CON: 10.0 kg/d; LYS: 9.2 kg/d; P = 0.21), and a significant group × day interaction (P < 0.01) indicated a smaller increase in DMI over time for LYS. Enteric methane emissions tended to be reduced in the LYS (CON: 3.8 kg CO_2e/day; LYS: 3.5 kg CO_2e/day; P = 0.09). Combined feed and manure related GHG emissions were estimated at 13.2 kg CO_2e/day for CON and 12.2 kg CO_2e/day for LYS. In conclusion, RPL supplementation demonstrated the potential to sustain growth performance while improving feed efficiency and reducing estimated GHG emissions, indicating a promising approach for more sustainable livestock production. This research was supported by FAPESP (2021/11922-2) and CNPq
Keywords: enteric methane, feed efficiency, greenhouse emissions, sustainable livestock production

The impact of Essential Oils on the in vitro methane production and ruminal fermentation

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Essential oils (EO) from aromatic plants are recognized for their biological activities, such as antimicrobial properties, and can modify ruminal fermentation and reduce the methane (CH_4) emissions by altering the ruminal microbiome. The present study aimed to evaluate the impact of increasing doses of EO from Oregano (Origanum vulgare L.), Thyme (Thymus mastichina L.), Rockrose (Cistus ladanifer L.) and Lavender (Lavandula stoechas L.) on in vitro ruminal fermentation and CH_4 production. Increasing doses of each EO (0, 300, 600, and 900 mg/L) were incubated at 39°C for 24 hours with ruminal fluid over six runs. A composite feed (40:60, forage to concentrate) supplemented with 6% sunflower oil was used as the substrate. Gas production was monitored using the AnkomRF Gas Production system, and CH_4 production and volatile fatty acid (VFA) composition were determined by gas chromatography. Oregano and Rockrose EO linearly reduced CH_4 production (P<0.001). Total gas production also decreased linearly for both oils (P<0.001). Oregano EO further reduced the total VFA (P<0.001), but Rockrose EO did not affect the VFA concentration. Thyme and Lavender EO did not affect the CH_4 production but moderately influenced the total gas production and VFA concentration. The results indicate that the oregano EO has the greatest capacity to inhibit the ruminal fermentation, though high doses may negatively impact productivity. Rockrose EO appears to mitigate CH_4 production without compromising ruminal fermentation, making it the most promising option for sustainable ruminant production.

Evaluation of essential oils on in vitro ruminal fermentation, gas production kinetics, and enteric methane mitigation

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This study aimed to evaluate the effects of increasing doses of essential oils (EO) on in vitro ruminal fermentation, gas production (GP) kinetics, and methane (CH_4) emissions under contrasting dietary conditions. Two independent experiments were conducted, each with five treatments: negative control (CON), three EO doses (150, 300, and 450 mg/kg DM), and monensin (MON; 30 mg/kg DM) as the positive control. Experiment 1 used a forage rich diet (90:10), while Experiment 2 employed a high concentrate diet (10:90). Fermentations were carried out in an Ankom system with six replicates per treatment. Total gas production (TGP), volatile fatty acids (VFA), ammoniacal nitrogen ($N–NH_3$), and CH_4 production were determined. Data were analyzed using ANOVA with Fisher's LSD and linear/quadratic contrasts. In Experiment 1, EO increased GP at 24 and 72 h compared with MON ($P \leq 0.01$), with values similar to CON. $N–NH_3$ increased with EO, exceeding MON ($P=0.0078$). EO also increased total VFA ($P=0.0002$) and altered fermentation profile, increasing acetate (69.0; 69.5 vs. 66.4%) and decreasing propionate ($P<0.001$). However, EO increased CH_4 compared with MON and elevated CH_4 related relative energy losses (154;187% vs. 108%). In Experiment 2, MON increased digestion rates ($P<0.04$), whereas EO reduced both coefficients (0.14 and 0.04 h^{-1}). EO increased total VFA and raised acetate ($P=0.02$) and valerate ($P=0.008$). CH_4 production also increased with EO ($P=0.03$), while MON presented the lowest value. CH_4 related energy losses were greater with EO, remaining lower with MON. Ammonia nitrogen increased linearly with EO inclusion, indicating greater proteolytic activity in these treatments as well as in the CON group. EO supplementation was effective in increasing total ruminal VFA concentration and also elevated the proportions of acetate and valerate. However, EO were not effective in reducing CH_4 production or relative energy loss via CH_4 compared with MON and CON treatments.

Dietary supplementation of Agolin Ruminant® reduced enteric methane emissions in dairy buffaloes monitored by sniffer method

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Interest in feeding strategies to mitigate enteric methane (CH4) emissions from ruminants has been increasing, and current research is focusing on natural additives for reducing the methanogenic activity in the rumen without compromising animal productivity or physiological functions. This study was aimed at evaluating the effect of dietary supplementation of Agolin Ruminant® (Agolin, Alltech Technology, US), a blend of natural essential oil extract, on enteric CH4 emissions in lactating dairy buffaloes. The trial included a 4-weeks control phase and an 8-weeks treatment phase, with the initial 4 weeks of treatment designated as a rumen-adaptation period to the supplement. Agolin was dispensed through the feeder of the automatic milking system (AMS, DeLaval, SE) as 1 g/head per day to 37 primiparous lactating buffaloes with 86.6±77.5 DIM, and with an average milk yield of 10.4±3.1 kg/d. A sniffer unit (Tecnosens, Brescia, IT) was installed in the AMS to monitor the individual emissions of enteric CH4. Animals were equipped with DeLaval ear tag sensors to record behavioural parameters such as the daily eating and ruminating time. Total mixed ration (TMR) was distributed twice daily and dry matter intake (DMI) was estimated considering the amount of TMR supplied and residual. Statistical analysis was performed using a general linear model and Tukey test to assess significant differences. Across the control and treatment phases, DMI, eating and ruminating times did not exhibit significant differences. Dietary supplementation of Agolin reduced enteric CH4 emissions by approximately 14% ($p < 0.001$) indicating that Agolin may be effective in mitigating CH4 emissions in lactating dairy buffaloes. Further studies are being carried out by using other CH4 monitoring systems.

Effect of garlic by-product supplementation on methane emissions in Merino lambs

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The use of agricultural by-products as natural feed additives represents a sustainable strategy in livestock production. Garlic waste, derived from unmarketable production, possesses antimicrobial, antioxidant, and immunomodulatory properties that may influence enteric methane emissions through modulation of rumen fermentation. The aim of this study was to evaluate the effect of including 4% garlic by-product in the diet of Merino lambs on CH_4 emissions. The trial was conducted at CICYTEX experimental farm (38.854°N, 6.670°W) using 30 Merino lambs, allocated to two groups of 15: a control group with no garlic inclusion and an experimental group receiving 4% garlic in the diet. Both diets were formulated to be isoproteic and isoenergetic. The trial lasted 24 days with individual feed intake recorded daily. Methane emissions were measured daily using a hand-held laser methane detector positioned at 1 meter from each animal for 3 minutes, recording respiratory CH_4 (CH4r), eructated CH_4 (CH4e), and total CH_4 in ppm. Statistical analyses considered the effects of treatment, day, and their interaction ($P<0.05$). Total CH_4 emissions did not differ between groups (8.40±0.2 vs 8.31±0.16 ppm; P=0.783). However, garlic supplementation significantly reduced CH4r (6.74±0.11 vs 7.66±0.13 ppm; P=0.001) and increased CH4e (19.44±1.79 vs 8.6±1.64 ppm; P=0.009). A significant treatment × day interaction was observed for CH4r, with respiratory methane emissions decreasing over time in the garlic group. Eructation frequency was significantly higher in garlic-fed lambs (60% vs 23.3% presence; P=0.001). These results demonstrate that 4% garlic by-product supplementation does not reduce total methane emissions but significantly modifies the emission pathway, shifting CH4 release from respiration to eructation, as reflected by increased eructation frequency. This suggests garlic by-product modifies rumen fermentation patterns without providing a net mitigation effect on total CH_4 emissions. Acknowledgements: Project 0100_TID4AGRO_4_E is co-financed by the European Union through the INTERREG VI-A Spain-Portugal Programme (POCTEP) 2021-2027.

Effects of dimethyl sulfoxide dose on in vitro rumen fermentation and methane production

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This study evaluated dose–response effects of dimethyl sulfoxide (DMSO) on ruminal fermentation characteristics and methane production using a 24-h in vitro batch culture system. Seven DMSO concentrations (0, 0.1, 0.2, 0.4, 0.5, 0.8, and 1% vol/vol) were incubated with a grass-hay substrate across three fermentation runs, with incubation run defined as the experimental unit. Data were analysed using PROC MIXED (SAS 9.4) with dose as a fixed effect and run and run dose as random terms. Linear (L) and quadratic (Q) contrasts were evaluated. The DMSO did not affect pH (P=0.49) or total gas production (P=0.46). Methane concentration and yield decreased quadratically ($P<0.01$), with CH_4 (%) reduced by 12–18% at 0.1–0.2% DMSO, by 24% at 0.4%, and by 29–32% at 0.5–1%. Total VFA concentration (mM) exhibited a strong quadratic response ($P<0.01$): 0.1–0.2% DMSO decreased total VFA by ~15% relative to control, 0.4% yielded values similar to control, and 0.5–1% increased total VFA by 13%, 33%, and 49%, respectively. The molar percentage of acetate also showed a quadratic pattern ($P<0.01$), increasing at 0.1–0.2% (+21% and +14%) followed by progressive reductions at 0.5–1% (−15% to −36%). Propionate exhibited a similar nonlinear trend ($P<0.01$), with increased at 0.1–0.2% (+18% and +13%), a slight reduction at 0.4% (−6%), and marked decreases (−16% to −36%) from 0.5–1%. Butyrate increased sharply with rising DMSO doses, shifting from a reduction at 0.1–0.2% (−89% and −59%) to substantial elevations at 0.4–1% (+16% to +171%). Minor VFAs (BCVFA, valerate, and caproate) declined linearly ($P \leq 0.03$) at DMSO concentrations ≥0.4%. The acetate:propionate ratio was unaffected (P=0.17). In summary, DMSO altered fermentation in a strongly dose-dependent, nonlinear manner. Low doses (0.1–0.2%) reduced total VFA but increased acetate and propionate % of total VFA, whereas higher doses (≥0.5%) stimulated total VFA production, decreased acetate and propionate, and substantially increased butyrate. Across all doses, methane production decreased quadratically. Collectively, DMSO modulated rumen fermentation pathways while consistently suppressing methane, suggesting dose-dependent shifts in microbial fermentation.

Malate salts as modifiers of ruminal fermentation and reducers of methane emissions

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This study analyzed the effects of disodium/calcium salts of malic acid (Rumalato®; RUM) on in vitro methane production and ruminal fermentation of a mixed dairy diet (40 % alfalfa hay and 60% high-cereal concentrate) as a strategy in reducing the environmental impact of livestock production. Sodium monensin (MON) was included as a positive control due to its antimethanogenic effects. Diet (300 mg) was incubated in 120-mL glass vials without additives (control) and with RUM (1.63 g/L) or MON (4.73 mg/L). Additives were added to the vials immediately before adding 30 mL of buffered ruminal fluid from 4 sheep. Methane, total volatile fatty acid (VFA) and NH3-N concentrations were measured at 12 and 24 h of fermentation. Data were analyzed by ANOVA using generalized linear mixed models with the treatment as a fixed effect and inoculum as a random effect, and post hoc analysis through Tukey test was performed. At 12 h incubation, RUM increased and MON decreased total VFA compared with control (P<0.05; 1.98, 1.56 and 1.65 mmol/vial, respectively). Both additives decreased acetate and butyrate proportions (63.3, 60.2 and 60.4%; 11.2, 9.52 and 9.90% for control, RUM and MON, respectively) and acetate/propionate ratio (2.77, 2.17 and 2.15 mol/mol), and increased propionate proportions (22.9, 27.9 and 28.4%) compared with control. Concentrations of NH3-N were unaffected by RUM, but were decreased by MON (P<0.05). Both additives decreased methane/VFA ratio compared to control (2.11, 1.62 and 1.62 mL/mmol for control, RUM and MON, respectively), indicating improved energetic efficiency. The effects of both additives were maintained after 24 h incubation, although acetate and propionate proportions were greater and lower, respectively, for RUM than for MON (62.0 vs. 58.2%; 25.6 vs. 29.8%), and MON decreased the methane/VFA ratio more markedly than RUM (3.08 vs. 3.83 ml/mmol). The results indicate that Rumalato® influences ruminal fermentation similarly to MON, increasing total VFA production and propionate proportion and decreasing methane/VFA ratio, thus improving the energetic efficiency of the diet.

The synergistic effect of malate and monensin enhances rumen fermentation

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Different strategies have been developed during the past decades to enhance rumen efficiency through maximizing carbohydrate utilization while maintaining animal health. This study evaluated the synergistic effects of sodium monensin (MON) and disodium/calcium salts of malic acid (Rumalato®; RUM) on the in vitro ruminal fermentation of a dairy diet composed of 40:60 alfalfa hay: high-cereal concentrate. The diet (300 mg) was incubated in 120-mL glass vials without additives (control), with MON (final concentration 4.73 mg/L), or with a combination of MON and RUM (MIX; MON + 1.63 g/ L RUM). Additives were added immediately before introducing 30 mL of buffered ruminal fluid obtained from four sheep. Methane and total volatile fatty acid (VFA) production and NH_3-N concentrations were measured at 12 and 24 h of fermentation. Data were analysed using ANOVA with generalized linear mixed models, including treatment as fixed effect and inoculum as random effect. Post hoc comparisons were conducted using the Tukey test. At 12 h of incubation, MON significantly decreased, while MIX increased total VFA concentrations compared to the control (P<0.05; 1.56, 1.94, and 1.65 mmol/vial, respectively). Both treatments reduced the proportions of acetate + butyrate (from 74.5% to 69.97% and 66.17% for MON and MIX, respectively) and the acetate-to-propionate ratio (2.77, 2.17, and 1.80 mol/mol). Propionate proportion increased from control (22.9%) up to 28.4 and 32.4% for MON and MIX, respectively. NH_3-N concentrations were reduced by the treatments. Both MON and MIX reduced the methane/VFA ratio from the control (2.11, 1.63, and 1.47 mL/mmol for control, MON, and MIX, respectively), indicating improved energetic efficiency. The effects of the additives remained at 24 h. MIX resulted in a higher propionate proportion than MON (33.14 vs. 29.8%). Furthermore, MON showed a lower acetate + butyrate proportion (65.11 vs. 68.2%), while MIX achieved a more pronounced reduction in the methane/VFA ratio compared to MON (2.85 vs. 3.08%). These results highlight the beneficial synergistic effects of RUM and MON on rumen efficiency.

In vitro evaluation of natural additives on ruminal fermentation and methane emissions in finishing diets

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The objective of this study was to evaluate the effects of ruminal fermentation-modulating additives on in vitro fermentation and methane (CH_4) production using a diet for feedlot cattle. The basal diet was formulated to support an average daily gain of 1.5 kg. Six treatments were evaluated: a negative control (CON), a positive control with monensin at 25 mg/kg DM (MON), Beeocattle at 50 and 200 mg/kg DM (BC50 and BC200), and Beeocattle Plus at 50 and 200 mg/kg DM (BPC50 and BPC200). Rumen fluid was incubated for 48 h using a wireless gas-production system (AnkomRF) across four incubation periods, with four bottles per treatment and four blanks per period. Gas-production kinetics, total gas production (GP), volatile fatty acids (VFA), ammoniacal nitrogen ($N–NH_3$), and enteric CH_4 were quantified. Data was analyzed using generalized linear mixed models. Kinetic parameters were estimated using the NLIN procedure, and means were compared using Fisher's LSD test ($P \leq 0.05$). All flavonoid-based additives reduced CH_4 compared with CON (BC50: 4.23 mmol, −29.4%; BC200: 4.82 mmol, −19.4%; BPC50: 5.15 mmol, −14.0%; BPC200: 4.03 mmol, −32.7%; CON: 5.99 mmol), while MON presented the greatest inhibition (2.69 mmol, −55%). Total VFA did not differ from CON (P>0,05), but Beeocattle and Beeocattle Plus shifted fermentation toward a higher acetate:propionate ratio (1.96; 2.05 vs. 1.54 with MON), reduced propionate (21.9; 22.3 vs. 27.7 mol/100 mol with MON) and increased butyrate (19.7–20.2 vs. 17.6 mol/100 mol with MON). In conclusion, Beeocattle and Beeocattle Plus reduced methane production without impairing ruminal fermentation and modified the VFA profile in favor of higher A:P ratios, though less effectively than monensin. BPC200 and BC50 were the most promising doses for future in vivo evaluation. This research was supported by FAPESP (2021/11922-2) and CNPq. Keywords: feed additives, flavonoids, methane emissions, ruminant livestock, sustainability

Inclusion of CaO2 in sheep diets to reduce methane emissions under Norwegian conditions.

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Calcium peroxide (CaO2) has been shown to be an effective methane (CH4) inhibitor. In Ireland, dairy bulls fed CaO2 showed a 16-29% reduction in CH4 emission compared to control. In Norway, CaO2 was used in an experiment with 24 Norwegian White sheep from February to April 2025. Ewes were blocked according to live weight and within block randomly assigned to one of two diets: a control diet of grass silage and pellet RoeBygg (RB), and a CaO2 diet aiming for a 1.5% inclusion of CaO2 based on dry matter intake, delivered in a mixture with the RoeBygg. Blocks were adapted to their respective diets over 20 days, followed by 48 hrs of CH4 measurements (g/day) in open-circuit respiration chambers as Period 1. Afterward, sheep were fed their assigned diets for 27 days, then underwent another 48 hr CH4 measurement as Period 2. Variables analysed included total dry matter intake (TDMI: kg/day), the ratio of RoeBygg pellets to silage consumption (RB:SIL), and CH4 yield, measured as g CH4/kg TDMI. A mixed model analysis evaluated the effects of diet, period, and their interaction on TDMI, RB:SIL, and CH4 production and yield. Results indicated no significant difference in either the main effect or the interaction on TDMI (2.01 vs. 2.04 kg/day, P=0.74; for control and CaO2, respectively) nor RB:SIL ratio (0.22 vs. 0.22, P=0.65). However, CH4 production exhibited significant main effects; the ewes fed the control diet emitted more CH4 than ewes fed CaO2 diet (39.52 vs. 32.72 g/day, P<0.01), and the first period had lower CH4 measurements than the second (34.18 vs. 38.05 g/day, P<0.01). Ewes fed the control diet had higher CH4 yield than the ewes fed the CaO2 diet (19.05 vs. 15.53 g/kg, P=0.02). In conclusion, the sheep fed CaO2 showed a 17% reduction in CH4 production and 18% in yield compared to the control, confirming its role as a methane inhibitor. The period effect observed in CH4 production requires further investigation, as factors like dietary quality and rumen microbial adaptation are of interest. This study is part of ongoing long-term testing of CaO2 fed to ewes to verify the product's effectiveness.

Methane emissions in gir dairy heifers fed diets containing different proportions of wheat silage

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Concerns regarding greenhouse gas emissions from livestock production have increased substantially in recent years. In this context, identifying nutritional strategies capable of mitigating these emissions is essential for promoting more sustainable cattle production systems. Therefore, the objective of this study was to evaluate the effect of different inclusion levels of wheat silage in the diets of Gir Dairy heifers. The experiment was conducted at the Agricultural Research Company of Minas Gerais, in Uberaba, Minas Gerais, Brazil, and approved by the Ethics Committee on Animal Use (1.385/2025). Thirty-two Gir Dairy heifers, with an initial body weight of 357 kg and an average age of 797 days, were assigned to collective pens in an automated feedlot equipped with electronic feed bunks and waterers with built-in weigh platforms. Treatments consisted of diets containing different proportions of wheat silage (0%, 33%, 67%, and 100%). The experimental period lasted 112 days, and enteric methane (CH_4) emissions were measured using the sulfur hexafluoride (SF_6) tracer technique. Data were analyzed using PROC MIXED (SAS Institute), and the best (co)variance structure was selected based on Akaike (AIC) and Bayesian (BIC) information criteria. Means were compared using Tukey's test at a 5% significance level. Diets composed exclusively of wheat or corn silage (1.06 and 1.00 g/kg BW, respectively) resulted in the lowest ($P < 0.05$) CH_4 emissions per metabolic body weight. The diet containing 67% wheat silage represented a critical point of fermentative inefficiency, leading to higher methane production relative to the animals' metabolic weight ($P < 0.05$). It is concluded that wheat silage is a viable alternative to replace corn silage in cattle feeding and may contribute to mitigating enteric methane emissions. Acknowledgements: FAPEMIG, INCT-CA, FINEP, CAPES

Mitigating ammonia and methane emissions in herbage-based dairy farming through tannin-rich diets: a multistage approach

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Ruminants uniquely convert non-edible plant biomass into human food, yet dairy farming contributes substantially to ammonia (NH_3) and methane (CH_4) emissions. Feeding strategies that mitigate one kind of emission often have limited or adverse effects on others, highlighting the need for integrated approaches. Tannin supplementation so far has shown mixed results. This project assessed herbage-based diets containing tannins for their potential to reduce NH_3 and CH_4 emissions in dairy systems using a multistage approach. The tannin sources tested, alone or combined, were the legume sainfoin (Onobrychis viciifolia) and Acacia mearnsii extract. First, two in vivo cow experiments investigated the effects of sainfoin and Acacia on urinary nitrogen (N) excretion and ruminal CH_4 emissions on animal level. These were complemented by in vitro experiments measuring NH_3 and CH_4 from slurry. Second, sainfoin and Acacia were tested at full scale in a naturally ventilated housing on herd level. At animal level, Acacia shifted N excretion from urine to faeces and reduced in vitro NH_3 volatilization from slurry by 37%. Both tannin sources lowered in vitro CH_4 emission from slurry. Emission reductions were accompanied by moderate performance loss, with decreased total ruminal CH_4 production but no reduction per unit of dry matter intake or milk. At full-scale level, sainfoin and sainfoin+Acacia reduced NH_3 emissions by 16–33% and 30–38%, respectively, with greater effects at higher ambient temperatures. The CH_4 emissions declined by 10% with sainfoin and 20% with sainfoin+Acacia, largely independent of temperature. Sainfoin and sainfoin+Acacia reduced milk urea concentration by 41–49%, urinary urea concentration by 30–58%, and milk yield by 11–20%. Overall, tannin enhanced diets simultaneously achieved NH_3 and CH_4 mitigation under practical housing conditions, albeit with some performance loss, confirming their potential to reduce the environmental footprint of dairy production.

Application of precision technologies to assess the environmental impact of mountain grazing system

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Grazing practices on mountain pastures influence cows' behaviour, productivity and emissions. The aim of the study was to quantify the environmental impact of cow milk production in the Italian Alps, comparing five pasture types and their related dairy productivity, as well as two approaches for estimating enteric methane emissions. An LCA was conducted on a Brown cattle dairy farm in Northern Italy. 24 lactating cows grazed for 70 days on pastures above 1700 m asl. Milk and pasture yield and quality were assessed biweekly and used for constructing five summer grazing scenarios. Forage samples were analysed using near-infrared spectroscopy, and biomass was estimated with a rising plate meter. Animals were equipped with GPS sensors for estimating the net energy expenditure for activity. Enteric methane emissions were calculated with IPCC (2019) (M1) and Niu et al. (2018) (M2) equations. M1 used actual data of activity, while M2 was built with real pasture DMI (Vazquez and Smith, 2001) and NDF. Pasture biomass was 2.89 tDM/ha (±0.74), with 13.9% (±0.80) crude proteins, 48.9% (±1.31) NDF and legume presence of 4.17% (±1.47). GWP were 1.83 (±0.04) kg CO2eq/kg FPCM for both M1 and M2. Enteric CH4/kg of milk ranged from 32.9 to 41.9 (M1) and from 31.6 to 49.1 (M2) depending on scenario, with strong correlation among the approaches ($r=0.99$, $p<0.01$). The differences among scenarios were mainly related to milk production rather than pasture characteristics, as observed in the correlation analysis. These results indicate that, depending on precision data available, either cows' energy expenditure (M1) or pasture features (M2) could be used for estimating enteric fermentation at pasture, without affecting GWP results. Precision technologies may support data collection in mountain grazing systems, helping to optimise management and sustainability of alpine dairy production. This study was carried out within the Agritech National Research Center and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – Missione 4 Components 2, Investimento 1.4 – D.D. 1032 17/06/2022, CN00000022).

Excellence Farms as live labs for climate-smart skills in dairy goats: integrating digital milk-yield data into training pathways

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Improving greenhouse gas (GHG) performance in small ruminant systems depends as much on skills and data as on technology. This study presents a data-driven "Excellence Farm" concept for a dairy goat farm, in which digital milk-yield and raw milk-quality records are used for herd management and training, focusing on emission intensity per kg of product. Individual records (daily yield, age, lactation number) were analysed at 3 points (January, June, November). Mean daily yield among lactating animals increased from 1.75 kg/d in January to 2.22 kg/d in June and declined to 1.56 kg/d in November ($P<0.001$). Yield distributions shifted markedly, high-yielders (≥ 3.0 kg/d) became frequent at peak season but almost disappeared by November, while low-yielders (< 1.0 kg/d) increased towards the end of lactation. Bulk-tank data linked to the 3 snapshots showed consistently rich milk (mean fat of 4.9, 4.3, and 4.1% and protein of 4.4, 4.1, and 4.0% in January, June, and October, respectively). To relate performance and quality to GHG outcomes, enteric CH_4 emissions per head were estimated from Tier 1 emission factors and expressed on both a volume (kg) and a fat- and protein-corrected milk (FPCM) basis. Assuming a constant emission factor per head, emission-intensity indices were calculated as enteric CH_4 per head divided by mean daily yield per head, using either raw milk or FPCM as the functional unit. With June taken as the reference (index=1.00), relative emission intensity per kg milk was 1.27 in January and 1.42 in November, whereas the corresponding indices per kg FPCM were 1.18 and 1.48, indicating that higher solids in early lactation partly offset lower volume yields. These indices and distributions are embedded in on-farm "live lab" sessions where farmers, staff, and advisors work with the farm dashboard and test alternative reproductive, culling, and replacement strategies. Routine farm data can be used to create a quantitative learning environment that links digitalisation, herd management, product quality, and GHG mitigation, and how Excellence Farms can support climate-smart skills in small ruminant systems.

The ammonia emission reducing potential of zeolite products when used as manure additive in cattle and goat barns

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Zeolites are volcanic minerals capable of adsorbing ammonia (NH_3). Livestock farmers consider them an accessible, low-cost measure to reduce NH_3-emission, applicable to different animal categories. This study investigated the effectiveness of various commercial zeolite products used as manure additive in mitigating NH_3-emissions from livestock manure, as well as their applicability to various manure types (slurry vs. barn manure) and ruminant species (dairy and beef cattle, goats). A multi-step approach was applied consisting of a literature review, market analysis, mineralogical characterization, in vitro test of a selection of commercial zeolite products in manure containers, and 2 trials under practical conditions with the best scoring product. A trial with dairy heifers was done in the mechanically ventilated straw bedded barn at ILVO using a cross-over design and measurements at box level (zeolite applied at a dose of 450 g/m² 3x per week). A trial with dairy goats was done at a commercial farm with measurements at the bedding surface (one pen with zeolite applied at a dose of 200 g/m² 1x per week and one negative control pen). Analysis of the mineralogical composition showed that most products contained clinoptilolite and clay minerals in different ratios. In vitro, zeolites did not significantly reduce NH_3-emissions from cattle slurry. However "on-top" addition of zeolite to cattle barn manure led to NH_3- emission reductions to up to 51%, but with large differences between products. Reductions in goat barn manure were lower, but total adsorption per g of zeolite was similar (8.8–9.4 mg NH_3/g). The practical trial with heifers showed an average NH_3-reduction of 9.4%, varying from 2.2% to 16.3% between measurement periods. The goat barn trial showed an average NH_3-reduction of 10%, but with a significant uncertainty, as it was a single-period trial with one replicate per treatment in one barn and with a high variability between measurements days. This variability, likely influenced by environmental factors such as barn temperature, humidity, and animal behavior, complicates interpretation and challenges the recognition of zeolites as an effective NH_3-emission mitigation measure.

Grass-legume mixture enhances N use efficiency and stability of grazing systems

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Integrating forage legumes in grazing systems might reduce the need for industrial N fertilizers, enhance the nutritive value of the diet, and provide additional ecosystem services. In this long-term trial (11 yr) we investigated ecosystem services and stability of contrasting grazing systems ranging from 34 kg N/ha/yr and presence of legumes to 224 kg N/ha/yr and no legumes. Treatments were 1) 'Argentine' bahiagrass (Paspalum notatum) and 'Ecoturf' rhizoma peanut (Arachis glabrata) during the summer overseeded with 'Ram' oats (Avena sativa) and 'Prine' annual ryegrass (Lolium multiflorum) with a blend of clovers (Trifolium incarnatum, T. nigrescens, T. pratense) and 34 kg N/ha (total annual N input); 2) 'Argentine' bahiagrass overseeded with similar mixture and N input as treatment 1; 3) 'Argentine' bahiagrass + 112 kg N/ha/yr overseeded with 'Prine' annual ryegras and 'Ram' oats + 112 kg N/ha/yr (total annual input of 224 kg N/ha/yr). Pastures were the experimental unit (0.85 ha each) and treatments were replicated 3 times in a RCBD. Angus yearling steers grazed these pastures from Jan to Oct, from 2015 to 2025, using continuous stocking with variable stocking rate. Overall, grass-legume mixtures (trt 1) produced similar gain per area as N-fertilized grasses (trt 3) but using 85% less N industrial fertilizers. Nitrogen use efficiency was greater in the mixtures, with 2-3x more beef produced per unit of recycled N. Mixtures provided more ecosystem services, including greater presence of bees. Nitrate leaching was lesser in the mixtures compared to N-fertilized grasses. Grass-legume mixtures demonstrated greater stability, with lower reduction in performance in poor environments (years). Integrating forage legumes is a potential path for sustainable intensification of beef cattle systems.

Animal density, nitrogen balance, and nitrous oxide emissions in New York dairies

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Improving whole-farm nitrogen (N) use efficiency is central to reducing the environmental footprint of dairy systems, yet empirical understanding of factors driving variation in whole-farm N balance and nitrous oxide (N_2O) emissions remains limited. Previous analysis of 78 northeastern US dairy farms identified animal density, crop yields, reliance on homegrown forages, dietary crude protein, milk yields and cull rate as key determinants of both N balance and N_2O emissions. Building on this work, we evaluated how meeting increased milk demand through higher animal density would influence whole-farm N balance and N_2O outcomes. We modeled expected changes in whole-farm N balance and N_2O emissions across three animal density categories under six management scenarios: (1) business-as-usual, (2) precision crop management (optimizing homegrown forage production), (3) precision feed management (optimizing feed efficiency, milk yield and components), (4) improved feed storage to reduce losses, (5) manure exports and (6) outsourcing heifer rearing. Key performance indicators (KPIs) were adjusted within plausible management limits to minimize N balances and N_2O emissions without compromising productivity. Across farms, annual N balance ranged from 13 to 323 kg N ha^{-1} (2.8-25.0 kg N Mg^{-1} FPCM), and N_2O emissions ranged from 2 to 16 kg N_2O ha^{-1} (0.3-1.0 kg N2O Mg^{-1} FPCM). Animal densities ranged 0.90 to 5.07 AU ha^{-1} (mean 2.54), with roughly one-third of farms below 2.0 AU ha^{-1}, one-third between 2.0–3.0 AU ha^{-1}, and one-third above 3.0 AU ha^{-1}. Findings show that increasing animal density does not inherently compromise environmental performance when paired with targeted management adjustments. However, manure exports become increasingly necessary as animal density increases. Among the KPIs evaluated, manure nutrient crediting to reduce fertilizer use, precision feeding to avoid nutrient oversupply, and precision crop management combined with improved feed storage to increase and maintain homegrown forage yield and quality were most influential in limiting N balance and N_2O emissions. These strategic adjustments can enable higher milk production while minimizing additional N losses at the whole-farm scale.

Identification of key indicators determining environmental impacts in German milk production systems

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In connection with the discussion about the climate crisis and increasing ecological demands on food from politics and society, it is necessary to record in detail the environmental impacts caused by agricultural production. For this reason, a project was composed, which enables firstly a documentation of the status quo and further an observation of the development in environmental impacts (EI) on German dairy farms. Secondly, an analysis of causalities between management and performance indicators and their influence on environmental efficiency was examined. The aim of this project was to identify key indicators which determine the level of EI in German milk production. Also, as a new approach, the link of the life cycle assessment (LCA) method and structural equation models shall be evaluated. The study was based on the data of 10 dairy farms in Germany. Three consecutive years are calculated in order to assess the development and effectiveness of mitigation strategies. Cradle-to-farm gate LCAs were calculated for each farm and year. Climate change, freshwater eutrophication, terrestrial acidification and land use were considered as categories of EI. Economic allocation was applied and the functional unit was defined as 1 kg energy-corrected milk. Preliminary results showed that the ration composition as well as feeding management is crucial. Comprehensive results will be presented and discussed at the conference. The study will provide new insights on the application of structural equation models to life cycle assessment data.

Environmental benefits of multicarbohydrase-phytase complex supplementation in broiler production : a life cycle assessment approach

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According to the FAO, feed production accounts for 78% of poultry greenhouse gas emissions (FAO, 2013). Addition of exogenous enzymes to poultry diets is a promising strategy to improve nutrient utilization and reduce environmental impacts, while maintaining profitability. The present study evaluated, through life cycle assessment (LCA), the environmental benefits of a multi-carbohydrase and phytase complex in broilers fed corn-wheat-soybean meal-based diets. A total of 960 day-old male Ross PM3 chicks were randomly assigned to four dietary treatments with 12 replicates pens of 20 birds per pen. Diets consisted of a nutrient adequate positive control (PC) diet, a negative control (NC) diet reduced in ME, dig. AA, avP and Ca by -5%, -4%, -0.18% and -0.16% respectively, vs PC diet, a NC supplemented with phytase at 1000 phytase units (FTU) per kg diet (PHY1000) or with multi-carbohydrase and phytase complex providing at least 1250 xylanase U, 860 β-glucanase, 9250 α-L-arabinofuranosidase and 1000 FTU per kg diet (MCPC) for 42 days. The LCA was performed from cradle to feed mill and farm gate using feed, performance, and French farm data. GFLI v2.2 database (2024) was used, and LCA followed FAO LEAP (2020) and PEFCR guidelines. Five impact categories were assessed: climate change, notably including land use change, acidification, eutrophication (freshwater and marine), and water use. Feed ingredient origins reflected average French imports. Compared to PC, NC diet reduced climate change impact from 1.90 to 1.75 kg CO_2eq/kg liveweight, mainly due to lower land use change emissions. Phytase and MCPC further reduced the climate change by 8 and 11% respectively, compared with PC. MCPC supplementation also improved acidification (-3%), eutrophication freshwater (-9%) and water use (-8%) in comparison to PC. Marine eutrophication slightly increased for NC (+4%), NC+PHY1000 (+3%), NC+MCPC (+0.2%) vs PC. The results show that diet reformulation with multi-carbohydrase and phytase supplementation was able to reduce the overall environmental impact of broiler production in specific contexts. They also highlighted that LCA could be a key tool to highlight trade-offs across impact categories and supports sustainability in poultry production.

Pastures redefined: Multispecies swards enhance the sustainability of a dairy-calf-to-beef system

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Pasture based ruminant systems harness the unique ability of ruminants to convert human inedible biomass into high value protein and micronutrients for human consumption. Such systems are often associated with negative externalities (greenhouse gas emissions, biodiversity loss, water quality deterioration, etc) that must be addressed to deliver sustainable food systems. The UCD Lyons Farm Long-term Grazing Platform (LGP), developed to address these challenges, is a globally unique facility to investigate the impacts of sward botanical diversity on the sustainability of a dairy-calf-to-beef system. The LGP consists of 12 x 2 ha hydrologically isolated units split across four blocks. Within each block, paddocks are allocated to one of three pasture types: PRG, a perennial ryegrass monoculture receiving 205 kg inorganic N/ha/yr; PRGWC, a mixture of perennial ryegrass and white clover receiving 92 kg inorganic N/ha/yr and MSS, a multispecies sward consisting of perennial ryegrass, timothy, white clover, red clover, chicory and plantain receiving 92 kg inorganic N/ha/yr. Each year 60 male dairy-beef calves are enrolled in the study (n=20 per pasture type) and managed in a leader follower system to produce a 315kg carcass. All forage is produced within each respective pasture type, with supplementary concentrates offered during the housed periods. The MSS reduced days to slaughter by 35 days, fertiliser nitrogen input by 55%, carbon footprint of beef produced by 15%, delivered a reduced water footprint and enhanced sward botanical diversity and herbage production with concurrent increases in farm profitability compared to PRG. Multispecies swards offer a pathway to transform the sustainability of pasture-based beef production.

CERZOO as a supersite for circular livestock farming: integrating research, monitoring, and co-design for sustainable dairy systems

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The CERZOO Research Centre (Piacenza, Italy) is an experimental infrastructure connecting scientific research with practical farming in a fully operational dairy system. As a "supersite," it combines real-farm complexity with advanced facilities and continuous monitoring. Its circular framework – field > forage > herd > manure > field – supports integrated assessment of material and energy fluxes, conversion efficiencies, and environmental trade-offs across the livestock chain. Using sensors, automated systems, and long-term data platforms, CERZOO quantifies carbon (CO_2, CH_4) and nitrogen (N_2O, NH_3, NO□□) fluxes, identifying hotspots of inefficiency and environmental impact to guide mitigation strategies. The supersite provides a testing ground for innovations across technological maturity levels (TRL 2–7): early-stage solutions can be evaluated under controlled conditions (e.g., mesocosms for crop eco-physiology and emissions), while higher TRLs are tested directly on-farm through spatially explicit trials that capture real-world variability and enable assessment of yield, efficiency, and environmental performance. Within the livestock unit, CERZOO enables detailed monitoring of forage preservation (especially silage) and quality, along with animal performance, welfare, physiological status, and environmental interactions. Real-time data on feed intake, behavior, rumination, body condition, and emissions (CH_4, CO_2, H□, NH_3) support the development of feeding and housing strategies that optimize productivity, health, welfare, and environmental outcomes. Beyond experimentation, CERZOO serves as a co-creation hub involving technology developers, farmers, industries, policymakers, and civil society to co-design and evaluate solutions that are scientifically robust and practically relevant. This integrated approach provides a reference model for climate-smart, resource-efficient livestock systems.

"Abattoir Air Quality: An Unknown Quantity." Volatile Organic Compound Characterisation in Beef Abattoirs.

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Abattoir systems are yet to be classified for their odour profile as processing facilities of livestock in the production cycle, despite their detrimental environmental, anthropic and economic impact. This study establishes the volatile organic compound (VOC) profiles of commercial cattle abattoirs operating under two contrasting management systems: an ultra-modern facility and a traditional handling architecture. Compounds were collected in the lairage and stun box, alongside continuous monitoring of general air quality concentrations using a bespoke device that recorded environmental parameters and agricultural gases (NH_3, CH_4, SO□, H□S, TVOC, PM). VOCs were sampled at the beginning and end of the working week and analysed using TD-GC-TOF-MS in a time-course analysis. Animal- and production-related factors (start vs. end of week, morning vs. afternoon, age, sex, breed, number of consignments, kill rate, lairage time, and transport time) were correlated with the presence or absence of individual VOCs and with air-quality thresholds using three binary machine-learning models (LR, SVM, RF) and a Tweedie-GLM. Fifty-five VOCs were identified, including alcohols, aldehydes, amines, alkanes, alkenes, esters, nitriles, phenols, and ketones. Significant associations were detected between production-week phase and specific compounds, as well as between time of day, production period, batch number, and kill rate with VOC group concentrations ($p < 0.05$). Many of the detected compounds are biologically linked to animal metabolism, waste decomposition, and sanitation processes, highlighting their relevance to animal welfare, meat quality, and worker environmental safety. These findings support the development of VOC-based monitoring methodologies for abattoirs and provide evidence to inform best practices and mitigation policies aimed at improving lairage conditions.

The impact of immunocastration on the carbon footprint of male fattening pigs

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Efforts to reduce the environmental impact of livestock production are crucial for achieving sustainable agriculture. The carbon footprint as one indicator for environmental sustainability can be calculated using life cycle assessment (LCA) and aims to compile all greenhouse gas emissions that arise directly or indirectly throughout a system. Immunocastration, using products like Improvac®, offers an alternative to surgical castration, which creates the possibility to use the physiological advantages of rearing entire male pigs while addressing issues such as boar taint, and animal welfare.This evaluation examined the effects of immunocastration on the performance and carbon footprint of fattening pigs, comparing immunocastrated males with entire males, gilts, and surgically castrated males. Data from 39 trials were analyzed to extract values for average daily gain (ADG), feed conversion ratio (FCR), and mortality. The mean values of these parameters were then used to calculate the carbon footprint. Results indicated that immunocastrated males achieved a higher mean ADG and a lower mean FCR than gilts and surgically castrated males, leading to carbon footprints that were 7.1% and 6.8% lower, respectively. Entire males, however, showed a slightly lower carbon footprint than immunocastrated males due to a more favorable FCR, although the difference was not statistically significant.These findings highlight the ecological benefits of immunocastration over surgical castration, primarily driven by improved feed efficiency and growth performance. From a sustainability standpoint, fattening entire males offers the lowest environmental impact. Nevertheless, practical challenges such as boar taint and behavioral issues persist. When boar fattening is not feasible, immunocastration stands out as the preferred alternative to surgical castration, aligning well with both ecological goals and animal welfare standards.

Meta-analysis of the effects of dietary inclusion of by-products containing polyphenols on milk production traits of goats.

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The recovery and valorisation of agro-industrial by-products (BP) for use in livestock feeding aligns closely with the European Union's objectives for achieving climate neutrality by 2050. Numerous studies have investigated the inclusion of these materials in ruminant diets, with particular focus on those rich in bioactive compounds such as polyphenols, which may provide various advantages for both animal health and production. Nevertheless, findings reported in the literature, especially concerning milk yield and quality, are often inconsistent, influenced by factors including species, inclusion rate, polyphenol concentration, and the overall dietary composition. The objective of this study was to evaluate the effects of dietary supplementation with polyphenol-rich BP on milk production, composition, and fatty acid profile in dairy goats. The systematic search was conducted using Scopus, Web of Science, and PubMed databases. Data were extracted from scientific papers including AIBP from grape, olive, tomato, citrus, cocoa, and coffee by-products. The effects of BP were evaluated through random-effects statistical models. Supplementation with BP did not affect milk yield in goats. However, the inclusion of by-products in the diet led to a decrease in saturated fatty acids (SFA) and an increase in monounsaturated fatty acids (MUFA), vaccenic acid (VA, C18:1trans-11), linolenic acid (LNA, C18:3 n3), and rumenic acid (RA, C18:2cis-9,trans-11). The dosage of polyphenols was never significant. In conclusion, the addition of agro-insutrial by-prodicts to goat diets did not modify milk yield but clearly improved milk quality through a reduction in SFA and an increase in fatty acids with nutritional properties. This work was supported by the Agritech National Research Center and funded by European Union Next-GenerationEU (PNRR) – Spoke 5 (CN00000022).

Subclinical Mastitis in Kenyan Herds: Milk Loss, Emission Intensity, and Food Security Risks

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This study quantified the impacts of subclinical mastitis (SCM) on milk yield (MY) and enteric CH_4 emissions intensity (EI; kg CO_2-eq/kg milk) in dairy cows. A total of 1,531 cows from 443 smallholder farms in Nandi County, Kenya, were assessed using quarter-level CMT scores (0–4). SCM was defined as any quarter with CMT > 0, and udder inflammation was summarized using composite CMT score (0–16). Effects of SCM and composite CMT score on MY and EI were analysed using linear mixed-effects models, with heart girth, parity, concentrate intake, and abortion history as fixed effects, and farm ID and evaluator as random effects. CH_4 emissions were estimated using IPCC Tier 2. Farm-level SCM presence and within-herd burden were compared across herd-size groups. Larger herds (≥5 cows) were more likely to have SCM, but the composite CMT score and the proportion of affected cows was similar, indicating that SCM becomes a whole-farm issue once present. MY and EI were evaluated under 25–100% reductions in the composite CMT score and SCM prevalence. Reducing the average composite CMT score (3.8) to 0 could increase MY by 247 mL/cow/day and lower EI by 0.15 kg CO_2-eq/kg milk. Eliminating current prevalence (54.6%) could recover MY by 133 mL/cow/day and reduce EI by 0.1 kg CO_2-eq/kg milk. Nationally, SCM was associated with 93,985 tons of annual milk loss or a per-capita milk consumption of 830,000 people, representing a major loss of locally produced food.

Simulating dietary protein and methane-mitigation strategies with the Ruminant Farm Systems (RuFaS) model

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Dairy farms increasingly seek management strategies that improve nitrogen (N) efficiency and reduce greenhouse gas (GHG) emissions while maintaining profitability. The Ruminant Farm Systems (RuFaS) model is an open-source, process-based, whole-farm simulator integrating animal nutrition, herd dynamics, manure management, crop production, and economics. Operating on a daily time step, RuFaS quantifies cascading effects of dietary and manure management changes on farm productivity and environmental outcomes. Nutritional strategies play a critical role in reducing environmental impacts of dairy systems. The RuFaS model provides a process-based simulation framework to quantify whole-farm responses to nutritional interventions. We used RuFaS to evaluate tradeoffs in environmental outcomes with diet intervention scenarios based on two diets from a recently published experiment: a high-protein (17.5% CP) and a low-protein (15% CP) diet. RuFaS replicated the slight increase in milk yield and dry matter intake observed with the high-protein diet and predicted the resulting similar overall N-use efficiency (~68%). RuFaS predictions shifted manure N partitioning toward urinary N in the high-protein diet, implying greater volatilization potential. The high-protein diet resulted in a lower enteric methane GHG emission intensity but when a methane-mitigation additive (3-NOP) was included, the difference in GHG intensity between diets was nearly eliminated, demonstrating the additive's potential to offset dietary effects. Comparison of the choice of enteric methane prediction equation altered emissions estimates, emphasizing the importance of model selection in mitigation assessments and illustrating the flexibility of RuFaS to test multiple formulations and modeling approaches. Overall, RuFaS proved an effective digital platform to quantify combined impacts of nutritional adjustments and mitigation technologies, offering insight into farm-level strategies for improving environmental performance without compromising productivity.

Native Warm Season Perennials as Climate Resilient Forage options for Semi-Arid Beef Systems in South Texas

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Sustainable livestock production in semi-arid regions requires forage systems that maintain nutritional value, reduce dependence on non-native species, and support adaptive grazing management. Native warm-season grasses are naturally adapted to South Texas' hot, drought-prone environment, yet their seasonal nutritive patterns and effects on cattle management are not fully understood. This study evaluated dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) concentrations in four native perennial bunchgrasses: Switchgrass (SG; Panicum virgatum L. var.), White Tridens (WT; Tridens albescens Vasey, Wooton & Standl.), Pink pappusgrass (PP; Pappophorum bicolor Fourn.), and false Rhodesgrass (FG; Trichloris pluriflora Fourn.) compared with the non-native control Bermudagrass (BG; Cynodon dactylon L. Pers.). The objective was to understand how native grasses contribute to environmentally resilient forage systems that also improve livestock nutrition and grazing efficiency. Monthly samples were collected for twelve months from replicated plots at Texas Native Seeds in Kingsville, Texas. Biomass was clipped, dried, and analyzed for DM, CP, NDF, and ADF. Linear mixed-effects models showed significant monthly variation in CP ($p = 0.0102$), a species × month interaction for NDF ($p = 0.0059$), and species-level differences in ADF ($p = 0.0037$). A prescribed burn in February produced notable shifts in fiber fractions, demonstrating how natural rangeland processes shape forage quality over time. Distinct nutritive trajectories among native species suggest complementary seasonal roles. These findings show that native grasses offer both ecological and livestock benefits. Their adaptability, low input needs, and stable nutrient quality can support efficient grazing, improve diet quality, and reduce dependence on irrigated or fertilized non-native forage. Upcoming in vitro true digestibility (IVTD) analysis will show how forage composition affects usable energy, giving producers practical tools for grazing, forage selection, and climate-resilient cattle management.

Efficiency of the Limousine cattle breed in Portugal based on technological and natural solutions.

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Within the scope of the Horizon DesirMED 101112972 project, a partnership between the Municipality of Fundão, the Polytechnic Institute of Castelo Branco (IPCB), and the Portuguese Association of Limousine Cattle Breeders (ACL), a Performance Improvement Center, was established in the Municipality of Fundão (Portugal) in 2025. The aim is to study nature-based solutions to reduce greenhouse gas emissions in an environment that respects animal welfare and prioritizes a diet based on local plants. Through the actions developed at the Center, equipped with innovative technology and using an ACL selection scheme, solutions will be presented and disseminated to cattle farmers, based on zootechnical data obtained from the study of the Limousine breed and its productivity and reproductive efficiency. The selection of animals will be made, and subsequent dissemination of future breeding stock will be carried out, with lower nutritional requirements, contributing to a reduction in methane emissions and lower costs for the producer, essentially in the fattening and finishing system, both in purebred lines and in crossbreeding with less efficient breeds. The development of the Center follows studies previously carried out by ACL, where 3 editions of testing of future breeding males were carried out, based on the genetic improvement criteria of the breed, which took place between 2021 and 2023 in the months of January to May, with an effective duration of 90 days for each test. During the first month, the animals were adapted to the location and the feeding regime. Weight control was carried out every 21 days. One of the selection criteria was feed efficiency, defined in 3 essential parameters: Average Daily Gain with minimums obtained of 1.19 kg/day and a maximum of 1.85 kg/day, Feed Conversion Ratio with minimums obtained of 4.72 kg DM and a maximum of 6.31 kg DM, and Residual Feed Intake with a minimum of -1.706 kg and a maximum of 1.607 kg. Efficient animals brings a economic and environmental contribution to the cattle breeding system.

Attributing upstream cattle emissions to Italian bovine leather: allocation choices and implications for the national tanning carbon footprint

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Sustainability assessments of bovine supply chains must account that climate impacts are generated along the whole chain and should be allocated not only to meat and milk, but also to marketable co-products (hides for leather industry). Italy hosts the world-leading tanning sector, with 95.4 million m² of finished leather produced in 2023 and bovine leathers representing 75.8 million m² and over 70% of total turnover. This contribution combines recent UNIC statistics with life cycle assessment (LCA) results for Italian beef chains to quantify the upstream (farm-to-slaughter) carbon footprint (CFP) of raw bovine hides and to upscale it to the national tanning output. Using large-scale Italian slaughter data (~750,000 head/y), we compared physical and economic allocation (Ph.A, Ec.A) of greenhouse gas emissions to hides and converted the resulting CFP from kg CO_2e per kg hide into kg CO_2e per m² of processed leather. Descriptive statistics and allocation scenarios were used to test whether hides bear a non-zero share of upstream emissions and how the choice of allocation method affects sector-level estimates. CFP of bovine leather was estimated at ≈29.6 kg CO_2e/m² under Ph.A and ≈13.6 kg CO_2e/m² under Ec.A. Applied to the 2023 Italian leather production, this corresponds to about 2.2 Mt CO_2e (Ph.A) versus 1.0 Mt CO_2e (Ec.A) of upstream emissions embodied in all bovine hides processed by Italian tanneries, irrespective of origin. However, Italy imports around 80% of its raw bovine material, so the upstream burden of those imported hides should remain in the producing countries. Adjusting for the ≈20% share of domestically sourced hides, Italian bovine supply chains account for roughly 0.4 Mt CO_2e (Ph.A) versus 0.2 Mt CO_2e (Ec.A) of the tanning sector's upstream climate impact. These results show that co-product allocation choices, and the distinction between domestic and imported hides, can change the climate burden attributed to the Italian leather industry by more than a factor of two, with direct implications for product footprints, transparency claims and circular-economy policies linking cattle and tanning supply chains.

Effect of cricket frass as an organic fertilizer on forage quality

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This study evaluated the fertilising potential of cricket frass as a partial substitute for mineral fertilisation in annual ryegrass (Lolium multiflorum). The treatments consited in: mineral control (TM) and eight cricket-frass treatments with four frass types: original (TFGO), thermally treated (TFGT), stabilised to 35% moisture (TFG35), and stabilised to 60% moisture (TFG60), each applied at two N-replacement levels, 25% (-1) and 50% (-2). In the first cut, frass treatments increased biomass production relative to the control (TM: 5.0 g pot DM), with the highest values recorded in FGO-2 (8.5 g DM), FGT-2 (7.6 g DM) and F35-2 (7.6 g DM), corresponding to 30-60% increases. No significant differences were observed in the second harvest. Plants chemical composition showed enhanced macronutrient accumulation under frass fertilisation. Total N reached 3.3% in FGO-2 in the first cut, compared with 1.9% in TM. Levels of P, K and Mg were also higher in frass treatments (e.g., K up to 8.6% in FGT-1 vs 2.3% in TM). Micronutrient concentrations varied among treatments but did not compromise forage quality. In the second cut, nutrient profiles remained elevated, with N ranging from 1.8-2.7%. Overall, the results demonstrate that cricket frass is an effective organic fertiliser, capable of complementing mineral fertilisation without yield penalties and improving the nutritional profile of the forage. The FGO-2, FGT-2 and F35-2 treatments showed the most favourable agronomic performance.

The effects of by-pass lysolecithin supplementation on milk quality parameters: sheep as a case study.

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The aim of this study was to evaluate the effect of a rumen-protected source of lysolecithin on milk quality parameters under commercial conditions. Data were obtained from a commercial dairy sheep farm located in Fuentepelayo (Segovia, Spain). The flock consisted of an average of 550 lactating ewes during the experimental period, which extended from September 2023 to July 2024. The trial was structured into two dietary phases. In the first phase (T1), from September 4, 2023, to September 12, 2024, receiving a control diet formulated to contain 18% crude protein, 32.7% NDF, and 4.09% crude fat. In the second phase (T2), from September 13, 2024, to June 6, 2025, the same basal diet was supplemented with 1 g/animal/day of LC-PRO®. Bulk-tank milk samples were collected daily (n=286) and analysed for fat content (FC, g/kg), protein content (PC, g/kg), dry matter content (DC, g/kg), cheese yield (ChY, g/kg), somatic cells score (log2(SSCC/10,000))+3, urea (cells/ml), casein (%), and bacteriology (FCU/ml.). Statistical analyses were conducted using ANOVA to assess the effect of treatments and a Tukey's post hoc test to estimate differences among treatments. The generalized linear mixed models included treatment, year, and month as fixed effects, with residuals as a random effect. Statistical significance was declared at $\alpha = 0.05$. Results showed an increase in milk solids for T2, with improvements of 15% in FC (from 6.08 to 6.79%, $p<0.05$), 11% in PC (from 5.02 to 5.57%, $p<0.05$), 7% in DC (from 16.8 to 17.7%, $p<0.05$), 11% in ChY (from 11.0 to 12.1%, $p<0.05$), and 10% in casein (from 3.76 to 4.09%, $p<0.05$). These results suggest an enhancement of milk solids content, likely be due to improved fat digestibility, and a possible increased fluidity of enterocyte membrane bilayers, which may facilitate nutrient absorption. Then, greater intestinal availability of triglycerides and other nutrients can lead to improved milk composition. In conclusion, supplementation with LC-PRO® is suggested as a strategy to optimize sheep productivity, particularly in cheese production, where milk composition is a decisive factor.

Isotopic characterisation of commercial pig feeds

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The use of stable isotopes has expanded in animal research, particularly for characterising feed ingredients and supporting traceability systems. The isotopic discrimination of C_3 and C_4 plants, resulting from their distinct photosynthetic pathways, produces characteristic $\delta^{13}C$ values that allow the identification of botanical origins within feed formulations. Typically, C_3 plants show $\delta^{13}C$ values between –22 and –34‰, whereas C_4 plants range from –9 to –16‰. Consequently, the final isotopic signature of a feed reflects the relative contribution of these plant groups. This study aimed to determine the isotopic signatures of commercial swine feeds and relate them to the predominant plant ingredients. Four feeds produced on Terceira Island were analysed, representing lactation (T1 and T2) and nursery phases (T3 and T4). Ingredient compositions were obtained from product labels. Samples were dried, defatted, ground, and analysed for $\delta^{13}C$ using isotope ratio mass spectrometry (IRMS). Data were evaluated using ANOVA one-way followed by Tukey's test at the 5% significance level. The feeds exhibited distinct $\delta^{13}C$ values. Feed T1 (–17.83‰) showed a moderately negative signature due to a mixture of maize (C_4) and various C_3 ingredients. T2 (–14.30‰), containing a higher proportion of genetically modified maize, presented a less negative value consistent with a greater C_4 contribution. Among the nursery feeds, T3 (–18.87‰) had the most negative $\delta^{13}C$ value, reflecting the predominance of C_3 sources such as soybean meal and wheat despite the presence of maize. T4 (–14.51‰) exhibited an intermediate value, influenced by both expanded maize (C_4) and substantial C_3 inclusions. Overall, the $\delta^{13}C$ differences clearly distinguished the feeds and corresponded to the proportions of C_3 and C_4 ingredients in their formulations. These findings confirm the usefulness of isotopic analysis for characterising commercial swine feeds and enhancing feed authenticity and traceability. Future applications should consider seasonal and regional variability in raw materials and combine IRMS with complementary analytical approaches to strengthen feed quality and sustainability assessments.

Global analysis of nutritional strategies to mitigate the environmental impacts of dairy production: the case of supplementing diets with microencapsulated B vitamins

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The objective of the present study was to assess the net environmental impact of adopting different nutrition strategies with and without supplementing rumen-protected B vitamins (RPBV) in dairy milk production. Seven representative regional dairy production systems across the United States, Canada, Mexico, Chile, Colombia, Australia, and France were investigated, utilizing a total mixed ration (TMR) feeding program supplemented with 3 g of RPBV. The estimated climate change impact scores for all control production scenarios ranged from 1.08 to 1.65 kg CO2-eq/kg fat protein-corrected milk (FPCM). However, the impact of climate change per kg of FPCM decreased by 5.6–18.0 % when RPBV was supplemented on top of the TMR feeding program. Additionally, the impacts of agricultural land use, water consumption, and acidification, as well as eutrophication potential, were reduced by 3.0–16.3 % (with an average reduction of 7.4 % across all scenarios) when the TMR feeding programs were supplemented with 3 g of RPBV. And there were reductions in enteric methane (up to 2.4 %) and nitrogen emissions (up to 10 %). The manufacturing and transportation of RPBV to the seven regional destinations examined in the current study had a minimal impact on the total environmental footprint of dairy production systems. The null hypothesis was rejected, indicating significant differences in results, as the p-value for all impacts and pairs (control and RPBV scenarios per 500 Monte Carlo runs) was less than 0.05, which is considered statistically significant. Overall, supplementation with RPBV constitutes a valuable nutritional strategy to support ongoing efforts and innovations in driving sustainable dairy production.

Reducing environmental footprints in low-input livestock systems through the integration of root and tuber by-products into smallholder diets

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Low-input livestock systems in tropical regions rely on conventional feed ingredients whose rising costs and limited availability constrain productivity and increase environmental pressures. Sweetpotato (SP) peels, leaves, and composite meals are abundant yet underutilized resources that offer strong potential for sustainable feed integration. This study assessed the environmental and nutritional benefits of incorporating SP-derived by-products into smallholder ruminant diets, using the West African Dwarf goat as a model. Twenty-four bucks (mean live weight 8.10 kg) were randomly allocated to four dietary treatments containing 0, 15, 30, and 45% composite SP meal (T1–T4). Diets were evaluated for effects on growth performance, nutrient digestibility, feed conversion efficiency, and manure nutrient composition. Across treatments, no significant differences ($P > 0.05$) were observed in growth performance, digestibility, feed conversion efficiency, or manure nutrient values. However, incorporating SP by-products improved overall nutrient utilization, reduced dependence on conventional feedstuffs, and lowered estimated nitrogen and carbon emissions per unit of liveweight gain. Enhanced feed efficiency was linked to reduced crude-protein requirements and lower excretory nutrient losses, key levers for mitigating environmental footprints in smallholder systems. These findings highlight root and tuber by-products as viable, locally available feed alternatives that support a circular, climate-smart approach to livestock production. Integrating such agro-industrial residues into smallholder diets can help reduce environmental impacts while maintaining productivity and strengthening resource-use efficiency in tropical low-input systems.

Liquid and powdered bacteriocin-rich γ-PGA feed additives in goose fattening: productive implications.

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The use of γ-polyglutamic acid (γ-PGA) combined with bacteriocins in goose nutrition is a promising strategy to improve production efficiency and bird health while reducing the need for antibiotic interventions. The aim of this study was to evaluate the effects of three water-supplied additives: γ-PGA-rich liquid (A), γ-PGA + bacteriocin-rich liquid (B), and γ-PGA + bacteriocins-rich powdered form (C), on survival rate, final body weight (FBW), feed conversion ratio (FCR) and Poultry Efficiency Factor (PEF) of geese, with sex included as a second experimental factor. A 105-day feeding trial was conducted on White Kołuda geese. Four groups fed identical diets were formed: control, A, B and C. Birds received compound feeds with meadow green forage until day 90 (starter and grower phase), followed by oat grain with green forage during the last 15 days. Additives were supplied via drinking water at 1% in groups A and B and at 50 g per 1000 L in group C for 6 days at the beginning of each rearing period. Additive type significantly affected survival, FBW and PEF ($p<0.001$). The highest overall survival was observed in group B. In females, survival reached 99.0% in group A and 95.2% in group B, with significantly lower values in the control ($p<0.001$). Group A showed higher FBW (6.62 kg) than group B (6.32 kg; $p<0.01$), with no differences versus group C and control. The powdered preparation (C) showed the highest PEF at day 105 (141±16.4). Sex significantly affected traits, with males having higher FBW but lower PEF than females ($p<0.001$). Water-supplied γ-PGA-rich liquid (A) and γ-PGA + bacteriocins-rich powdered form (C) significantly improve survival, FBW and overall production efficiency of geese, confirming their high applicability in efficient goose production systems.

Environmental and production aspects of the use of dried berry pomace in the feeding of fattening pigs.

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By-products of the agri-food industry pose a major challenge in a rapidly developing world, necessitating effective management strategies to reduce environmental impacts. Numerous studies have highlighted their potential for use across various industrial sectors, including the feed industry. Fruit pomaces are an important source of nutrients and also bioactive compounds, which exhibit strong antioxidant properties. Dried chokeberry pomace contains pectins that support digestive processes, as well as organic acids with anti-inflammatory activity and beneficial effects on lipid metabolism. Its high content of soluble fibre exerts a prebiotic effect by promoting a healthy gut microbiota. Reports indicate that blackcurrant pomace, by modifying the composition and activity of intestinal microbiota, can limit undesirable fermentation processes and reduce the production of potentially harmful metabolites, what not only supports animal health but may also contribute to lowering greenhouse gas emissions. The aim of the study was to apply innovative practices involving the use of dried blackcurrant and chokeberry pomaces in pig feeding to determine their effects on production performance, nutrient digestibility, and the excretion of environmentally harmful components, as well as to assess their potential to reduce greenhouse gas emissions. The results indicate that berry fruit pomaces have potential as a nutrient source for pigs. The findings demonstrate that including dried berry pomaces at a 7% dietary level does not adversely affect animal growth. However, depending on their origin and chemical composition, these pomaces may differentially influence the digestibility of pig diets and the excretion of harmful elements. Data obtained from respiration chambers further revealed the possibility of reducing methane and ammonia emissions from pigs. This underscores both the potential and the importance of selecting appropriate types and inclusion levels of agri-food by-products in livestock diets as part of strategies to mitigate climate change. Research financed by the EU Horizon Europe research and innovation programme under grant agreement No.101059609.

Lactation Curve of Sindi Cows (Bos taurus indicus) in a Tropical Environment of the Brazilian Cerrado

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The Sindi breed representes a strategic option for dairy production in tropical environments, due to its rusticity, adaptability, and efficiency under conditions of heat stress and feed restriction. However, genetic improvement programs targeting dairy performance remains incipient, and the lactation curve in this breed is still underexplored. This study aimed to describe the lactation profile of Sindi cows by fitting Wood's model to their milk yield data, generating precise parameter estimates relevant for management and selection. Daily milk production records from 30 Sindi cows were analyzed over a 25-month period, under pasture conditions, with an average lactation length of 219 days. Wood's model was fitted using the Nonlinear Mixed Model NLMIXED procedure in SAS, including a random cow effect associated with parameter A (initial production level). The estimated fixed parameters were A=5.56, B=0.206, and C=0.0059, all statistically significant ($p < 0.01$), demonstrating the model's ability to capture the typical lactation curve pattern. The variance of the random effect associated with parameter A (VARA=2.96) showed a tendency toward significance (p=0.068), suggesting individual variability in initial milk production potential. The residual variance was estimated as $S_2 = 5.40$. Based on the fitted parameters, peak milk yield was estimated at 9.42 kg/day (95% CI: 8.11–10.72), occurring early at 34.9 days in milk (95% CI: 20.7–49.1). Fitting Wood's model proved to be a robust and biologically coherent approach for describing the lactation profile of Sindi cows in Brazil. The results confirm a productive pattern characterized by an early peak, typical of Zebu and crossbred dairy animals, underscoring the need for future selection programs to target improving lactation persistency (parameters B and C). The precise quantification of these key parameters contributes to strengthening and promoting Sindi as a tropical dairy breed. Acknowledgments: FAP DF, CNPq, the Brazilian Sindi Breeders Association, the AgroIntegra Innovation Program.

Residual feed intake as a tool for efficiency in beef production systems in tropical regions

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The development of strategies designed to improve feed efficiency in beef cattle is essential for rational use of feed resources. Residual feed intake (RFI) is a measure of feed efficiency that permits to identify animals that consume less food and exhibit similar levels of production and lower enteric methane emission. However, the usefulness of RFI as an indicator of feed efficiency can be compromised by type of diet and age of evaluation. This study aimed to evaluate RFI variation throughout the growth of Nellore cattle fed different diets. Eighty-one Nellore bulls were submitted to a post-weaning feed efficiency test (PWT) and subsequently to another feed efficiency test at finishing (FT). In PWT, animals (265 ± 4.6 days; 235 ± 5.2 kg) were fed diet formulated to meet requirements of growing cattle, with 60% total digestible nutrients (TDN) and 12% crude protein (CP). In FT, animals (367 ± 4.6 days; 366 ± 4.6 kg) were fed diet formulated to meet requirements of cattle during carcass fattening phase, with 82% TDN and 14% CP. Animals were classified as negative or positive RFI in PWT and FT. Repeatability of RFI was determined based on data from each test. The change in ranking was evaluated by agreement analysis (Cohen's Kappa coefficient) using FREQ procedure and AGREE options of SAS. Forty-two of the 81 animals evaluated were classified as negative RFI in PWT. However, only 30 animals maintained this RFI class in FT, corresponding to 71.43%. Among the 39 animals classified as positive RFI in PWT, 26 maintained this RFI class in FT, representing agreement of 66.67%. Kappa coefficient of agreement in the ranking of negative and positive RFI animals was 0.3813, classified as fair or acceptable. Kappa coefficient also shows 30.86% of reranking of animals. Nellore cattle ranked for RFI in PWT may change their class at FT. However, most animals maintain the same RFI class, demonstrating that post-weaning assessment is reliable throughout the animal's life. Acknowledgments: FAPESP 2021/11922-2.

Associations Between Expected Progeny Differences and Measured Feed Efficiency in Post-Weaned Red Angus Calves

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Feed efficiency is a critical economic and biological trait in beef production, yet its genetic predictors remain difficult to quantify. The objective of this study was to evaluate the relation between individual animal expected progeny differences (EPDs) and directly measured feed efficiency traits during a 48-55 day post-weaning period. Heifers (n=47) and bulls (n=96) were monitored using the SmartFeed and SmartScale systems (C-Lock Inc, Rapid City, SD) to collect dry matter intake (DMI), average daily gain (ADG), feed conversion ratio (FCR) and body weight data. These phenotypes were paired with each animal's corresponding growth and efficiency EPDs to determine which genetic indicators best predicted actual post-weaning performance. Regression analyses were used to evaluate the strength of associations between 15 EPD predictors (DMI, Milk, CED, BW, WW, YW, ADG, CW, HPG, CEM, Stayability, Marbling, YG, RE, and BF) and sex and measured feed efficiency outcomes. Models were used to determine which EPD traits, along with sex, best predicted variation in DMI, ADG and FCR. The DMI model accounted for 54.2% of total variation in DMI ($P<0.01$). Sex ($P<0.01$), DMI EPD ($P<0.01$) and Milk EPD ($P<0.01$) were significant predictors. The ADG model accounted for 66.7% of total variation in ADG ($P<0.01$). Sex ($P<0.01$), DMI EPD ($P<0.01$) and CEM EPD ($P=0.03$) were significant predictors. The FCR model accounted for 36.6% of total variation in FCR ($P<0.01$). Sex ($P<0.01$), CED EPD ($P<0.01$), and CEM EPD ($P=0.01$) were significant predictors. These findings indicate that sex and individual animal EPDs, particularly DMI, Milk, CED and CEM, can provide insight into post-weaning feed efficiency. This suggests that ranches may be able to use specific EPD profiles to effectively identify replacement animals with favorable intake and performance characteristics. Future work will expand the dataset to a larger population to further improve model accuracy and predictive value.

Milk production and composition of Sindi cows under grazing conditions in the Cerrado biome

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Sindi is a dual-purpose breed known for its hardiness, heat tolerance, and high feed efficiency, serving as a genetic resource for adapting livestock production to climate change in tropical grazing systems. Milk production and quality are key factors for dairy farmers, representing higher yield and profitability. The aim of this study was to evaluate milk production and composition through monthly milk recording in 30 purebred Sindi cows raised in the Cerrado biome between September 2023 and October 2025. The study was conducted at the Centro de Tecnologia para Raças Zebuínas Leiteiras (CTZL) of Embrapa Cerrados, Brasília, DF. The cows grazed on Urochloa sp. or Megathyrsus sp. pastures and were fed a concentrated supplement based on corn, soybean grain, wheat bran, and a lactation mineral premix, adjusted to individual production at a 3:1 ratio. Milking was performed twice daily, with the calf present to stimulate milk letdown. Individual milk production was measured using a weighing device attached to the mechanical milking machine, and milk samples were analyzed by infrared spectroscopy to determine their constituents. In this longitudinal observational study, a descriptive analysis of the variables was performed. The average milk yield corrected to 4% fat was 7.6±3.6 kg/day, and the average lactation length was 231±60 days. Average and peak milk production were 11.1±4.4 kg/day and 18.6 kg/day, respectively. The mean percentages obtained were: fat = 4.4±1.0; protein = 3.7±0.3; lactose = 4.6±0.4; and total solids = 13.6±1.3. These results demonstrate the quality of Sindi cow milk, indicating higher yield in dairy products and increased profitability for producers. The variations observed can be attributed to non-selective milk recording, an essential tool for genetic selection and improvement. Therefore, this breed proves to be an effective option for milk production in tropical climates, well-suited to current climatic and production challenges, requiring animals that are adapted to the system and capable of performing under demanding conditions. Acknowledgments: FAP-DF, CNPq, and the AgroIntegra Innovation Program.

Growth Potential of ½ Sindi × ½ Montbéliarde Animals Using the Gompertz Growth Curve

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Estimating adult body weight and growth rate through growth curve modeling in young animals is an effective genetic and nutritional strategy. Selecting precocious animals contributes to reducing the intensity of enteric methane emissions and the environmental footprint of meat and milk production. This study aimed to determine the growth parameters of 29 crossbred ½ Sindi × ½ Montbéliarde calves (17 females and 12 males) during the pre-weaning phase, up to 241 days of age. The calves were raised in the Cerrado biome at Embrapa Cerrados (Brasília, DF), a tropical region of Brazil. Growth (body weight vs. age) was modeled using the nonlinear Gompertz function: where Y is body weight (kg) at age (t) (days), A is the asymptotic weight (kg), k is the relative maturation rate, and b is the integration constant of the model. Model fitting using PROC MODEL (SAS) resulted in excellent predictive performance, with a coefficient of determination of 0.902. All estimated parameters were significant ($p < 0.01$), with the following values: (A = 558) kg, (k = 0.0046), and (b = 1.05). The estimated asymptotic weight (A = 558 kg) is consistent with the adult body size expected for this crossbred group. The relative maturation rate (k = 0.0046) is higher than values typically reported for pure Zebu herds, indicating greater biological precocity. Animals with higher (k) values exhibit faster relative growth and reach physiological maturity more rapidly. In conclusion, the Gompertz model was appropriate for describing the growth pattern of the studied population. The high estimated (k) value suggests a superior potential for precocity in this genetic group, which, from a sustainability perspective, implies a shorter production cycle and consequently a reduced lifetime duration of enteric methane emissions per animal. The authors thank FAP DF, CNPq, and the AgroIntegra Innovation Program for their support.

Effect of Lactation Stage on Energy-Corrected Milk (ECM) Yield in Sindi Cows

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Energy-Corrected Milk (ECM) is a more precise indicator of feed efficiency as it standardizes milk yield by adjusting for fat and protein content. Its relevance is further emphasized by its strong association with sustainability, as higher ECM production per unit of feed consumed results in lower methane (CH_4) emission intensity per kilogram of product. This study aimed to evaluate the effect of lactation stage (early, mid, and late) on ECM yield in Sindi cows managed under tropical pastures conditions. A total of 164 records of milk yield and milk composition (fat and protein) from 30 Sindi cows were collected over a two-year period, with an average lactation length of 219 days. ECM was calculated using the equation: ECM = (0.327 × milk) + (12.95 × fat) + (7.2 × protein). Lactation stages were classified as early (≤50 days), mid (51–135 days), and late (>136 days). A mixed linear model for repeated measures was fitted, including lactation stage as a fixed effect and cow as a random effect. The early stage showed the highest mean ECM yield (10.24 kg/day), reflecting peak lactation, whereas the late stage had the lowest yield (5.98 kg/day). Least squares means comparisons revealed that the declines in yield from early to late (–4.26 kg/day) and from mid to late (–3.30 kg/day) were highly significant ($p < 0.0001$). No significant difference was observed between the early and mid stages ($p = 0.1626$), indicating good lactation persistency after peak production. These findings confirm the expected physiological decline across lactation and highlight the productive potential and adaptability of the Sindi breed under tropical pasture conditions. The maintenance of similar ECM levels during the early and mid stages, with a marked decline only in the late lactation, suggests the breed's suitability for sustainable milk production under tropical pasture-based systems. Acknowledgments: FAP DF, CNPq, the Brazilian Sindi Breeders Association, the AgroIntegra Innovation Program.

Cattle health and sustainability: The impact of bovine respiratory disease on the performance and carbon footprint of cattle – A systematic literature review and meta-analysis

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Cattle farming is responsible for more than half of the agricultural greenhouse gas (GHG) emissions worldwide. Since the reduction of emissions is one of the key factors in the environmental dimension of sustainability, cattle are important in terms of sustainable agriculture and food production. Previous studies suggest that improving animal health reduces GHG emissions in livestock farming by increasing production efficiency. This study investigates the impact of bovine respiratory disease (BRD) on the performance and carbon footprint of cattle production. BRD is a leading cause of morbidity in cattle and has major implications for animal health and welfare. The aim of this study is to support the hypothesis that improving animal health reduces the environmental impact of cattle farming. Therefore, this study comprises a systematic literature review and meta-analysis of the effects of BRD on performance, conducted in accordance with the PRISMA guidelines. A literature search of the PubMed database was performed and 81 studies that met eligibility criteria were identified. Health and performance data for healthy and BRD-affected cattle from all production sectors were extracted from the included studies. Statistical analyses of the converted data are ongoing. The results of the meta-analysis will be used to compare the production efficiency and the resulting carbon footprint of diseased and healthy cattle by conducting life cycle assessments (LCAs). This method is standardized by the International Organization for Standardization (ISO) 14040 and 14044 standards. LCAs evaluate the impact on climate change by calculating the carbon footprint, which comprises all occurring GHG emissions of a production system. Additionally, the environmental effects of preventive measures such as vaccination against respiratory pathogens could be considered. The results and discussion will be presented at the conference.

Mild Protein Restriction During Mid-Gestation Does Not Affect Placental Health or Calf Birth Outcomes in Extended-Grazed Beef Cows

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Extended grazing (EG) is a cost-effective and sustainable winter management strategy for beef cattle. However, EG may expose cows to mild protein restriction, impacting placental development, fetal growth, and calf immunity. This study examined the effects of protein supplementation during EG on placental health and phenotypic outcomes in cows (1st and 2nd parity) and birth performance in their calves. Angus cows (n=32) were fed a corn silage-based diet simulating EG management and individually supplemented (S; n=16) or not (NS; n=16) during mid-gestation (86.0±3.5 – 176.0±3.5 days of gestation) to provide either 100% or 80% of the crude protein (CP), respectively. All cows were group-managed under similar conditions during early (<86d) and late gestation (>176d). Cows' body weight, average daily gain (ADG), body fat, gestational length, and serum bovine pregnancy-associated glycoprotein (bPAG) concentrations (a placental health marker) were evaluated monthly from EG to calving and post-calving, and calf birth weights (BW) and vigor were assessed at birth. Cow data were analyzed using a linear mixed model approach (repeated measures), while calf data were analyzed using a Student's T test (BW) in R. Mild protein restriction during mid-pregnancy did not affect cow serum bPAG concentrations, body fat, gestational length, calf vigor, or calf BW ($p>0.05$). The impact of supplementation on ADG varied across gestation and post-calving, as indicated by a treatment × time period interaction effect ($p=0.02$), where, NS cows gained more weight ($p=0.01$) than S cows post-calving. Overall, the mild protein restriction during mid-pregnancy does not alter EG-cows' placental health or birth weight and vigor of calves, suggesting potential placental compensatory and protective mechanisms. Ongoing analysis will explore the effects on placental vascularization and calf immune priming, supporting strategies to improve nutritional management in EG systems. Keywords: Extended grazing, Maternal nutrient restriction, neonatal calves

Factors Affecting the Recurrence of Diarrhea in Purebred Sindi and ½ Sindi ½ Montbéliard Calves

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Diarrhea represents a serious challenge in calf rearing, as it generates morbidity and mortality in young animals, and its recurrence—defined as the occurrence of diarrhea in the same animal two or more times—is frequently observed during the cow–calf phase. In this context, resistance to disease is an important trait for selecting animals with greater hardiness and adaptability. This study, conducted at the Brazilian Agricultural Research Corporation (Embrapa), Cerrados unit – CTZL, aimed to identify factors that influence the recurrence of diarrhea in purebred Sindi calves and ½ Sindi ½ Montbéliard calves. Recurrence in 114 observations was analyzed as a binary variable (presence/absence) using a generalized linear model with binomial distribution and logistic link, including the following fixed effects: calf breed (Sindi and ½ Sindi ½ Montbéliard), season of birth (rainy or dry), dam genetic group (Sindi, crossbred, or Gir), sex, and the interaction between calf breed and season of birth. The random effect of the animal was included to account for repeated measures within individuals. Adjusted means (LSMeans) and differences between categories were estimated, with multiple-comparison adjustments performed using the Tukey–Kramer method. The results indicated that all evaluated factors significantly affected the probability of diarrhea recurrence ($p<0.01$). The breed × season interaction was highly significant ($p<0.0001$): ½ Sindi ½ Montbéliard calves born during the rainy season showed the highest probability of recurrence (LSMean = 1), whereas pure Sindi calves born during the dry season showed the lowest (LSMean = 0). This extreme difference was confirmed by the Tukey–Kramer contrast analysis ($p<0.0001$), demonstrating that the effect of calf breed depends on the season of birth. These findings suggest that both genetic and environmental factors influence diarrhea recurrence, highlighting the importance of implementing management strategies tailored to each risk group, especially during the rainy season. Acknowledgment: FAP-DF, CNPq, and the AgroIntegra Innovation Program.

Incidence of Diarrhea in Purebred Sindi and ½ Sindi ½ Montbéliard Calves

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Diarrhea is a major health challenge in livestock, causing economic and productivity losses during the cow–calf phase. Because it is a multifactorial condition, the evaluation of genetic, environmental, and management components is crucial for identifying more resistant animals and supporting selection programs. This study aimed to assess the incidence of diarrhea in Purebred Sindi and ½ Sindi ½ Montbéliard calves and to identify factors influencing disease risk.The study was carried out at Embrapa Cerrados (CTZL) with 88 calves (59 Purebred Sindi and 29 crossbred ½ Sindi ½ Montbéliard). Diarrhea incidence (binary: 1 = presence, 0 = absence) was analyzed using a binary logistic regression model (PROC LOGISTIC, SAS) with Fisher's scoring. Fixed effects included calf breed, season of birth, calf sex, and dam/recipient breed.The Likelihood Ratio, Score, and Wald tests indicated that, overall, the factors included were not statistically significant ($p > 0.10$). However, Type 3 Wald Chi-Square revealed a significant effect of dam breed on diarrhea probability (estimate = 0.76; $p = 0.0411$). Other variables showed no meaningful influence. Odds ratios confirmed this result: calves from crossbred dams were about 4.5 times more likely to develop diarrhea than those from Sindi dams (95% CI: 1.013–21.392).Model discrimination was moderate ($c = 0.678$; 64.4% concordance), suggesting that additional aspects—such as colostrum quality, hygiene, or nutritional stress—may also contribute to disease occurrence. Dam breed thus appears to be a relevant risk factor in this herd. Implementing targeted management strategies for crossbred dams and their calves may help reduce susceptibility and improve health during the early rearing phase. Acknowledgment: FAP-DF, CNPq, and the AgroIntegra Innovation Program.

Qualitative classification of reactivity in Gyr and Guzerat heifers during pre-milking training

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Pasture-based dairy production in tropical regions is predominantly carried out with Zebu cattle (Bos taurus indicus L.), which are known for higher reactivity. This parameter reflects the animals' responses to external stimuli and human interaction, directly influencing welfare and handling efficiency. Training heifers is essential to reduce fear and resistance and to prepare them for the milking routine. This study aimed to qualitatively classify and compare the reactivity of Gyr and Guzerat heifers across five phases of pre-milking training: initial restraint in a chute, contact with rope, cotton-swab, brush, and simulated pre-milking. The study was conducted at Embrapa Cerrados, Brasília-DF, between November and December 2023. Twenty-three heifers (12 Gyr and 11 Guzerat) were evaluated, totaling 154 behavioral observations across phases. The reactivity score (RS) was obtained from the sum of six indicators, ranging from 6 (very calm) to 18 (highly reactive). The indicators were: movement (1–5), tension (1–4), body posture (1–3), and respiration, vocalization, and kicking (1 = absent/normal; 2 = present/abnormal). Reactivity was classified as calm (RS < 7), reactive (8–9), and highly reactive (≥10). For breed comparison, the Mantel–Haenszel trend test for ordinal variables was applied. Considering all phases, Gyr heifers were classified as reactive in 50.65% of observations, calm in 28.57%, and highly reactive in 20.78%. Guzerat heifers showed 37.66% reactive, 40.26% calm, and 22.08% highly reactive classifications. No significant difference was found between breeds (p = 0.2557). Nevertheless, the average of 21.5% highly reactive animals and the substantial proportion of reactive individuals highlight the need for continued and improved handling interventions. It is recommended that rational handling practices be intensified in dairy Zebu heifers, with individualized procedures when necessary, to reduce reactivity, enhance animal welfare, and increase safety during handling. Acknowledgments: Embrapa Cerrados, ABCZ and ACZP.

Reactivity of Gyr and Guzerat heifers during different phases of rational taming

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Reactivity is a critical factor in the management of Zebu cattle, particularly Gyr and Guzerat breeds, as it directly influences animal safety and adaptability during milking. Because behavioral responses to rational taming training may vary according to breed and the specific handling phase, it is essential to quantify these interactions to better understand and improve this procedure. The objective of this study was to quantify the reactivity of Gyr and Guzerat heifers throughout the different phases of rational taming (initial restraint, beginning and end of the rope desensitization, cotton-swab desensitization, brush desensitization, and first milking) in order to determine how behavioral responses vary across stages and between breeds. Ordinal behavioral indicators were quantified as the sum of scores assigned to movement, body posture, respiration, vocalization, and kicking, with total scores ranging from 6 to 13. The study included 154 observations from 26 heifers of both breeds. A generalized linear mixed model (GLIMMIX) with multinomial distribution and cumulative logit link function was applied, with animal included as a random effect. The phases of rational handling were highly significant ($F=7.12$; $p<0.0001$), and breed showed a tendency ($F=3.66$; $p=0.06$). The final training procedures were strongly associated with calmer behavior (greater probability of lower scores), particularly the beginning of milking (Estimate: 4.3569; $p<0.0001$) and the end of brushing (Estimate: 2.4797; $p<0.05$), when compared with the early rope phase (Estimate: –0.0434; $p>0.05$) and cotton-swab phase (Estimate: 0.2612; $p>0.05$). Gyr heifers (Estimate: –1.1267; $p=0.06$) had a marginally lower probability of being classified in calm categories (lower scores) than Guzerat. The final stages of rational taming promote greater calmness in heifers. Gyr and Guzerat heifers exhibit distinct behavioral responses, reinforcing the importance of adopting handling strategies tailored to breed characteristics and specific phases of the training process. Acknowledgments: Embrapa Cerrados, ABCZ and ACZP.

Apparent digestibility of diets with different inclusion levels of wheat silage for Holstein × Gyr cows

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The wheat cultivar MGS-3 Brilhante (Triticum aestivum L.) has been selected for silage production, becoming an alternative to corn silage (Zea mays L.) during the second crop season in the state of Minas Gerais, Brazil. Therefore, the objective of this study was to evaluate the apparent digestibility of dry matter (DM) and dietary nutrients in Holstein × Gyr (Bos taurus taurus × Bos taurus indicus) cows fed increasing inclusion levels of wheat silage (WS) replacing corn silage (CS). The experiment was conducted at EPAMIG, in Leopoldina, MG, under the Animal Use Ethics Committee protocol no. 01/2021. Twelve cows with an average body weight of 518 kg and average milk yield of 10.9 kg/day were assigned to three 4 × 4 Latin squares balanced according to stage of lactation. The treatments consisted of diets with different levels of WS replacing CS (0%, 33%, 67%, and 100%). Diet, orts, and total fecal samples (collected on the last evaluation day) were obtained and analyzed for DM, organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), ether extract (EE), and nonfiber carbohydrates (NFC). Nutrient digestibility was estimated using the equation: Digestible Nutrient = [(Nutrient Intake – Nutrient Excreted) ÷ Nutrient Intake]. Apparent nutrient digestibility data were subjected to analysis of variance using SISVAR©, and treatment means were compared using Tukey's test at a 5% significance level. Increasing WS inclusion did not affect ($P > 0.05$) the apparent digestibility of dietary nutrients (means of 60.8%, 68.4%, 67.9%, 74.4%, 59.9%, 67.8%, and 77.3% for DM, OM, CP, NDF, ADF, EE, and NFC, respectively). Thus, wheat silage can be included in total mixed diets for Holstein × Gyr cows, partially or totally replacing corn silage, without causing negative effects on nutrient digestibility. Acknowledgments: FAPEMIG, INCT-CA.

Advancing Bioactive Compounds into Antimethanogenic Feed Additives: Framework for Discovery, Evaluation and Selection

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Feeding antimethanogenic compounds may offer an effective mitigation strategy to control enteric emissions from ruminants, but clear guidelines and uniform testing for their discovery, evaluation and selection are lacking. This work reviewed the advantages, limitations, and technical considerations of each step and methodology involved in identifying and screening potential candidates, ultimately providing technical guidelines for discovery, evaluation and selection of such compounds. The process starts with discovery, where mechanistic approach relies on theoretical knowledge to discover candidates, while empirical approach physically screens various sources in search for the candidate. The in vitro assessment of the candidates is done at subcellular level, in pure cultures of methanogens or in mixed rumen microbial populations. Selected candidates then proceed to in vivo evaluation, where they are administered to animals to measure enteric methane emissions, as well as effect on health and productivity. Overall, the recommendations emphasized the importance of study design and methodology, but also consideration of co-factors such as variability in source material, nature of effect, interaction with diet, relevance to the production system, safety and practicality. In conclusion, claims regarding enteric methane mitigation should only be made after the efficacy of the candidate has been confirmed through studies designed and conducted in accordance with the provided guidelines.

Dietary fibre and protein content influence formation of methane in the hindgut and in manure of pigs

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Methane formation in the hindgut and manure of pigs contributes to agricultural greenhouse gas (GHG) emissions. This study investigated the effects of dietary ingredient composition and nutrient levels on methane formation in the gastrointestinal tract and on methane emissions from manure of growing pigs. Faeces, urine, and mid-colon digesta were obtained from 36 pigs (45 kg body weight; 6 animals per treatment) housed in metabolism pens during a nutrient balance trial after a 14 d adaptation and 5 d collection period. Six nutrient balanced, restricted fed diets (2.8 times the maintenance requirement for energy; 9.62 MJ NE/kg; 8.7 g/kg standardized ileal digestible lysine) differed in crude protein (CP; high, HP: 170 g/kg; low, LP: 137 g/kg) and in the inclusion of fibre sources that increased fermentable fibre (Fs; sugar beet pulp, corn DDGS) or more inert fibre (Fi; sunflower seed meal). Total dietary NSP was calculated to range from 180 to 283 g/kg and digestible NSP from 98 to 200 g/kg. Colon digesta was incubated anaerobically for 24 h at 39°C, whereas manure (faeces + urine mixed according to individual output) was incubated anaerobically for a period of 6 weeks at 20°C using a manure inoculum collected from the manure collection system at a pig farm. Dietary treatments affected faecal organic matter (OM) digestibility (84.9 – 90.1%; $P < 0.05$). Compared with the HP diet, HPFs and LPFs numerically increased total gas production per unit OM in colon digesta, but markedly reduced CH_4 formation per unit OM incubated (-79% and -85%, respectively; $P < 0.05$). In manure, total gas production per g OM incubated was numerically higher for HPFi and HPFs (+23% and +15%, respectively) and lower for LP, LPFi, and LPFs (-21%, -20%, and -29%, respectively) relative to HP. Methane formation from manure was numerically lower for LP compared to HP diets (-49% to -58%), whereas HPFi and HPFs increased CH_4 by 25% and 15% compared with HP (overall diet effect, $P<0.05$). Overall, these findings indicate that optimizing dietary crude protein level and the type and amount of dietary fibre can reduce enteric methane formation and methane emissions from pig manure.

Full-scale implementation of a chemical additive, GasAbate, for reduction of GHG emissions from animal manures

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Stored livestock liquid manures are a significant source of greenhouse gas (GHG) and ammonia (NH3) emissions, accounting for >10% of agricultural emissions in the EU (FAO 2022). Indeed, in some cases, manure emissions can be far in excess of those predicted by inventory systems (Ward et al., 2024). These emissions detrimentally affect the environment and human health and represent elemental losses lowering the nutrient and biogas value of stored manures. Chemical slurry additives are potential treatment technologies for mitigating gaseous losses (Ambrose et al., 2023) potentially enabling the closing of nutrient loops. A peroxide-based slurry additive system, GasAbate, has demonstrated efficacy in reducing GHG and NH3 emissions at lab- and pilot-scale (Nolan et al., 2024), where the objective of this work was to develop a full-scale implementation of the additive. Dosing lances were designed to fit between slats of existing livestock flooring and sit near the base of the slurry tank. A suitable number of dosing points were designed to ensure equal distribution of GasAbate within the tank. Dosing points were serviced by a manifold system connected to 1m3 bulk containers of additive located outside the animal housing connected with stainless-steel piping. A Programmable Logic Controller (PLC) was integrated to determine optimal dosing rates and to record use of the additive for future accreditation purposes. In addition, the PLC was designed to preclude farmer involvement, to avoid increased workloads and reduce handling errors. A floating emissions chamber was employed to measured methane emissions. The designed installation was successfully completed and has since been used on multiple working farms in Ireland, the UK and Sweden. Methane emissions recorded in the chamber were 81% lower following GasAbate application. By retaining the nutrient value of the manure, this improves its biogas value and reduces the need to buy in costly synthetic fertilisers, which offset costs associated with applying such an additive to stored manure. Together this work demonstrates the progression from successful pilot-scale work to full-scale implementation of GasAbate at multiple sites.

Process based models for calculating methane emission from stored liquid manure

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Methane emissions from stored liquid manure are a significant contributor to global warming prompting increasing effects to mitigate these emissions. For decades there has been a common understanding that cleaning liquid manure stores removes the methanogenic microorganisms and reduce emissions (Canada, Germany, The Netherlands). The IPCC standard tier one and two models don't account for this effect, as they lack explicit representation of microbial growth dynamics. Most studies investigating mitigation methods use manure already rich in adapted methanogens, thereby overlooking the potential impact of cleaning practices. Further, due to high variability and limited availability of data, the methane conversion factors (MCFs) used in the calculations exhibit large coefficient of variation and may not accurately reflect regional conditions or management practices An alternative to using emission factors is to develop process-based models which include growth of methanogens, and incorporate these in inventory calculations and use them in developing mitigation techniques and strategies. Although this approach is challenging due to the complexity of microbial and physicochemical processes, they offer substantial benefits by enabling more accurate and site-specific emission estimates as well as effects of mitigation technologies. We hypothesize that it is feasible to develop simple process-based models that includes the most relevant bioprocesses and achieve a more accurate an valid emission estimate on a farm and national scale. At the conference we will present a promising novel process-based model and show that model calculations give valid estimates of the emission from stored liquid manure. This will be exemplified with a case-study in a pig-house with frequent manure removal compared to a control scenario. The model simulations suggest that ca 50% reduction can be achieved inside the pig-house with weekly removal and by more than 95% with a scraping system. However, depending on temperature and management the in-house reduction may be overshadowed by outdoor storage emissions if no cleaning or mitigation technology is applied here.

Enteric methane emission from grower-finishing pigs fed organic protein-rich feed ingredients

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Abstract In pigs, enteric methane (CH4) production is primarily influenced by dietary fiber composition and the fermentative capacity of the gastrointestinal tract. Undigested protein may contribute to enteric CH4 production through proteolytic fermentation, particularly when fermentable fiber in the hindgut is limited or depleted. As organic protein sources generally contain higher fiber levels than soybean meal, their inclusion may contribute to hindgut fermentation and, consequently, CH4 production. The present study aimed to evaluate the influence of organic protein-rich feed ingredients on enteric CH4 emissions in organic growing–finishing pigs. An experiment using a repeated incomplete 2 × 4 Latin square design was carried out with 16 crossbred organic pigs (38.7 ± 3.22 kg body weight). Each period consisted of 14 days of adaptation to the diets, and 3 days of continuous gas-exchange measurements in respiration chambers. The four dietary treatments were: a control diet (CON) based on corn starch, fishmeal, and potato protein; a diet with 7% inclusion of grass protein (GP); a diet with 18% inclusion of lupins (LP); a diet with 32% inclusion of faba beans (FP). The GP, LP, and FP ingredients were included as partial substitutions for the CON diet on a dry-matter basis. All parameters were analyzed using a linear model including period, dietary treatment, and their interaction. Methane production (L/day; $P<0.01$) and CH4 yield (L/kg dry matter intake (DMI); $P=0.05$) were higher for LP (4.64 L/d and 2.39 L/kg DMI) compared to CON (2.51; 1.46) and GP (2.37; 1.28), and for FP (4.29; 2.17) compared to GP. As expected, crude protein intake ($P<0.01$) of FP, GP, and LP was higher than CON (415, 352, 370 and 280 g/day, respectively) but did not differ among the investigated protein diets. Dietary fiber intake (g/day, $P<0.01$) was two-fold higher for LP (211) and FP (169) compared to CON (44.0) and GP (71.1). In conclusion, protein ingredients that had the highest fiber concentration also had the highest CH4 production and yield.

Enteric methane emission from organic growing-finishing pigs fed ingredients rich in insoluble fiber

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Driven by economic, nutritional, and sustainability considerations, dietary fiber (DF) levels in pig diets are expected to increase as more low-cost, fiber-rich co-products are expected to replace conventional feedstuffs. DF is generally the most influential factor affecting enteric methane (CH4) production in pigs; however, feed ingredients high in insoluble DF (iDF) may limit hindgut microbial fermentation and consequently decrease enteric CH4 production. Therefore, the present study aimed to evaluate the influence of organic feed ingredients high in iDF on enteric CH4 emissions in organic growing–finishing pigs. An experiment was conducted with 16 crossbred organic pigs (41.5 ± 2.69 kg body weight) using a repeated incomplete 2 × 4 Latin square design. Each 17-day period included 14 days of dietary adaptation, followed by 3 days of continuous gas-exchange measurements in respiration chambers, during which pigs were offered 2.8 kg feed per day. The experiment included four diets: 1) a control diet based on corn starch, fishmeal, and potato protein (CON; 25 g DF/kg DM); a diet with 20% inclusion of wheat bran (WB; 109 g DF/kg DM); a diet with 13% inclusion of oat bran (OB; 109 g DF/kg DM); and a diet with 16% inclusion of alfalfa (AA; 119 g DF/kg DM)). The WB, OB, and AA ingredients were included as partial substitutions for the CON diet on a dry-matter basis. Data were analyzed using a linear model with period, dietary treatment, and their interaction as fixed effects. Intake of insoluble non-starch polysaccharides (NSP) (g/d) was higher for pigs fed WB (121) than AA (85.3) and CON (22.2; P<0.001) and tended to be higher than OB (93.3). CH4 yield (L/kg DM intake) tended to be lower for OB (0.53) compared to CON (1.39; P=0.06) but not compared to WB (1.15) or AA (1.02). Daily CH4 production (L/d) was lower for OB than CON, WB, and AA (P<0.01). Oat bran contains more lignin, which may explain the low CH4 yield for OB. In conclusion, CH4 yield was more influenced by fiber type than by total DF concentration.

Equation for daily methane emissions of fattening pig unit depending on excretions and temperature

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In pig farms, climate change impact is mainly linked to manure management, particularly methane emissions. Temperature is announced to increase in the coming decades and is known to be an important factor influencing methane emissions. In this context, the objective of this work is to develop an equation describing the daily methane emissions of fattening pig units as a function of manure excretion and building temperature. The IPCC (2019) provides an Excel-based model that estimates a methane conversion factor (MCF) according to average monthly temperature, applied to slurry storage and accounting for monthly slurry inputs and outputs. The model is derived from the van't Hoff-Arrhenius equation, which defines a mounthly hydrolysis rate constant (k) as a function of temperature. In the present study, the IPCC model was adapted to a daily time step using the daily k value from Dalby et al. (2023), obtained for the volatile solid (VS) content of fresh pig slurry at 25°C and used as the reference k (kref). The daily model calculates k as a function of temperature (T) and the kref, and applies it to the daily quantity of VS resulting from both daily excretion and the residual VS from previous days after hydrolysis. The model was applied to different physiological stages and manure management strategies (removal frequencies) to estimate the resulting MCFs. These MCFs were then compared with average emissions factors from the ELFE database (Guingand, 2026), which compiles gaseous emissions measurements. 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. Further work will include testing the equation with dynamic experimental datasets collected across different seasons, and comparing the simulated daily emissions with measured values. The final equation will be integrated into the Thermipig model (Quiniou et al., 2021) to assess the vulnerability of pig production to increased temperatures in the future.

Development of a slurry additive for pig manure, to reduce GHG emissions, retain nutrient value and influence animal health

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Slurry additives represent a valuable means of mitigating GHG emissions, which contribute to global climate change, and ammonia emissions. Methane (CH4) emissions from pig slurry are significant and are a means of rapidly reducing agri-based GHG emission contributions. At laboratory scale, a peroxide-based additive notably reduced slurry gaseous emissions (Thorn et al., 2022). The objective of this work was to validate the additive's (GasAbate) effects on swine manure in pilot scale (1 m3) tanks at 20°C then demonstrate the concurrent retention of biogas and fertiliser value of the treated slurry. Biogas value was determined by biomethane potential (BMP) assays and in 100L pilot scale reactors, while fertiliser value was assessed using a yield trial in replicated pots, using 2 soil types. Odour levels were assessed from 1m3 tanks. We then proceeded to full-scale installation on a working pig farm, monitoring in room emissions readings and evaluating biogas value. After 24 days and a single dosing, emissions in 1m3 slurry tanks were reduced by 75% (CH4), 50% (CO2), 40% (N2O) and 40% (NH3) (Nolan et al., 2024). Odour levels, in particular H2S were reduced by 58 – 76%. Retention of the biogas value of fresh manure was demonstrated by BMP assays, with an 57% increase in biogas value. An independent yield trial using Lolium perenne was performed and pots receiving GasAbate treated manure yielded 20% higher than untreated slurry pots. The additive was successfully installed at full scale, with stainless steel tubing connecting, via a manifold system, to a 1m3 tank of GasAbate outside the animal housing. A programmable logic controller was added to preclude farmer interaction and reduce human error. Monitoring of emissions in-room demonstrated efficacy of the additive. This was substantiated by increased biogas yields when slurry from GasAbate treated slurry was fed into a full-scale, 270 m3 onsite digester, with a yield of 22 m3 biogas per tonne when compared to a previous highest yield of 11 m3 per tonne of untreated slurry. The final phase consists of evaluating changes in pig health and/or finishing weights and this work is ongoing.

Influence of Cultivation Intensity on the Net Carbon Footprint of a Mediterranean Cow–Calf System

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This study aimed to estimate the net carbon footprint (Net-CFP) of Mediterranean cow-calf system and to assess the role of cultivation intensity in shaping the environmental performance. Eighteen beef farms adopting a cow-calf grazing system, with an open productive cycle, were considered. Farms were selected in relation to the cultivation rate (CR) and classified as: high (high-CR; > 15% of cultivated lands) and low (low-CR; <15% of cultivated lands). Data were collected by interviewing farmers, in a cradle to farm gate approach, and according to ISO14040:2006 and 14044:2006 standards. The average of five producing years was chosen as the temporal boundary. Emission intensity was reported as kilogram of CO2 equivalent (CO2e) per kg of live weight (LW) sold from yearling beef, per kg of total LW (TLW) sold from end-career cows, bulls, and yearling beef, and per hectare (ha) of land. Soil carbon sequestration was estimated by considering the above- and below-ground biomass residues, and the organic carbon from manure deposition. Carbon sequestration from Meriagos, forests, and Mediterranean scrubland was also considered. Gross CFP was lower in low-CR farms than in high-CR farms (19.80 vs. 26.75 kg CO_2e/kg LW sold). Enteric methane was the main contributor, accounting for 68.3% and 74.2% of total GHG emissions in high and low-CR farms, respectively. When carbon sequestration was included in the model, Net-CFP was significantly lowest ($P<0.01$) in low-CR farms. In conclusion, lower cultivation intensity reduced the CFP of cow-calf systems, generating higher carbon credits that could fully offset the emissions of the fattening phase.

Mitigation of enteric methane emissions in Italian Holstein heifers through nutritional strategies

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Reducing enteric methane emissions is essential for the environmental sustainability of dairy production, especially under increasingly challenging climatic conditions. This study integrated four in vivo trials to evaluate nutritional strategies for mitigating methane emissions in Italian Holstein heifers. In Trial 1, 36 heifers received diets supplemented with 0, 2,000, 4,000, or 10,000 FPI U/kg DM lysozyme for 42 days. Trial 2 used a crossover design with 16 heifers assigned to isoenergetic corn-based or hydrogenated-fat diets for 10 weeks. Trials 3 and 4 were conducted under summer heat stress. Trial 3 allocated 36 heifers to a micro-cooling system, an appetizing feeding schedule, or a control group for 42 days; Trial 4 involved 36 heat-stressed heifers receiving the same micro-cooling system, rumen-protected calcium gluconate, or a control for 35 days, in both trials recording physiological responses, feed intake, and methane emissions. In all trials, methane emissions were measured with a laser methane detector, and growth parameters were recorded. Data were analyzed using mixed models with treatment, time, and their interaction as fixed effects, and heifer as a random effect. Results showed that lysozyme at 4,000 and 10,000 FPI U/kg DM significantly reduced peak methane emissions (163.15±9.19 vs 137.54±9.19 and 132.88±9.19 ppm-m; $P<0.05$) on day 42 without affecting feed intake, growth, or health. Corn-based diets lowered methane emissions compared with hydrogenated-fat diets, indicating that dietary energy source modulates enteric methanogenesis (125.65±8.64 vs 131.95±8.64 ppm-m; $P<0.05$). Under heat stress, no differences were measured among treatments for methane emissions. Calcium gluconate enhanced nutrient digestibility but did not mitigate methane production as well. Overall, integrating lysozyme supplementation and optimizing dietary energy source can effectively modulate enteric methane emissions in Italian Holstein heifers. These findings provide practical, sustainable strategies for dairy farming that uphold animal welfare.

Producer Adoption and Economic Pathways for Reducing Enteric Methane in U.S. Feedlot Cattle Using 3-Nitrooxypropanol (3-NOP)

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The U.S. beef cattle industry is under increasing pressure to reduce enteric methane (CH_4) emissions. Feed additive 3-Nitrooxypropanol (3-NOP) offers a means of mitigating methane. However, upon approval, its future adoption in U.S. feedlots remains uncertain due to a lack of clear market incentives. This study's objectives are (1) to estimate potential 3-NOP adoption by U.S. feedlot producers under alternative incentive structures and (2) to assess how different approaches to achieving the U.S. Roundtable for Sustainable Beef's goal of a 10% reduction in feedlot emissions by 2030 affect economic efficiency and social welfare. A survey of U.S. feedlot producers (n = 65) was conducted from November 2023 to January 2024. Willingness-to-adopt measures were elicited using a double-bounded dichotomous choice design; interval-censored regression models were estimated to evaluate the effects of additive cost, incentive type (processor premium versus government subsidy), and inclusion of net profit information. Data were weighted to reflect national feedlot demographics and analyzed separately for small (<2,000 head sold/year) and large (≥2,000 head sold/year) operations. Results show producers prefer processor premiums to government subsidies, requiring on average 2.54 USD/cwt (1 cwt = 45 kg) less to adopt when offered a premium. Presenting net profit information further reduced required incentives by 3.82 USD/cwt. Small producers required incentives of about 4.04 USD/cwt more to adopt 3-NOP compared to large producers. The least-cost pathway to achieving emissions targets would rely on processor premiums primarily directed toward large feedlots, which raises equity concerns. Welfare analysis indicates that the marginal cost of adoption rises with each additional animal, suggesting investment in research to improve the efficacy of 3-NOP could deliver greater methane reduction at lower social cost than broad producer subsidies. These findings provide evidence-based guidance for policymakers, processors, and researchers seeking economically sustainable solutions to enteric methane mitigation in beef production systems.

Combined effects of hydrogen sink compounds and dietary NDF level on enteric methane emission measured using SF_6 tracer in a dual-flow continuous culture system

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Two complementary experiments evaluated the combined effects of hydrogen sink (HS) compounds and dietary neutral detergent fiber (NDF) levels on enteric methane (CH_4) production using the sulfur hexafluoride (SF_6) tracer adapted to a dual-flow continuous culture system. The first experiment followed a 4 × 4 Latin square in a 2 × 2 factorial, testing HS compounds and antimicrobials (virginiamycin and monensin) in diets with 15% or 45% forage. The second was an in vivo trial with twenty-four Nellore young bulls assigned to two treatments in a completely randomized design to validate culture system outcomes. In the dual-flow study, CH_4 production increased with forage level (8.78 vs. 7.17 g/kg DM; $p < 0.05$). Diets with 15% forage plus HS compounds showed lower CH_4 output than those without HS (5.75 vs. 8.59 g/kg DM; $p < 0.10$). Ruminal pH was lower in the low-forage diet with antimicrobials, while other treatments remained within physiological limits (6.17 vs. 6.84, 6.58, and 6.70). A synergistic effect was evident between fiber reduction and HS addition, further decreasing CH_4 formation compared with either factor alone. In vivo, HS supplementation in high-grain diets without roughage sharply reduced CH_4 emissions (9.91 vs. 23.11 g/kg DM; $p < 0.0001$), confirming HS efficacy under low-fiber conditions. Methane formation in the dual-flow system was consistently lower than in vivo values, reflecting differences in microbial adaptation and hydrogen dynamics. Overall, reducing forage inclusion limited hydrogen availability for methanogenesis, enhancing HS effectiveness. The SF_6 tracer integrated into the dual-flow culture system proved reliable, affordable, and animal-sparing, allowing simultaneous evaluation of ruminal fermentation and methane production under controlled conditions.

The Efficacy of Greenhouse Gas Mitigation Practices in Pasture-Based Livestock Systems: A Meta-Analysis

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Temperate grasslands are managed for both livestock production and the provision of ecosystem services, including carbon sequestration and nutrient cycling. Pasture-based livestock systems contribute to CO2, CH4, and N2O emissions, with impacts modulated by management practices such as fertilization, grazing intensity, soil amendments, and animal genetics. Evidence on the comparative effectiveness of mitigation interventions is scattered, limiting policy translation and farm-level decision-making. This meta-analysis aims to identify the interventions that most effectively reduce GHG emissions, while also considering cost-effectiveness, informed by MACC data. A systematic review was conducted using the search features in Google Scholar, Scopus, and Web of Science (March-July 2025), yielding 106 articles and 126 effect sizes across 13 categories of mitigation practices. Effect sizes were computed as Hedges' g and pooled using multivariate random-effects meta-analysis with restricted maximum-likelihood estimation and cluster-robust variance correction. Moderator analyses examined the effects of baseline soil pH, study design, year of publication, stocking rate, and study duration. Cost-effectiveness was interpreted in the context of published Marginal Abatement Cost Curve (MACC) data for Irish pasture-based systems. The meta-analysis showed significant overall mitigation across all categories (g = -2.27; 95% CI -2.66 to -1.89). Highest reductions were observed for feed additives (g = -2.61), improved genetics (g = -2.30), and soil pH management (g = -2.23). Moderate reductions were found for multispecies swards (g= -1.87), grazing and stocking rate (g = -1.78), anaerobic digestion (g = -2.040, and peatland rewetting/tillage interventions (g = -1.71). Integrating results with MACC estimates highlights that pasture-embedded practices (legume-based swards, genetic improvement, and pH correction) offer high mitigation per unit cost. In contrast, additive-based interventions, although effective, are less cost-efficient.

Enteric methane emissions of beef heifers grazing naturalized pastures in Western Canada under high and low stocking rates

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Stocking rate (SR) influences forage use, growth performance, and greenhouse gas emissions. We evaluated the effects of high (HS; 2.3 animal unit months [AUM]/hectare, target-70% biomass utilization; n=61) and low (LS; 1.1 AUM/hectare, target-30% biomass utilization; n=29) SR on enteric methane (CH_4) and carbon dioxide (CO_2) emissions and their intensities in ninety beef heifers (370 ± 43 kg; 13–15 months; 4 pastures per treatment) grazing naturalized pastures over two summers (2024 and 2025; 81±5 days). Animals were weighed every ~28 days, with emissions monitored continuously (GreenFeed; C-Lock Inc., Rapid City, SD, USA). Data were analyzed via linear mixed models with SR and experimental day as fixed effects and paddock nested within year as a random effect. Body weight (BW) and average daily gain (ADG) showed SR × day interactions ($P < 0.001$; $P = 0.003$): BW increased seasonally for both groups, but LS heifers gained more (0.85 vs 0.99 kg/d) and were ~20 kg heavier at the end of grazing, with ADG increasing in LS and declining in HS heifers through the grazing season. Daily CH_4 g/d emissions decreased over time ($P < 0.001$). Daily CO_2 emissions showed an SR × day interaction ($P = 0.033$); LS animals maintained stable emissions (7,341 ± 118 g/d), whereas HS declined (from 7,200 to 6,400 g/d). CH_4/ADG (169 vs. 201 g/kg; $P = 0.002$) and CO_2/ADG (6,771 vs. 7,493 g/kg; $P = 0.009$) were lower in LS than HS. These results indicate that LS improves enteric emissions intensity per unit of ADG but yields higher emissions per unit of BW. This study will be replicated in the next grazing season.

Restricted grazing reduces enteric methane emission of high-yielding dairy cows

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Enteric methane emission from dairy cattle account for a substantial share of agriculture-derived greenhouse gases. This study evaluated the impact of spring grazing on methane emission of high-yielding dairy cows. Twenty-seven cows were allocated to a two-period incomplete Latin square design with three dietary treatments: full indoor feeding (A); 6 h d^{-1} grazing on perennial ryegrass (Lolium perenne) with indoor feeding (B); and 6 h d^{-1} grazing on a multispecies sward of perennial ryegrass, white clover (Trifolium repens) and ribwort plantain (Plantago lanceolata) with indoor feeding (C). The indoor roughage of B and C was slightly different than that from A and was adjusted to the different nutritional requirements of the cows in these groups due to the combination with fresh grass. Methane emissions were measured using GreenFeed units both indoors (n=1) and on pasture (n=2, 1 per treatment). Grass intake was estimated using both the n-alkane method and the Dutch net energy for lactation (VEM) approach. Based on the VEM method, average fresh grass dry matter intake was similar between B (5.22 kg d^{-1}) and C (4.78 kg d^{-1}). The n-alkane method (C33/C32) yielded lower absolute values but confirmed the same pattern (3.75 and 3.46 kg d^{-1} for B and C, respectively). Fat- and protein-corrected milk (FPCM) yield did not differ among treatments, although it was numerically highest for A (38.7 kg d^{-1}), followed by C (38.0 kg d^{-1}) and B (37.1 kg d^{-1}) ($P = 0.208$). Methane production was significantly lower for B and C (466 and 478g d-1, respectively) compared with 545 g d-1 for A ($P < 0.001$). Methane intensity was reduced ($P = 0.002$) in both grazing treatments, with B and C reaching 12.7 and 12.6 g kg^{-1} FPCM, respectively, compared to 14.25 g kg^{-1} FPCM for A. These results demonstrate that integrating restricted grazing (6 h d^{-1}) into the feeding strategy of high-yielding dairy cows can reduce enteric methane without compromising milk production. Further research should investigate the long-term effects of multispecies swards in methane mitigation.

Seasonal and Diurnal Variation on Enteric Methane Emissions of Beef Cattle Grazing Rangelands.

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The goal of this study was to quantify methane (CH_4) emissions from cattle raised in the Western U.S., where cows are typically fed during the winter and graze on native rangelands from spring to fall. Twenty-two cows (Angus × Hereford) were randomly selected from the Eastern Oregon Agricultural Research Center (EOARC) herd, and were acclimated in the spring to Greenfeed (GF) Pasture System monitoring units (C-Lock) to measure CH_4 emissions (g/day). During the acclimation period, the cows were maintained as a group and fed meadow hay ad libitum, (8.5% CP and 56% TDN). Once the cows were acclimated to the GF, both were transported to the Northern Great Basin Experimental Range (NGBER) to assess CH_4 emissions during the grazing season. The GF were strategically placed near water sources and programmed to record up to 8 visits per cow each day, with alfalfa pellets used as an enticement. Summer and fall forage CP and TDN were 3.5% and 57%, and 2.8 % and 55%, respectively. Preliminary data for CH4 emissions for the seasons were analyzed over time as repeated measures, including week, and period of the day, using cow as a covariate ($P < 0.001$), with the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC, USA). Methane emissions were greatest ($P < 0.0001$) during summer (216 ± 1.06 g/cow daily), and similar between spring and fall (198 ± 1.40 g/cow daily; $P = 0.51$), illustrating the seasonal variation in emissions of grazing beef cattle. For the period of the day, variations within the day ($P \geq 0.001$; morning, afternoon, evening, and night) were observed for all seasons, with the prevalence of the lowest CH4 emissions happening in the morning. These preliminary data show large seasonal and diurnal variation in CH4 emissions, which should be accounted for when evaluating cattle CH4 emissions and developing mitigation strategies.

Enteric methane emissions and animal performance in mixed pastures with forage legumes.

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Forage legumes have the potential to improve diet quality and modulate rumen fermentation, making them a promising alternative for reducing enteric methane (CH_4) emissions in cattle. This study assessed canopy structure, animal performance, nutrient intake and digestibility, and enteric CH4 emission of heifers grazing three pasture types (PT): Urochloa brizantha (Marandu palisade grass) monoculture with no nitrogen (N) fertiliser application (Unfertilised), Marandu palisade grass monoculture fertilised with 150 kg of N/ha/year (Fertilised), and Marandu palisade grass/Grona heterocarpa subsp. Ovalifolia (ovalifolium legume) mixed pasture with no N fertiliser application(Mixed). Two test animals were used per experimental unit, totalling 18 animals evaluated. Pastures were managed under rotational stocking with seven days of grazing and 28 days of rest, and variable stocking rate adjusted via the put-and-take method to ensure similar forage allowance across PTs. Methane (CH_4) emissions were measured using the sulfur hexafluoride (SF_6) tracer gas technique. The legume proportion in the Mixed pasture averaged 26% throughout experiment. The diet from the Mixed pasture showed increases of 5% in crude protein, 58% in condensed tannins, and 19% in iNDF, without affecting dry matter intake (1.88% BW) or dry matter digestibility (average of 54%). Animal performance also did not differ among PTs, with average daily gain (ADG) of 0.460 kg/day and stocking rate of 1.85 AU/ha ($P > 0.10$). Enteric CH_4 emissions form heifers were significantly lower in the Mixed pasture, with reductions of 25% when expressed per animal, per unit of body weight, metabolic weight, per dry matter intake, and per ADG ($P<0.10$). The Marandu palisade grass/ovalifolium legume mixed pasture emerges as a promising strategy to reduce CH_4 emissions without compromising animal performance or productivity, contributing to more productive and sustainable grazing systems. Keywords: Nitrogen fertiliser; ovalifolium legume; warm-season legume.

Impacts of cow–calf system intensification on performance and enteric methane emissions in beef cattle

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Enteric methane is a key environmental challenge in cow–calf systems, especially under extensive conditions with degraded pastures. Intensifying grass-fed beef operations can improve nutrient supply and productivity per land area. This study evaluated 36 cows and their calves performance and CH_4 emissions in three systems at the Federal University of Lavras, Brazil: (1) palisade grass (Urochloa spp.) without N fertilization and cows receiving year-round mineral supplementation (MS); (2) palisade grass fertilized with 165 kg N/ha/yr, with mineral supplementation in the rainy season and protein concentrate in the dry season (CS); and (3) palisade grass fertilized with 165 kg N/ha/yr, with mineral supplementation in the rainy season and partially mixed ration during the dry season (silage enriched with 8.1% DDG; FS). Methane (CH_4) emissions were measured using the sulfur hexafluoride (SF_6) tracer gas technique. The CS and FS increased dietary crude protein (CS: 14.8%; FS: 13.3%; MS: 10.3%; P<0.001) and DM digestibility during lactation (CS: 57.8%; FS: 57.3%; MS: 47.0%; P<0.001). Stocking rate increased substantially in CS and FS (2.61 and 2.53 AU/ha) compared with MS (1.81 AU/ha; P<0.001). Calf liveweight gain per area was greatest in CS (504 kg/ha/year), followed by FS (450 kg/ha/year), and MS (317 kg/ha/year; P=0.006). The CH_4 emissions (g/d) of cows did not differ among systems (P<0.10), whereas calves in CS and FS showed lower emissions per unit of feed intake due to greater diet digestibility. Methane emission per hectare mirrored stocking rate and was greater in CS (P=0.035), while emission intensity (kg CO_2-eq/kg product) did not differ among cow-calf production systems (P =0.147). Intensification via nitrogen fertilization and strategic supplementation increased productivity per hectare without changing individual emissions, improving the efficiency and sustainability of tropical beef production. Keywords: Cow–calf systems; greenhouse gases; nitrogen fertilisation; sustainability.

Effect of forage cultivar selection on digestive capabilities and greenhouse gas emission potential of beef cattle

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In the discipline of forage agronomy, much attention has been paid to cultivar development and selection. Within this system, selections are made based on hardiness to environmental conditions, resistance to biotic and abiotic stresses, and improvement in nutritive value parameters. However, there is a lack of information on comparisons among cultivars for in vivo digestibility under grazing conditions. The objective of this study was to evaluate the effect of cultivar selection on in vivo digestibility and methane emissions in beef cattle production systems. In a Latin square design, ruminally-fistulated heifers (n = 4) were randomly allocated one of four bermudagrass (Cynodon dactylon [L.] Pers.) cultivars ('Coastal' [COS], 'Russell' [RUS], 'Tifton 44' [T44], or 'Tifton 85' [T85]) for four 30-d in vivo periods (21-d adaptation and 9-d collection). This metabolism experiment was used to determine intake and digestibility as well as estimate CH4 emissions via the IPCC Tier 2 calculations. There was no effect of treatment on intake (7.0 kg/d; P = 0.33), excretion (3.4 kg/d; P = 0.29), or digestibility (52.4%; P = 0.95) of DM. Nor was there an effect of treatment (P = 0.13) on digestibility of NDF (55.9%), ADF (50.9%), hemicellulose (59.3%), or acid detergent cellulose (59.6%). There was, however, an effect of treatment (P < 0.01) on CH4 emissions estimated from the IPCC Tier 2 equations. Estimated CH4 emissions were less (P < 0.05) from T85 (106.6 g/d) than from RUS (134.2 g/d), COS (132.4 g/d), or T44 (129.7 g/d). Results are interpreted to mean that, while cultivar advancements may result in improved agronomic performance and nutritive value parameters, these improvements may not translate to improved livestock efficiency, at least at the individual animal level.

Methane emissions in Verata goats under extensive grazing in dehesa system: preliminary results

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Extensive goat production systems in Mediterranean dehesa ecosystems remain poorly characterised regarding methane emissions, despite reducing dependence on external inputs and reliance on natural resources. This study aimed to characterise CH_4 emissions in Verata goats, an autochthonous dual-purpose (milk and meat) breed well-adapted to the local environment, under extensive grazing conditions throughout a complete annual cycle. Ten Verata goats grazed continuously, without supplementation, on an eight-hectare plot of holm oak trees at the CICYTEX experimental farm (39.0614°N, 6.8631°W) from October 2024 to October 2025, covering non-pregnant and gestation stages. Methane emissions were measured monthly using a hand-held laser methane detector positioned at 1 meter from each animal, recording individual emissions for 4 minutes. On each measurement day, five pasture samples were collected across the plot, oven-dried and analysed by NIRS. Respiratory CH_4 (CH4r), eructated CH_4 (CH4e), and total CH_4 (CH4T) were recorded in ppm. Mean annual CH_4 emissions were 6.32±0.25 ppm for CH4r (range 1.99-10.13), 99.69±8.45 ppm for CH4e (range 36-279), and 107.25±9.01 ppm for CH4T (range 39.52-234.78). Seasonal variation was significant for CH4r (P=0.024), with the highest values in winter (7.74 ppm) and the lowest in summer (5.77 ppm). Total CH_4 emissions showed a seasonal trend (P=0.088), with lower values in summer (71.68 ppm) compared to spring (131.49 ppm), autumn (116.19 ppm), and winter (128.35 ppm). These preliminary results provide baseline data on methane emissions from an autochthonous dual-purpose breed in extensive dehesa systems, essential for improving national GHG inventories. Future research will relate emissions to pasture quality parameters to develop tailored mitigation strategies for extensive Mediterranean systems, while preserving the sustainability benefits of dehesa-based production. Acknowledgements: Project 0100_TID4AGRO_4_E is co-financed by the European Union through the INTERREG VI-A Spain-Portugal Programme (POCTEP) 2021-2027, and by the FEDER fund SOSTEGAN.

Rice bran supplementation on heifers grazing native pasture: Ruminal environment and methane emissions

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Beef production in rangeland systems is associated with higher enteric methane (CH4) emissions. In Uruguay, rice bran (RB) supplementation has improved animal performance and overcome the nutritional limitations of native pastures in winter. In turn, this byproduct could be a nutritional strategy due to high fat content. The aim of this study was to evaluate the supplementation with rice bran on ruminal environment and methane emissions of beef heifers grazing native pasture in winter. Fourty-eight Aberdeen Angus×Hereford heifers (LW 356±11.1 kg) were assigned to each of two treatments: (i) native pasture (NP = 24); (ii) native pasture + rice bran (0.7% LW, RB = 24). Methane production was measured for 85 days using the GreenFeed system (GF; C-Lock Inc., USA). The rumen samples were collected by oesophageal intubation to determine pH, volatile fatty acids (VFA) and NH3. The data were analyzed with the MIXED procedure of SAS (9.0; USA) with a model that included the fix effect of the diet. Heifers in RB presented lower ruminal acetic and higher propioniate respect to NP ($P < 0.001$). pH and ammonia not differ between treatments. Methane emissions was similar between RB and NP (148 vs 143 g/d repesctively), but the intensity of methane emissions was lower in RB respect to NP (195 vs 428 g/kg LW, $P < 0.001$). The supplementation with rice bran 0.7% LW reduced ruminal acetate and the intensity of methane emissions, being a nutritional strategy to reduce methane emissions in rangeland systems in winter.

Lessons learned about on-farm N emissions from ruminant systems and strategies for mitigation

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Nitrogen (N) use efficiency in ruminant systems tend to be low (<30%) which can lead to losses of reactive N into the environment. The major losses of concern are the gaseous losses of ammonia (NH3) and nitrous oxide (N2O) and leaching losses of nitrate (NO3). These losses contribute to air quality degradation, climate change and water pollution and ultimately, generate potential negative impacts on human and in some cases animal health. Reactive N losses occur across the cycle of ruminant production including animal housing, manure storage and feed/forage/pasture production. In many cases the pathways of loss can be complex and influenced by many factors such as how animals are fed, how and where they are housed, how manure is handled/stored, how manure is managed in pasture and cropping systems as well as climatic, soil, and plant variables. These complexities can also provide opportunities along the cycle to intervene and improve overall nutrient use efficiency and mitigate the losses of reactive N to the environment. This presentation will cover the main pathways of losses and potential strategies to reduce these, in some cases using examples from on-farm research conducted in dairy and beef systems including challenges faced when operating at scale.

Nitrogen efficiency in animal farming systems with specific emphasis on pigs and poultry (invited talk)

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Nitrogen efficiency in animal farming systems can be evaluated at different scales. The most common is to calculate efficiency at animal level, as the ratio between N retention and intake. This efficiency is higher in pigs and poultry (30-50%) than in ruminants (10-25%), and among monogastric animals, it is higher for fast-growing broilers (~50%), lower for laying hens (~ 30%) and intermediate (~ 40%) for pigs and slow-growing broilers. The evaluation of N efficiency at farm level is more difficult to assess, since it requires quantifying N-gaseous emissions and the amount of N recycled as fertilizer within the system. This generally results in a higher efficiency at farm compared to animal level (up to 70%). In pigs and poultry, two complementary nutritional approaches are used to improve N retention efficiency: (i) ensure adequate protein/amino acids supplies over time according to the genetic potential of animals, and (ii), improve dietary amino acid balance, allowing to reduce total protein intake. In practice, the most efficient is to combine both approaches, the ultimate improvement being obtained with daily precision feeding. At farm level, N efficiency can be improved be reducing gaseous emissions, and enhancing N recycling as fertiliser. In slurry-based systems, most of N-gaseous losses occur as NH3. This emission is largely affected by slurry pH and ammonia concentration, which depend mainly on feeding strategy (protein, EB, fibre, additives) and slurry management . When animals are reared on litter, N is also emitted as N2O and N2, in amounts depending a lot on litter management. In broilers, there is a strong synergistic effect of lowering dietary protein on N excretion, pH and humidity of the litter, resulting in a significant decrease of NH3 emission (-27% per 10 g protein/kg). More recently, a new efficiency criterion was proposed in the context of feed-food competition. It is calculated as the amount of human-edible protein in animal products (meat, milk, eggs) allowed by one kg of human-edible protein in animal feeding. With this approach, N efficiency is much higher and close or above one for pigs and poultry. It can be further improved by increasing the proportion human-non edible ingredients in the diet.

Assessing Environmental Impacts of Using Plasma Technology for Manure Treatment: A Whole-Farm Dairy System Analysis

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Plasma treatment has recently been introduced as an innovative solution for reducing ammonia (NH_3) and methane (CH_4) emissions and improving nitrogen retention in manure. Although former studies showed promising impacts, the trade-offs have not been well assessed. In this study, a comprehensive assessment was carried out using a material flow analysis based on a mass balance approach. Two scenarios were assessed, namely i) a conventional manure management system, ii) treating the liquid fraction using plasma. The results showed that electricity contributed most (50%) to the total GHG emissions of the plasma treatment. The main sources for environmental benefits were replacing mineral fertilizers (production and application emissions) and reusing the heat for warming purposes. Treating the liquid fraction of the slurry by plasma reduced the methane emissions by 94% while nitrous oxide emissions increased by 55%. In total, plasma reduced the environmental burdens of the conventional manure management system by 40%. The reduction of ammonia emissions during all manure processing stages was 22% on an annual basis. Economic assessment showed that the cost effectiveness of plasma technology varies between 315 and 376 €/ton CO_2eq. Sensitivity analysis was carried out, and the results showed that the nitrogen content of raw slurry, the share of renewable electricity, and the N_2O emissions factor of NEO during storage have substantial impacts on the total GHG emissions of the plasma treatment, while the methane conversion factor of slurry during storage did not have such a significant impact. The results of this study illustrated that although plasma technology might have a promising effect on GHG emissions through reducing emissions from manure management systems and stabilizing nitrogen in manure at the farm scale, its large-scale application faces several practical challenges, including high cost per nitrogen enriched and high energy demand. Widespread deployment of this system requires sufficient grid infrastructure, which should be considered. Further studies on N_2O emission factors of nitrogen-enriched organic fertilizer during storage and application are needed to fill the gaps.

Comparative evaluation of four carbon assessment tools for dairy production systems

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Quantifying greenhouse gas emissions on dairy farms is a critical step for developing effective mitigation strategies and supporting farmers in their transition toward carbon neutrality. However, the diversity of available assessment tools can lead to inconsistent estimates. The aim of this study was to compare the results of four widely used carbon assessment tools in Canada (Holos, Agriclimat, Logiag, and the Cool Farm Tool) and to identify the key factors driving differences among their results. Each tool relies on distinct methodological frameworks, applying different assumptions, emission factors, equations and data sources, all of which influence how emissions are quantified. The comparison was carried out on 20 dairy farms in the province of Québec, Canada. The average milk carbon footprint (expressed as CO2eq. per kg of fat and protein corrected milk; FPCM) and the distribution of emissions across sectors are presented in the table below. Spearman correlations (ρ) and concordance correlation coefficients (CCC) revealed limited consistency and poor agreement across tools, with the strongest correlation between Holos and Agriclimat (ρ = 0.34) and the weakest between Agriclimat and Logiag (CCC = 0.06). Differences among calculators were observed across all emission sources. Variations in enteric and manure related emissions were mainly driven by differences in Tier 2 equations, dietary variables, and climatic data. Differences in crop and input related emissions stemmed from the inclusion of winter emissions, lime and fertilizer use, electricity and feed databases, as well as calculator specific assumptions that altered input requirements. The allocation method between on farm and cash crops also had an effect on the results. This study highlights the importance of methodological transparency and the need for increased interoperability between carbon accounting tools to support consistent and credible climate assessments in the dairy sector. Average results obtained from the four assessment tools HolosAgriclimatLogiagCool Farm ToolMilk carbon footprint (CO2 eq./kg of FPCM)1.021.051.131.16Emissions from enteric fermentation (%)45463846Emissions from manure management (%)28201420Emissions from crop (%)14161713Emissions from inputs (%)13183121

Validation of a New Multi-Compartment Dairy Research Barn for Controlled Gas Emission Measurements

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The evaluation of measures to reduce emissions from dairy cattle housing requires reliable data obtained under controlled experimental conditions. Studies conducted on commercial farms using a multi-site approach often show high variability in results. This can be attributed to numerous influencing factors, many of which cannot be controlled. To address this, a new dairy research barn with five identical compartments was constructed to enable controlled case-control measurements. Before cows were introduced into the barn, it was essential to verify whether the barn would allow reliable, compartment-specific emission measurements. The concentrations of methane (CH_4) and ammonia (NH_3) were continuously monitored in all compartments using a cavity ring-down spectrometer (CRDS). In parallel, climatic variables (temperature, humidity, wind speed and wind direction) were recorded inside and outside the barn. Potential cross-contamination between compartments was assessed in a dedicated methane tracer experiment, in which CH_4 was released in a single compartment while concentrations were simultaneously recorded in all compartments under naturally ventilated conditions. Blank measurements confirmed homogeneous background concentrations throughout the research barn. No significant differences were detected between compartments, and the relative deviations of CH_4 and NH_3 remained below 4 %. This demonstrates that compartment location did not affect background levels, and no measurable external or stall-related contamination occurred. During the tracer experiment, CH_4 concentrations in the source compartment reached levels typical for naturally ventilated dairy barns, while cross-compartment transfer remained clearly below 1 %, showing limited air exchange and effective functional separation between compartments. These results confirm that the barn provides controlled, reproducible and low-interference measurement conditions. The validated setup represents a reliable platform for evaluating emission mitigation strategies, as well as for integrated studies on emissions, housing environment and animal welfare.

Novel Dairy Research Barn: Precision Emission Measurements and Animal–Environment Interaction Analysis

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Ammonia emissions in dairy barns are strongly influenced by floor condition, surface contamination and underfloor slurry storage. Gas formation is conducted by urease activity on moist surfaces, impacted by temperature and humidity. Floor design and cleaning frequency therefore play a key role in emission levels. In commercial barns, however, measurements are affected by uncontrollable factors such as building layout, weather and animal behaviour, making it difficult to isolate effects of mitigation measures or to assess welfare impacts. Controlled yet realistic conditions are required. Animal-based indicators such as comparable locomotion, cleanliness, claw health and behaviour also reflect floor properties, although emission reduction and welfare goals may conflict. A dedicated research barn is essential to study these interactions. The newly constructed dairy research barn provides such a platform. It houses 24 Holstein Friesian cows in each of five airflow-separated compartments, including separated slurry pits. Compartments differ only in predefined structural or management factors, enabling a regulated case–control design. Flooring systems include conventional slats, slats with urine drainage and rubber inserts, and variants with sealing flaps aimed at reducing gas emissions. Emissions of methane (CH_4) and carbon dioxide (CO_2) in the five compartments are continuously monitored using cavity ring-down spectroscopy (CRDS). Temperature, humidity, airflow and weather data provide full microclimatic characterisation. Animal welfare indicators are recorded through video analysis, observations and scoring. This study addresses three hypotheses: (1) airflow separation prevents cross-contamination; (2) single-factor changes produce measurable differences in emissions and welfare indicators and (3) sealing flaps provide emission-reducing effects beyond natural slat blockage. The barn enables precise, reproducible evaluation of mitigation strategies and controlled testing of housing technologies under identical conditions, supporting the development of sustainable and welfare-friendly barn design.

Equation for daily ammonia emissions of fattening pig unit depending on excretions and temperature

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Acidification is an environmental impact managed by European directives (NEC and IED) with reduction goals per country, and obligations for the biggest pig farms to annually declare their ammonia emissions and to respect emission ceilings. Temperature is announced to increase in the coming decades and is known to be an important factor influencing ammonia emissions. In this context, the goal of the work is to establish an equation for daily ammonia emissions of fattening pig units depending on excretions and temperature of the building. Pigammo, a mechanistic model of ammonia emissions for pig fattening units associated with an external storage pit (Padioleau et al., 2024) developed on Vensim, was used for the building section of a 96 pigs unit housing and a fattening period of 150 days. A sensitivity analysis was performed using Vensim with a range of outdoor temperatures between 0°C and 30°C considered constant throughout the fattening period: 100 simulations were carried out. The results of simulations provide data per minute: ambient temperature, room ventilation flow rate, amount of nitrogen excreted, and ammonia emitted. 75% of these data were used to perform a linear regression with the lm() method on R, taking into account the above parameters both individually and in interaction. The equation obtained was tested on the rest of the data and analyzed using the Goodness of fit() method from the ZeBook package on R. The equation was applied to two new simulations with Pigammo for contrasting climate data (January for cold period and June for warm period) from 2020. The result obtained with the equation gives total ammonia emissions with a difference of 3.5% for cold and warm periods compared to the complete Pigammo simulation. It is also planned to test the equation with dynamic experimental data obtained for different fattening periods during a year and to compare the simulation of daily emissions with those of measured emissions. The equation will be included in the Thermipig model (Quiniou et al., 2021) in order to assess the vulnerability of pig production to future temperature increases.

Development of NH3 emission factors for pig housing systems from a comprehensive literature analysis

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Reducing gaseous emissions from pig housing has been a topic of extensive research, particularly since the implementation of the IRPP BREF linked to the Industrial Emissions Directive. Despite the large number of publications, comparing results is often difficult due to the various breeding conditions and also to the wide range of units used to express emissions. Based on this, a database, called ELFE, was developed within a consortium bringing together research organizations (Inrae) and technical stakeholders from the livestock sector (Ifip, regional chamber of agriculture). With more than 2 000 emission factors extracted from around 1 000 articles published between 1964 and 2022, ELFE enables the assessment of the effectiveness of various systems and facilitates the identification of data gaps, thereby informing and guiding future research efforts. Most publications are dedicated to the reduction of ammonia emissions from pig buildings and more especially to fattening rooms (60%). The analysis of published emission values leads to identify different techniques/strategies implemented in pig facilities (nutritional strategies, manure management, end-of-pipe treatments, etc.). A reference itinerary has been defined as a fattening pig kept on fully slatted floor with slurry storage underneath the animals and fed with a single diet (average crude protein (CP) content: 16.7%) with the emission factor (EF) associated (2.96 ± 1.11 kg N_NH3 per place per year). Calculation of NH3 emission factors for different nutritional strategies mainly based on the reduction of the CP content shows reduction close to 30% (2.15±1.01 kg N_NH3 per place per year with a 13.1% CP multiphase diet). The implementation of manure collection in water combined with a 16% CP multiphase diet permits to reduce ammonia emission (-30%). Concerning manure management, the most effective technique is the V-scraper with a reduction around 50%. However, other techniques, such as manure cooling or in-house slurry acidification are less well documented and calculated EF are considered less robust. Technical sheets per technical itineray, freely downloadable from the Elfe Website, present all the values obtained for the EF calculation based on publications. Analysis of EF and restrictions about applications are also given.

Ammonia Reduction in Laying hens via Alfalfa-Based Organic Diets

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Alfalfa tops (AT) represent an alternative protein source for poultry nutrition. They are regionally available and provide a favorable amino acid profile. Their secondary plant metabolites, particularly saponins, may contribute to reducing ammonia (NH_3) emissions. Studies have shown that saponins from Yucca schidigera can reduce NH_3 emissions in broiler manure, suggesting similar potential for AT-based diets. Therefore, we tested the hypothesis that AT supplementation reduces NH_3 emissions. A feeding trial with 960 laying hens from two breeds (dual-purpose: Coffee; layer hybrid: Lohmann Brown Plus) was conducted. Pullets received either a control diet (C) or AT-supplemented diet (5%/10%). From week (wk) 19 to wk 52, animals received 0% AT (C), 10% AT (C–AT; control diet during rearing), or 10% AT (AT–AT; 10% AT during rearing). From wk 52, AT inclusion was increased to 15%. Hens were housed in 24 pens with 40 birds each (3 diets × 2 breeds × 4 replicates) and the trial ended in wk 72. NH_3 was measured in wk 29, 37, 41, 45, 51, 63, and 72 using a dynamic chamber system. Three manure samples per pen were analyzed. Emissions per bird were calculated with a 2-diode AXETRIS laser analyzer. Data were evaluated using 2-way ANOVA (Proc Mixed, SAS Studio) followed by Tukey's test ($p \leq 0.05$). Significant reductions in NH_3 emissions were observed in wk 29, 37, 41, 45, and 72 for hens fed C-AT. The AT–AT group showed the greatest reductions in wk 29, 41, and 72, indicating that early-life exposure may enhance the emission-reducing effect. Furthermore, increasing AT inclusion from 10% to 15% appeared to sustain the emission response. In conclusion, AT supplementation showed potential to reduce NH_3 emissions from laying hen excreta

By-product based diets may enhance methane formation in pig manure whereas ammonia emission can be controlled by dietary strategies

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Future pig diets may contain more regional protein sources and by-products to improve circularity of food production. In 5 studies the impact of this development on faecal and urinary (TAN) nitrogen (N) excretion was calculated adopting an assumed N content in the pig body. Potential methane (CH4) emission was calculated from volatile solid (VOS) excretion (Mostert, 2024). In 3 experiments in nursery pigs replacement of SBM by other oil seed meals (OSM) or legume seeds (LS), and replacement of wheat by bakery products (BP) or by-products of cereal grain processing (CGP) was evaluated. In 2 experiments in GF pigs replacement of wheat and SBM by BP and OSM, LS or CGP was studied. Each study comprised 4-8 treatments, with 8-16 pens, each with 5-11 pigs, per treatment. Grab sampling of faeces was used to determine digestibility of N and organic matter (OM). Overall, N-excretion relative to N-intake varied from 35-41% in nursery pigs and 54-60% in GF pigs. In nursery pigs, replacement of SBM by OSM or LS increased faecal N-excretion by 25-30%, with 5-15% reduction in TAN excretion. Replacement of CG by BP reduced faecal N excretion by 10% and increased TAN excretion by 25%, while replacement by CGP increased faecal N excretion by 25% and reduced TAN excretion by 35%. In GF pigs, replacement of SBM and CG by CGP increased faecal N excretion by 25% and reduced TAN excretion by 40%. Replacement of SBM and CG by LS increased faecal N excretion by 10% while replacement by LS and BP increased TAN excretion by 35%. In nursery pigs, BP reduced the calculated CH4 emission by 30% whereas OSM, CGP and LS enhanced CH4 emission by 20%. In GF pigs, calculated CH4 emission was increased by 17% for BP to 45% for CGP. Use of OSM, CGP and LS increased faecal N and OM excretion due to their lower digestibility. Calculated TAN excretion varied between diets due to ingredients, amino acid profile and use of free amino acids. Additionally, fermentable fibre of plant by-products may stimulate excretion of bacterial protein in faeces at the expense of urinary N. As a result, circular ingredients may increase potential CH4 emission, while the effect on ammonia emission can be partly controlled by dietary strategies.

A Statistical–Machine Learning approach for Assessing Methane Emissions in Pig Production Systems based on Physiological, Nutritional and Fecal Composition parameters

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Effective management of methane (CH4) emissions in pig barns is essential for environmentally responsible pig production. However, this remains challenging due to complex interactions among CH4 emissions, nutritional factors and excreta composition. Therefore, this study used statistical and machine learning models to identify the most influential variables in predicting CH4 emissions from pig slurry. Data were collected from 7 experiments conducted with growing-finishing pigs (2013-2021). The input variables were selected using a correlation matrix of physiological, nutritional, and fecal composition parameters, along with a variable inflation factor (VIF) analysis. Dry matter intake (DI; kg day-1 pig-1), neutral detergent fiber intake (NI; kg day-1 pig-1), ash in feces (AF; g day-1 pig-1), crude protein in feces (CF; g day-1 pig-1), and ether extract in feces (EEHF: g day-1 pig-1) showed stronger positive correlations with CH_4 emissions ($r > 0.4$) than the other variables. Among the models, the SVR model demonstrated the highest performance during both training ($R^2 > 0.57$) and testing ($R^2 > 0.54$) phases, whereas the polynomial regression model showed the lowest prediction accuracy ($R_2 > 0.30$). Despite moderate predictive accuracy, this study identified key variables influencing CH4 emissions as follows: CF > DI > EEHF > NI > AF. Overall, results provide a crucial step towards incorporating the nutrient balance (intake and excretion) into CH4 emission modeling for sustainable pig production and supports the need for further investigations considering larger datasets and environmental factors, which may improve prediction accuracy.

Impacts of Straw Characteristics and Manure Management on Ammonia and Methane Emissions in Straw-Bedded Pig Housing

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Straw-bedded, naturally ventilated pig housing is widely used for animal welfare reasons, but the assumed impacts of straw material characteristics on gaseous emissions remain insufficiently tested under commercial conditions. This study evaluates the hypotheses that (i) straw types with higher moisture retention reduce ammonia (NH_3) emissions, and (ii) straw-based bedding systems promote methane (CH_4) formation due to anaerobic microenvironments in contaminated bedding. Four straw variants (barley, wheat, wheat +50% additional straw, wheat with 10% biochar) were investigated on three commercial Bavarian farms in rearing and fattening units. Emissions were measured across seasons using an open dynamic chamber and the mobile measurement MoSES system equipped with diode-laser absorption spectrometers. Climatic data and manure patterns were recorded, and straw/excreta analysed in the laboratory. Statistical analyses included Kruskal–Wallis and Dunn post-hoc tests as well as correlation analyses ($p < 0.05$). Initial results did not support hypothesis (i) in general terms: variation in NH_3 emissions was dominated by manure removal frequency rather than straw type. Barley straw tended toward lower NH_3 emissions in fattening units, consistent with its higher water-holding capacity described in literature, but this trend has not yet reached statistical significance. Winter conditions substantially reduced NH_3 emissions, indicating temperature-driven emission dynamics. Measurements in outdoor runs showed strong climatic influences (temperature, humidity, air velocity, solar radiation) but consistently confirmed the mitigating effect of frequent manure removal. Hypothesis (ii) was rejected: CH_4 concentrations remained low and near the detection limit across seasons, indicating no relevant CH_4 formation in these straw-bedded, naturally ventilated systems and no need for mitigation strategies. Monitoring until 2026, combined with laboratory results, will further test straw-related mitigation mechanisms. These findings inform realistic, welfare-compatible emission-reduction approaches consistent with European Green Deal goals.

Development of a decision tool to evaluate NH3 concentrations in pig houses

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Ammonia in pig facilities varies according to numerous parameters related to the animals, manure management, feeding strategy, as well as climatic conditions and ventilation management. For both animal welfare and the quality of farmers' working conditions, this concentration must remain below 20 ppm. Measuring ambient concentration requires equipment whose use in livestock buildings may be unsuitable. Portable sensors exist and are widely used in industry to alert operators when critical thresholds are exceeded. These sensors are affordable and easy to use. However, their use in livestock buildings shows certain limitations, particularly due to high particle concentrations combined with elevated humidity. Regular and therefore costly calibration is required. To address this metrological challenge, a decision-support tool called Sim'Ammo has been developed. The user is asked to provide information about 4 categories (animals, manure and feeding strategies, ambience). To date, the application operates only for fattening rooms. After entering his location, the farmer provides information about the animals (number, entry date, weight), followed by details on manure management (more or less frequent gravity emptying with vacuum system, manure collection on water, scraping, cooling manure). The nutritional strategy must also be specified by indicating the crude protein content of each feed. Finally, the farmer enters the ambient temperature and the ventilation percentage displayed on the control panel.For each parameter filled in, the application Sim'Ammo performs a consistency check and alerts the user to any values that appear incorrect. The concentration is calculated based on the amount of nitrogen ingested and the proportion retained by the animals according to their age and weighted and by factors from the literature related to manure management and environmental control. Based on the answers to these around 10 questions, Sim'Ammo calculates a range of ambient ammonia concentrations and provides an appropriate response to the user. If the concentration is close to or above 20 ppm, the application suggests various short- or long-term strategies depending on the information provided. Downloadable technical sheets are also offered free of charge, tailored to the configuration of the room.

Continuous Monitoring Reveals Substantially Lower Ammonia Emissions in Fattening Pig Units with 40% Convex Solid Floors compared to Full Slatted Floors

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Ammonia emissions from pig housing are a major environmental concern, contributing to air pollution and nitrogen deposition. Reliable quantification of these emissions in livestock housing systems is needed to determine the effect of measures to reduce ammonia emissions. However, ammonia quantification is a complex and challenging task under practical conditions, as it requires a high level of expertise and poses challenges for careful evaluation and reliable validation. We conducted continuous monitoring of ammonia emissions in two fattening pig stables, each with distinct floor designs. The first stable had units with a 40% convex solid floor in the middle, a slatted floor above a manure pit at the back, and a slatted floor above a water channel at the front. The other stable had units with a fully slatted floor. In each stable, two units were monitored for ammonia emissions. Measurements were collected over a full production round. Ammonia emissions were analysed using linear mixed models with floor type and day as fixed effects. Preliminary results indicate that the compartment with the convex floor exhibited substantially lower ammonia emissions compared with the slatted floor compartment (P-value < 0.01). During this period of the year (August–November 2025), the reduction was 38%. This preliminary study describes the continuous monitoring system that was used to detect differences in emission dynamics between different floor designs in fattening pig units. A more extensive, year-round study at multiple locations, including further protocol optimisation, are required to confirm these preliminary results and to enable a robust comparison between the floor designs.

Potential environmental and production benefits of integrating farm-grown lupin and faba bean seeds into closed-loop feeding systems for native pig breeds

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Sustainable livestock production increasingly requires the development of feeding strategies that reduce environmental impacts while enhancing farm-level resilience to economic and climatic variability. In this context, the cultivation and on-farm utilization of narrow-leafed lupin (Lupinus spp.) and faba bean (Vicia faba L.) seeds represent a promising pathway toward circular, low-emission feeding systems, particularly for native pig breeds well adapted to less intensive production conditions. Synthesizing current knowledge on the nutritional value of these legume seeds and their role within closed-loop agricultural systems, the study focused on their practical application in pig nutrition. The aim of the research was to evaluate the effectiveness of diets containing narrow-leafed lupin seeds or faba bean seeds in feeding a Polish native pig breed, and to assess their impact on fattening performance and slaughter characteristics. This evaluation provides a basis for determining the potential of these locally grown protein sources within sustainable livestock production models. These results highlight the potential of both faba bean and narrow-leaved lupine seeds as viable. The findings from this preliminary investigation suggest that complete dietary replacement of soybean meal with these legume seeds can be achieved without compromising growth performance or carcass quality in pigs of the Puławska breed, thereby offering a promising alternative for more sustainable and locally integrated feeding systems. Additional examinations of physiological indicators, blood metrics, and tissue composition from this trial are currently underway, aiming to provide a more complete understanding of how the inclusion of these legume seeds in the diet influences both production outcomes and broader biological responses. Future research should further quantify emission reductions across full life-cycle stages, determine optimal legume inclusion rates, and evaluate long-term impacts on animal health, welfare, and product quality within circular agricultural frameworks. Research financed by the EU Horizon Europe research and innovation programme under grant agreement No.101059609.

New indicators for whole-farm sustainability: linking milk, land use, nitrogen surplus, and nitrous oxide emissions on New York dairy farms

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Nitrogen (N) use efficiency and greenhouse gas (GHG) emissions are insightful sustainability indicators for dairy systems. Whole-farm nutrient mass balance (NMB) assessments provide a practical framework for evaluating N use efficiency by quantifying annual N inputs and outputs to a farm boundary. Resulting N balances can be expressed per unit land area, reflecting the farm's capacity to cycle nutrients, or per unit of milk produced, representing conversion efficiency. A comparable set of indicators can be derived for whole-farm GHG emissions, enabling calculation of emission intensities relative to land base or milk output. Because N is readily lost from farm systems, a substantial share of surplus N ultimately contributes to environmental N losses, including both direct and indirect nitrous oxide (N_2O), a potent GHG. This linkage implies that farms with higher N surpluses may also exhibit increased N_2O emissions. In this study, we analyzed 2023 data from 78 commercial dairy farms in the northeastern US, representing herds from 44 to over 6,000 lactating cows. For each farm, whole-farm N balances were estimated on both a hectare and milk-production basis, alongside GHG emission intensity for both direct and indirect N_2O. We examined associations between N balance and N_2O metrics, and evaluated a combined "milk-per-hectare" indicator that captures both productive efficiency and land-based nutrient pressure. Across farms, lower N balances consistently corresponded with improved N_2O emission intensities, highlighting the tight association between nutrient surplus and gaseous N losses. Several management and structural characteristics, including stocking rate, forage and crop productivity, degree of self-sufficiency in home-grown feeds, dietary crude protein levels, milk yield, and culling strategy, emerged as influential drivers of both N balance and N_2O outcomes. These findings emphasize the interconnection of nutrient use and GHG mitigation and identify leverage points for improving environmental performance at the whole-farm scale.

Re-feed: renewable energy production at farm level for energy efficiency and defossilization

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Agricultural activities generate substantial amounts of organic waste, including crop residues, manure, and by-products from food processing. Converting this biomass into bioenergy is crucial for reducing waste, dependence on fossil fuels, and carbon emissions, thereby supporting climate objectives. The pig sector, essential for food security and characterised by high energy demand, produces significant quantities of slurry that require sustainable management. The RE-FEED project addresses these challenges by: (i) promoting energy efficiency through audits and tailored actions on pig farms, (ii) developing strategies to transform pig slurry into bioenergy and organic fertiliser, and (iii) demonstrating farm-scale anaerobic co-digestion of slurry with agri-food biomass. RE-FEED also empowers farmers by fostering energy communities and promoting renewable technologies such as biogas and solar power. These solutions help reduce operational costs and create new income opportunities through carbon credit markets. However, their wider adoption still faces barriers such as high initial investment and regulatory constraints. Overcoming these challenges requires coordinated support through government policies, financial incentives, and technical assistance. Expected outcomes include improved energy efficiency, reduced greenhouse gas emissions, enhanced waste management, and economic benefits for farmers, reinforcing the environmental, economic, and social advantages of integrating renewable energy solutions into agriculture.

Ammonia emission rates from fattening pig housings with outdoor yard in Germany

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Consumer demand for improved animal welfare in pig farming can be met by constructing stables with outdoor access. As no valid data on the associated ammonia emission rates was available, emission measurements were carried out on commercial pig farms with outdoor access. The measurements were carried out at eight locations in Germany over at least six one-week periods to take different weather conditions over the course of a year into account. Two types of pigsties with outdoor runs were measured at four locations each: closed flooring in the run with bedding and slatted flooring in the run. The ventilation rates and thus the emission rates of pigsties with outdoor yard were determined using the tracer gas ratio method with SF6 as artificial tracer gas. SF6 was introduced into the floor area of the outdoor yard at a constant volume flow. The tracer gas concentrations in the air were measured using GC-ECD in parallel with the ammonia concentrations at the same location using FTIR. No statistically significant differences in annual ammonia emission rates were found between the two types of pig farms. The total ammonia emission rate calculated in this study for pig farms with outdoor yard is 2.6 kg NH3-N per animal place per year (average live weight during the fattening period: 67 kg). This ammonia emission rate for pig farms with outdoor yard is lower than the emission level of 3.0 kg NH3-N per animal place per year for forced-ventilated housings with fully slatted floors, which is currently used in Germany in state approval practice.
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Manure Management Network - Research priorities for manure management in a changing world

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The Manure Management Network (MMN) is a global forum for scientists under the Global Research Alliance (GRA) focused on reducing Agricultural Greenhouse Gas (GHG) emissions. This poster presents the four main research priorities for the MMN. I: Global South In Global South countries, increased income and population growth lead to higher consumption of livestock products. To keep up with this increased demand, livestock production is changing from smallholder farming and pastoral grazing systems to more intensive, confined operations (housing or feed lots). This increases manure production and subsequent GHG emissions in regions without a strong tradition of managing manure. The MMN is reviewing manure management in Africa, with the aim of supporting development of locally adapted, environmentally-friendly management options. II: Measuring methods Worldwide, scientists measure gaseous emissions from manure using different techniques that are not always directly comparable. Because of this disparity, results cannot be easily combined to parameterize emission models or calculate emission factors (EFs). The MMN calls for "intercalibration studies" comparing measurement technologies used for housing, storage and land application of manure. III: Solid manure Although solid manure management is used globally there are few studies on emissions from this management chain, even though EFs of GHG, NOx and NH3 are highly variable. To ensure this category is accurately represented in emission inventories, the MMN recommends more research on solid manure management to improve our understanding of key drivers, quantify emissions and provide data for models. IV: Models Predictive models describing CH4 emissions from both in-house and outside liquid manure stores need to be improved, specifically calibration and validation of process-based models. For the IPCC Tier 2 CH4 model there is a need for improved understanding of dietary, livestock and regional effects on B0 (maximum CH4 production), and production kinetics.

Assessing measurement strategies to characterise barn emission behaviour with external emission sources

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For climate and environmental protection, emissions from livestock housing must be reduced in the future. In order to evaluate emissions, gas concentrations must be measured accurately. For mechanically ventilated barns, this requires measuring the ventilation rate, outside concentration and inside concentration. The outside concentration is subtracted from the inside concentration to calculate the methane and ammonia emissions of the barn. In the case of naturally ventilated barns it is necessary to adapt the measurement setup and to take further parameters into account. The ventilation rate has to be calculated using either the CO2 balance method or the tracer gas ratio method. Barns effected by external emission sources need several outside sampling points. These additional parameters make the pairwise assignment of inside and outside concentrations within the same time interval more difficult. The aim of this study is to investigate the challenges and effects of different approaches for linking inside and outside concentrations. While recommendations for measurement setup and data validation are known, there is little guidance on this specific issue. For this purpose, a naturally ventilated dairy barn was investigated continuously over the course of one summer month. The recorded data were used to calculate emissions using four different methods. Only two methods resulted in realistic emissions (9.56 kg NH3-N per animal place and year and 177.49 kg CH4 per animal place and year) within the range reported in the literature. However, increased amounts of data had to be discarded due to unstable conditions. This issue is related to the CO2 balance method. If external CO2 emission cause outside concentration to exceed inside concentration, the method incorrectly produces negative ventilation rates and misleading estimates of emissions. It has to be determined whether discarding data results in underestimation or overestimation of actual emissions. To address this question, a dairy barn equipped with the same measurement setup will additionally be equipped with the tracer gas method in spring. This enables the valid calculation of ventilation rates when external CO2 concentrations are elevated.

Effects of a modified building and proactive ventilation on animal welfare in a conventional broiler barn

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The objective of this study was to establish a conventional broiler barn with a proactive ventilation as prototype. The hypothesis was that the pre-cooling of the fresh air and the proactive ventilation can reduce air and litter humidity and thereby improve respiratory and footpad health. The study was performed on a conventional farm operating with long-fattening in one trial (T) and one control barn (C) for ten consecutive fattening periods, starting with 25,000 Ross 308 broilers per barn. Broilers were fattened until day 42, with 1/3 of animals being slaughtered at day 32. In T, a model for predicting the air exchange rates based on animal weight, feed, water intake and resulting CO2, NH3 and air humidity was developed using data of three fattening periods. Fresh air was pre-warmed/-cooled using heat exchangers. CO2, NH3 and air humidity were monitored continuously, while litter humidity was assessed bi-weekly. The ventilation model was tested in seven fattening periods. The footpad health was assessed bi-weekly. Data regarding the occurrence and treatment of respiratory diseases was obtained from the farm. Normal distribution of the residues was evaluated using QQ plots before evaluating the data with independent samples t-tests. Litter humidity was decreased in T (32 vs. 50% in C; $p<0.001$). Air humidity in T was decreased (58% vs. 67% in C; $p=0.008$). Concentrations of NH3 and CO2 were below legally required thresholds in both barns. The footpad health was improved (1.1 in T vs. 1.4 in C; $p=0.046$). No effect on respiratory diseases was found. These results indicated that a modified broiler barn with proactive ventilation might contribute to the improvement of barn climate, litter quality and footpad health. However, the study included one single farm. Consequently, effects of the farm and management cannot be excluded.

Does Intensification Improve Environmental Efficiency in Pasture-Based Dairy Systems? A Three-Year Footprint Analysis

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Intensification is a key strategy for increasing productivity in pasture-based dairy systems. However, it is essential to assess its environmental implications to ensure long-term sustainability. This study aims to evaluate the environmental footprints of two contrasting pasture-based dairy systems over three consecutive fiscal years. The systems compared were: Operational Simplicity (OS), with a stocking rate (SR) of 1.8 Livestock units per hectare (LU/ha) and self-sufficient; and High Productivity (HP), with a higher stocking rate (3.0 LU/ha) and greater reliance on external inputs, both located at the Centro Regional Sur research station (Faculty of Agronomy, UDELAR; Canelones, Uruguay). Multiple impact categories were estimated per kilogramm of fat- and protein-corrected milk (FPCM). The Carbon Footprint was assessed following IPCC Tier 2 (2019) guidelines, while additional impact categories were calculated using the ReCiPe methodology. Preliminary results from the first year show that the AP system exhibited lower impacts across several categories (including Carbon Footprint, Acidification, Eutrophication, and Water Scarcity) indicating greater environmental efficiency per unit of product despite higher external input use. This trend extended to other resource depletion and emissions indicators. These initial findings suggest that, within the measurement period, intensification improved environmental efficiency at the product level, although higher productivity may still lead to a greater absolute environmental burden. The full three-year assessment, currently underway, will allow a more robust evaluation of whether these patterns persist over time and under varying environmental conditions.

Does Collecting Greenhouse Gas Emission Data in Small Cattle Populations and Native Breeds Make Sense?

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Monitoring greenhouse gas emissions, especially methane, in cattle is becoming increasingly important. Many native breeds and small cattle populations include only a few thousand animals. They are often kept in small herds or represented by a single larger reference herd. This situation raises a crucial question: does systematic collection of methane emission data in such small populations make practical and scientific sense? Our project aims to address this question by considering several anticipated challenges: (i) small populations provide limited data, (ii) variability between animals is high, (iii) statistical power is restricted, and (iv) genetic parameters may be difficult to estimate with confidence. These limitations are expected, but they do not necessarily rule out the value of collecting methane emission data. We propose that repeated and well-standardized measurements can still provide useful information. When combined with pedigree or genomic records, they may help describe emission levels in native breeds. They may also support early identification of animals with consistently high or low emissions. Data collected across several small herds, or within one well-managed reference herd, could improve the representativeness and usefulness of the dataset. This approach may offer a realistic way to characterize the entire population. By starting this project, we aim to determine under which conditions methane emission recording in small cattle populations is feasible, informative, and valuable for future breeding or conservation strategies.

Application of a CO_2 emission calculator to assess the impact of forage crop production and grassland management on emissions in livestock farms

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Achieving climate neutrality in agriculture requires analytical tools capable of assessing greenhouse gas (GHG) emissions. To meet this need, a CO_2 emissions calculator has been developed, that integrates livestock production data with models of emissions arising from forage crop cultivation and the use of grassland-derived feed. The tool incorporates a wide range of environmental and agronomic parameters, including soil characteristics, microclimatic conditions, cropping structure, fertilization intensity, yield levels, residue management and fuel use during field operations, as well as the transport, processing, and storage of harvested biomass. Considering these variables enables a comprehensive evaluation of both direct and indirect emission pathways associated with feed production. The application of the calculator demonstrates that integrating emission assessments from both crop and livestock production is essential for accurately determining the carbon footprint of agricultural holdings. This combined perspective makes it possible to identify the most climate-effective practices, evaluate potential trade-offs, and support the development of targeted mitigation strategies within livestock systems. The tool has significant potential applications in scientific research, environmental monitoring, and agricultural advisory services. By enabling the quantification of emissions under various production models, it provides robust support for the implementation of European GHG reduction strategies and contributing to the advancement of sustainable, climate-efficient crop–livestock systems. Moreover, its adaptable structure allows for application across diverse farming conditions and production intensities. In the long term, the calculator can facilitate evidence-based decision-making and strengthen the transition toward low-emission agricultural practices.

Possibilities of using remote sensing in the context of CO_2 emissions reduction and sustainable grassland management on ruminant farms

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The rational management of grasslands is a key component of sustainable livestock production. It influences the efficiency of feed use and reduces CO_2 emissions by optimising agricultural practices. Properly organised grazing, based on continuous assessment of sward productivity, enables the full utilisation of pasture production potential, reducing the need for additional forage. The production and transport of this forage generates a significant carbon footprint. This study aimed to evaluate the potential of remote sensing as a tool for precisely monitoring grass growth dynamics and estimating productivity. The analysis included data from various sources, such as field measurements, satellites and UAVs. The research was conducted on a private farm near Krakow and at the Experimental Station of the National Research Institute of Animal Production in Odrzechowa. Traditional methods included collecting plant material samples, determining dry matter yield and assessing botanical composition. Remote sensing methods utilised Sentinel-2 data (10–20 m), Planet data (3.7 m) and UAV imagery acquired using a MicaSense RedEdge-P multispectral camera (7–8 cm). The UAV data underwent georeferencing, geometric calibration and block adjustment to enable the calculation of vegetation indices such as NDVI and NDRE. The results showed that the NDVI and the UAV-derived data were correlated with biomass yield, enabling reliable productivity assessment. Remote sensing also enabled the detection of spatial differences in yield. The collected data indicate the usefulness of remote sensing tools for the precise monitoring of biomass growth and grazing management on grasslands. Implementing such systems could improve pasture management, reduce the need for excessive fertilisation and additional forage production, and consequently contribute to reducing CO_2 emissions in ruminant-based farming systems.

A Regional-Local Approach for Assessing Seasonal Heat Stress in Livestock Farming

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In livestock farming, prolonged exposure to high temperatures compromises productivity, reproductive performance, and animal welfare. Heat stress is stress was assessed in 11 farm locations with the sample incorporating a mix of ruminants and pig farms. A combination of local measurements and modelled thermal parameters was used to quantitatively assess indicators of heat stress while retaining enough information to disaggregate local thermal and shading effects from the regional and larger-scale climatic contributions. For determining the regional and short-term climatic effect, a 5-year dataset of temperature, humidity and radiation fields was extracted from the ERA5-Land reanalysis, covering the Thessaly area in Northern Greece at a spatial resolution of 0.1° × 0.1°. In parallel, local measurements were performed for sample periods during the hot season. From these two datasets, local timeseries of the same parameters were extracted on the selected farm locations and two thermal stress indicators were calculated: the Temperature-Humidity Index (THI) and the Wet Bulb Globe Temperature (WBGT). Scale analysis indicates that large parts of the region exhibit summertime daily temperature maxima exceeding 40°C, with a spatial temperature range across the area of about 6 to 8°C. Cases of extremely consecutive hot days (>38°C) during May and September indicate an extended hot season in this region. The distribution of estimated THI values reveals that in several lowland areas of the region, moderate to high heat stress is exceeded for more than one third of the summertime hours, with extended periods of elevated THI persisting for multiple consecutive days. In contrast, locations situated at slightly higher elevations or exposed to natural wind ventilation show a noticeably reduced incidence of high-stress conditions. The study demonstrates the value of multiscale assessment of heat stress, both towards a reliable assessment of existing conditions in indoor farms and as a tool for obtaining an accurate projection of their future development based on large-scale climatic datasets.

Relationship between climate and mycotoxin contamination in different corn matrices

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Livestock contribute to climate change mainly by releasing greenhouse gases. Climate change, in turn, negatively impacts livestock production through higher temperatures, drought, altered rainfall, and increased disease prevalence. Mycotoxin contamination of feed is part of this puzzle. Mycotoxins, such as deoxynivalenol (DON) and zearalenone (ZEA), cause feed refusal and decreased productivity in ruminants. However, there are limited studies correlating mycotoxin contamination with climate. Therefore, we aimed to study the correlation of climate variables with DON and ZEA levels in corn matrices such as silage, whole grain, mashed grain, and mashed cob with husk. For this, 11688 samples were collected by the Regional Breeders Association of Lombardy, from 2014 to 2023. Of this, 7504 samples were studied for DON and 4917 for ZEA contamination using ELISA. The contamination level was statistically analysed using Tobit regression and correlated with climate variables. We found that whole and mashed grains were the most contaminated by DON (1389- 1767 ppb). However, these values are less than 5000 ppb, the maximum levels recommended by the European Union (EU) for large ruminants. ZEA levels in corn matrices were also below the EU safety recommendations of 500 ppb. Climate variables were correlated to both DON and ZEA contamination in corn matrices. Specifically, cumulative monthly relative humidity (>80%, at two meters) was positively related to both DON and ZEA contamination. Conversely, consecutive dry days were negatively related to DON and ZEA contamination in corn. In conclusion, DON and ZEA occur in the corn matrices of Lombardy, but at levels below the EU safety threshold. Our findings highlight the relationship between specific climate variables, such as humidity and dry period, with mycotoxin contamination in corn. Monitoring individual corn matrices in relation to the climate is a key mitigation strategy to combat mycotoxin contamination.

Associations between nutrient composition and enteric methane yield in grazing and zero-grazing dairy systems

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This study aimed to examine the correlation between CH4 yield (g/kg DMI) and dietary composition in 2 grass-based systems: unrestricted grazing (UG; pasture access for 24 h/d apart from milking) and zero-grazing (ZG; fresh grass cut and fed indoors). Production of CH4 from 30 lactating cows (15 per system) was measured during 3 periods (April-May, June-July, and August-September) in 2020 and 2021 using the GreenFeed system (C-lock Inc.). Cows received fresh grass supplemented with 5.3 kg DM/d concentrates, and total DMI was estimated based on energy calculations for UG and measured using automated recording feed bins for ZG. Daily fresh grass samples were analysed by near-infrared spectroscopy, and CH4 yield was related to nutrient composition (g/kg DM) of the complete ration (i.e., fresh grass and concentrate) using Pearson correlations at period level (n = 6 per system) and repeated measures correlation at day level (n = 84 per system). At period level, CH4 yield was or tended to be positively correlated with NDF (r = 0.85, P = 0.034 for UG; r = 0.81, P = 0.050 for ZG), ADF (r = 0.82, P = 0.044 for UG; r = 0.93, P = 0.006 for ZG) and crude fibre (r = 0.76, P = 0.078 for UG; r = 0.96, P = 0.003 for ZG). A tendency for a negative correlation between CH4 yield and sugar content was observed for UG (r = -0.74, P = 0.092), whereas negative correlations between CH4 yield and net energy for lactation (NEL ; r = -0.93, P = 0.007) and digestible OM (r = -0.90, P = 0.015) were observed for ZG. Most of these established period-level correlations were not observed with the day-level repeated measures correlations. For UG, the correlations between CH4 yield and both fibre and sugar shifted direction and weakened. For ZG, the positive correlations between CH4 yield and both ADF and crude fibre, and the negative correlations between CH4 yield and both NEL and digestible OM, persisted but became weaker. In conclusion, the period-level associations appear driven by between-period differences rather than day-to-day covariation. For UG, day-to-day variation in CH4 yield may be influenced more by grazing behaviour, uncertainty of DMI estimates, or other factors than by dietary composition alone.

The effect of sward type on lamb methane production and age at slaughter

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Enhancing the efficiency of lamb finishing systems is key to reducing the carbon footprint of pasture-based sheep production. While perennial ryegrass (Lolium perenne L) forms the foundation of temperate grazing systems, incorporating legumes and herbs, such as white clover (Trifoluim repens L) and plantain (Plantago lanceolate L) have been identified as a promising strategy to improve performance and mitigate enteric methane (CH4) from lambs post-weaning. Plantain contains bioactive compounds that can modify rumen fermentation processes, potentially contributing to a reduction in enteric CH4. This study assessed the effect of sward type on lamb CH4 production and age at slaughter. Three sward treatments were investigated: perennial ryegrass (PRG), PRG plus white clover (PRG+WC), and PRG+WC plus plantain (PRG+WC+Plan). All treatments were stocked at 11 ewe/ha with an average weaning rate of 1.8 lambs/ewe. A leader-follower grazing system was implemented post-weaning. Sward production, quality and composition were recorded, as well as lamb performance. Methane measurements were obtained using portable accumulation chambers (PAC) on 252 lambs in each production year (2024 and 2025), twice post-weaning (n=84 per treatment). The PAC provides a point in time measurement for CH4, carbon dioxide and oxygen over a 50-minute period. Lambs were removed from feed 1 hour prior to methane measurements and live weight was recorded immediately prior to entering the PAC.The PRG+WC+Plan lambs reached slaughter 8 days earlier compared to PRG lambs ($P<0.05$). Lambs grazing PRG+WC and PRG+WC+Plan had 5% and 8% lower CH4 output respectively, over those grazing PRG ($P<0.001$), while PRG lambs also had the highest CH4 output when expressed per kg of liveweight ($P<0.001$). Results show that including legumes and herbs can reduce age at slaughter, with concurrent reductions in enteric CH4 emissions by grazing lambs thereby identifying sward diversification as a promising strategy to support the environmental and economic viability of these systems.

Mitigating Methane Emissions Without Impairing Production Performance: Grazing Strategies for Suckler Beef Cows?

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This study aimed to evaluate the greenhouse gas emissions and the performance of suckler beef cows grazing three different forage systems: perennial ryegrass and white clover (GC), multispecies swards (MS), and willow silvopastoral systems (W). 36 Aberdeen Angus cross lactating suckler beef cows (first parity) were selected and balanced across treatments based on calving date, live weight, body condition score, and calf gender. A randomized block design was employed, with cows randomly allocated to three forage treatments (GC, MS, and W, n = 12 per treatment). Each treatment was further divided into two independent paddocks, with six cows per paddock. The 14-week experiment was conducted under a rotational grazing system. Concentrates were provided via individual GreenFeed units. Live weight and body score were recorded weekly. Methane (CH_4) and hydrogen (H□) production were measured daily using the GreenFeed system and analyzed separately into two periods (first and last 7 weeks). Data were analysed using linear mixed-effects models in R (version 4.3.2), with treatment, paddock, and time as fixed effects, and cows as random effects. Pairwise comparisons were adjusted using Tukey's HSD test, and statistical significance was declared at $P < 0.05$. The results showed that W decreased the CH4 by 36.05% and 40.08% compared to GC in two periods, respectively ($P < 0.01$). Compared to MS, W decreased the CH4 by 29.12% in period 2 ($P < 0.01$). The MS decreased the CH4 by 15.48% compared to GC in period 2 ($P = 0.03$). W decreased H2 by 73.33% compared to GC in period 2 ($P < 0.01$). Compared to GC, W and MS did not affect live weight and body score of cows ($P > 0.05$). To sum up, W showed a greater mitigation effect of CH4 and H2 compared to the MS without impairing the production of the suckler cows. In general, the W silvopastoral systems and multispecies swards offer a practical agroecological solution for more sustainable and productive grazing suckler cows' systems.

Options and strategies for stacking methane-mitigating interventions to enhance enteric methane reduction in ruminant livestock

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Enteric methane from ruminant livestock represents a major source of agricultural greenhouse gas emissions. While individual mitigation strategies such as feed additives, dietary modification, genetic selection or rumen manipulation can deliver significant methane reductions, each intervention faces limitations in effectiveness, persistence, practicality or animal performance, safety and cost, particularly in grazing livestock. This review evaluated concept of combining mitigation interventions ('stacking') to enhance and sustain enteric methane abatement while overcoming these limitations. The study identified mechanistic, temporal and system-specific compatibilities towards effective stacking. Mechanistic complementary combinations (e.g., direct methanogen inhibitors with hydrogen sinks or rumen modifiers) show potential for synergistic methane reductions exceeding those of single interventions. Temporal stacking – pairing short-term (i.e. additives) with long-term (i.e. breeding) can deliver immediate, but also persistent abatement, while system-specific stacking options are proposed for intensive and grazing systems. In conclusion, stacking interventions can improve methane mitigation, productivity, safety and adoption potential, while maintaining economic viability and regulatory compliance. Key challenges include identifying complementary interventions, ensuring their safety and practicality.

Breed differences in enteric emissions of Angus and Hays Converter beef heifers grazing naturalized pastures in Western Canada

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Rising concern over livestock-derived methane has increased interest in strategies that reduce enteric emissions while maintaining productivity. Heritage breeds, such as the Hays Converter (HC) have been promoted for environmental adaptability and production efficiency, which could lower methane emission intensity. This study evaluated whether HC beef heifers differ from Angus heifers in enteric methane emissions and their intensities under naturalized pasture conditions. Ninety heifers (370±43 kg; 13–15 months old), including 36 HC and 54 Angus, were monitored over two summer grazing seasons (2024 n = 42; 2025 n = 48). Enteric CH4 and CO2 were measured using a GreenFeed system (C-Lock Inc., Rapid City, SD, USA) over 81±5 days in each season. Body weight (BW) and average daily gain (ADG) were recorded every ~ 28 days. Linear mixed models evaluated the fixed effects of breed, day of grazing, year, and their interactions, with a random intercept for animal nested within year. Daily CH4 (HC = 174 vs. Angus = 174 g/d; P = 0.803) and CO2 (HC = 6676 vs. Angus = 6656 g/d; P = 0.602) emissions and BW-based intensities (CH4/BW and CO2/BW; P = 0.960 and P = 0.634) did not differ between breeds. However, CO2/BW, CH4/ADG, and CO2/ADG decreased as the grazing season progressed ($P < 0.001$), indicating improved emission efficiency over time. HC heifers tended to have lower CH4/ADG (183 vs. 215 g/kg ADG; P = 0.067) and CO2/ADG (7115 vs. 8140 g/kg ADG; P = 0.059) than Angus heifers. Year effects were detected for CH4 g/d (150 vs. 198; $P < 0.001$), CH4/BW (0.131 vs. 0.587; $P < 0.001$), CO2/BW (7.08 vs. 20.73; $P < 0.001$), and CO2/ADG (8532 vs. 6723; $P < 0.001$). Although significant breed effects were not detected, when expressed relative to ADG, Hays Converter heifers tended to emit less than Angus which could indicate a potential breed reduction on emissions. This study will be replicated in the next grazing season.

What the Azorean Catrina Can Teach Us in Contrast to the Holstein-Friesian

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Background: Methane from rumen fermentation is a major contributor to livestock greenhouse gas emissions. While mitigation usually targets feed additives or management, the influence of host genetics remains underexplored. The Catrina, a native Azorean breed, offers an opportunity to investigate whether locally adapted animals exhibit methanogenic profiles distinct from Holstein-Friesians. Methods: Rumen and faecal samples were collected from both breeds under two diets. Total DNA was extracted for shotgun metagenomic sequencing, and taxonomic profiles were compared using the Mann–Whitney U test. Results: The Catrina breed consistently showed higher representation of methanogenic species than Holstein-Friesian cows. Several Methanobrevibacter species were significantly more abundant in Catrina animals, and one species, M. thaueri, appeared almost exclusively in this breed. Diet also shaped the profiles, although it did not overturn the breed signal. These results point towards a breed-dependent methanogenic profile that may help explain the higher methane emissions previously associated with Holstein-Friesian cattle. Conclusions: These findings suggest that host genetic background and local adaptation play a substantial role in shaping rumen methanogenesis than is usually assumed. While diet remains an important factor, the persistence of a breed signature across gut regions points towards a biological basis that current mitigation strategies rarely consider. Understanding how these microbiomes have evolved in locally adapted animals could provide alternative approaches for reducing emissions, complementing rather than replacing nutritional interventions. Acknowledgements: Funding: FCT-https://doi.org/10.54499/2023.15029.PEX. CBA-UAc is financed by FCT (UIDB/05292/2025; UIDP/05292/2025), and DRCT (A/FUNC.UI&D/016/2025). ARA is supported by FRCT M3.1.a/F/035/2020.

Methane emissions as affected by animal traits and productivity in dairy sheep: a GreenFeed® study on lactating ewes

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Quantifying enteric emissions from small ruminants is increasingly important for climate-change mitigation, aiming to reduce livestock methane and identify animal traits linked to lower methane production (g/day) and intensity (g/kg of milk or meat). GreenFeed® (GF) allows collection of daily methane data without affecting animal behaviour or farm management. From November 2024 to March 2025, an on-farm experiment was conducted at the ASSONAPA genetic centre on dairy sheep in Siena (Italy) to evaluate methane emissions in Comisana lactating ewes using two GF devices designed for small ruminants. Two groups of 24 ewes were monitored (48 animals in total), with one device assigned to each group in two separate pens for three weeks. This procedure was repeated four times, with different animals included in each period. Live body weight data for each animal were collected once per period. In addition, the number of daily visits to the GF unit and daily milk yield were recorded. The effects of test period, days in milk, live body weight, milk yield, and daily GF visits on methane production were analysed using a linear mixed-effects model with animal as random effect. Average daily methane emission was 64.5±7.05 g, with mean milk yield of 1.6±0.64 L/day and 50±22 days in milk. Statistical analysis showed that only the effects of test period and days in milk were statistically significant. Further analyses and experiments are required to investigate additional animal traits that may be associated with daily methane emissions.

Vaccination reduced Enteric Methane, without adverse effect on performance and nutrient digestibility of Beef Cattle

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Methanogen-targeting vaccines offer a promising alternative to dietary additives. This study evaluated the efficacy of a methanogen-specific vaccine on intake, growth performances, gaseous emissions, feeding behavior and nutrient digestibility in confined beef cattle. In a randomized complete study design, 78 crossbred beef cattle (30 steers, 48 heifers; 463±57 kg initial BW; mean age 551±22 d) blocked by body weight, stratified by breed type, and sex, were randomly assigned to either control (n=29) or vaccine-treated group (n=49). Weekly BW, daily feed intake and gaseous emissions were recorded using automated feed intake bunks (Vytelle SENSE) and a GreenFeed system (C-lock Inc., USA), each housed in 4 pens for 84-d study period. Animals received a prime-boost vaccine regimen administered subcutaneously on days 0 and 21. Statistical analyses were conducted in JMP Pro v.16 (SAS Institute Inc., USA), with a model that included treatment as a fixed effect, pen and sex as random effects. Initial BW, DMI, mid-test metabolic BW ($BW^{0.75}$), G:F and RFI did not differ (P>0.15) between the vaccinated and control groups. Average daily gain tended to be lower in the treated group (P=0.09) however did not affect the final BW (P=0.39). Treated cattle produced 6.4% less CH_4 (P=0.02), and 5.9% less CH_4 per unit of metabolic body weight (P=0.03) as compared to control animals. This amounts to mitigation of ~89 kg of CO2e per animal (assumes 20-year GWP). CO_2 emissions tended to be lower (P=0.10) in the vaccinated group. Bunk visit (BV) frequency, BV duration, and eating rate did not differ (P>0.16). A tendency was observed toward a shorter head down duration (P=0.07) at bunk in the treated group. No effect of vaccination on the apparent nutrient digestibility of DM, ADF, NDF and CP was observed (P>0.29). Future studies should optimize vaccine formulation and delivery to boost efficacy in diverse production settings.

Bivariate analyses increase genomic prediction accuracy for enteric methane emission in Nelore cattle

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The aim of this study was to compare the prediction accuracy for methane emission using univariate and bivariate models. A total of 2,621 Nellore animals were evaluated for methane emission (CH4), dry matter intake (DMI), average daily gain (ADG) and body weight (BW). The data were evaluated using single-step GBLUP model. Genetic parameters were determined considering the contemporary group as fixed effects and age as covariate. Validation was carried out considering the animals' age, setting the animals born up to 2020 as the training population, and the younger animals born in 2021 and 2022 as the validation population. Adjusted phenotypes (y*) were used as the response variable in the genomic prediction models. The univariate model using only CH4 (uni) was: $y^* = 1\mu + Za + e$, where μ is the model intercept; a is the vector of additive genetic effects; Z is the incidence matrix on a; and e is the vector of residual effects. Equivalent bivariate models were used with the following traits CH4 + DMI (bi1), CH4 + ADG (bi2), and CH4 + BW (bi3). Predictive accuracy was assessed by dividing the Pearson correlation coefficient between y* and the predicted genomic value by the square root of the heritability for CH4. The heritability estimates were 0.29 ± 0.06, 0.35 ± 0.03, 0.36 ± 0.04 and 0.37 ± 0.03, for CH4, DMI, ADG and BW, respectively. The genetic correlation values were 0.55 ± 0.12, 0.74 ± 0.13 and 0.63 ± 0.12 between CH4 and DMI, ADG and BW, respectively. The predictive accuracy values were 0.31 ± 0.11, 0.53 ± 0.14, 0.34 ± 0.12 and 0.53 ± 0.15 for the uni, bi1, bi2 and bi3 models, respectively. These results show that including correlated traits in the models increases the accuracy of genomic prediction for CH4 emission. Recording DMI and BW showed the highest potential to improve genetic prediction. Keywords: breeding, heritability, greenhouse gas

Which Cow Breathes Cleaner? Comparing Methane emissions from the Catrina and the Holstein-Friesian

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Introduction: Resilient livestock production under climate change requires better insight into methane (CH_4) and other greenhouse gas emissions from cattle. Portable tools for CH_4 monitoring allow us to explore the influence of breed under shared conditions. This study compares CH_4 emissions from Catrina and Holstein-Friesian cattle fed the same diet. Methods: Fifteen dry cows were kept by breed in groups of five and fed ad libitum with mixed grass and corn silage and water. Methane measurements were taken with a portable laser methane detector. Descriptive statistics were generated for raw CH_4 recordings, breath values, peak events, and estimated daily and annual outputs. Results: Catrina cows showed mean CH_4 values of 37.04±40.09 ppm*m (raw), 33.15±28.59 ppm*m (breath), and 218.65±67.13 ppm*m (peaks). Holstein-Friesian cows exhibited higher means of 65.62±87.11 ppm*m, 57.57±52.59 ppm*m, and 514.19±266.02 ppm*m, respectively. Statistical analyses indicated a consistent breed effect, with greater emissions in Holstein-Friesians. Conclusion: These results suggest that conserving regional breeds may support climate-resilient livestock and not only for cultural reasons. Lower CH_4 values in Catrinas align with the view that locally adapted animals can deliver efficient, lower-impact production. Even so, CH_4 output reflects multiple drivers beyond breed. Integrating dietary, microbiome, host genetic, and environmental information will improve mitigation strategies. Native breeds merit consideration in sustainability planning for pasture-based systems. Acknowledgements: Funding: FCT-https://doi.org/10.54499/2023.15029.PEX. CBA-UAc is financed by FCT (UIDB/05292/2025; UIDP/05292/2025), and DRCT (A/FUNC.UI&D/016/2025). ARA is supported by FRCT M3.1.a/F/035/2020.

Effect of early weaning and feed additive supplementation on enteric methane emissions in new born dairy beef calves

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Early life programming could be a promising strategy to mitigate enteric methane emissions from ruminants by altering the rumen characteristics in early stages. The present study analyzed the effect of early weaning (EW) alone and EW combined with a novel feed additive (EW+FA) of medium-chain fatty acids, yeast extract, fruits, and herbs on enteric CH_4 emissions in dairy beef cross calves. 57 dairy beef calves (British Blue cross and Aberdeen Angus cross), averaging 5.5 weeks of age, were balanced for body weight (BW), sex, and breed and allocated to three groups: control (CON), EW, and EW+FA. Methane emissions were recorded daily using a GreenFeed system from November 2024 to March 2025, and BW was recorded biweekly. Phase 1 lasted 14.3 weeks, with calves remaining within their original treatments; Phase 2 lasted 6.0 weeks, during which calves were reallocated between three pens while maintaining treatment assignment. Phase 1 was analyzed using a completely randomized design with treatment as the fixed factor, while Phase 2 included pen as a blocking factor, with treatment and age at allocation as fixed effects. In Phase 1, EW calves emitted less CH_4 than both CON and EW+FA, which did not differ (CON: 79.1 g d^{-1}; EW: 60.6 g d^{-1}; EW+FA: 77.6 g d^{-1}; $P < 0.01$). Age at allocation and treatment × age interactions were not significant. After calves were reallocated among pens, treatment effects were not significant in Phase 2 ($P = 0.078$ for CH_4 g d^{-1}; $P > 0.90$ for CH_4/kg BW). Thus, CH_4 emissions during this period primarily reflected normal growth rather than treatment effects. Although EW reduced enteric CH_4 emissions by 23% during the early phase, this effect did not persist in Phase 2. The feed additive did 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 sustained. Future research should assess emission patterns under grazing and investigate rumen microbiome characteristics underlying early-life programming.

Breeding for Lower Emissions: Exploring Enteric Methane, Residual Feed Intake, and Parasite Resistance in Lleyn Sheep

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Methane emissions from ruminant livestock significantly contribute to agricultural greenhouse gas emissions, with enteric fermentation in sheep being a notable source. This project investigates the potential of genetic selection to reduce methane emissions in sheep without compromising productivity and efficiency. Enteric methane emissions of ewe lambs from the Harper Adams University Future Farm pedigree Lleyn flock were measured over a 3-year period (n=597) using portable accumulation chambers (PACs). These ewe lambs were also tested for parasite resistance (n=585) using faecal egg count (FEC) and plasma Immunoglobulin A (IgA) techniques, and underwent feed efficiency assessment (n=190) to determine residual feed intake. Here, we explore the phenotypic variation and correlations between these traits and determine whether sire contributes significantly to this variation. Across the 3-years, lambs represented the progeny of 14 different sires. Our findings indicate considerable between-animal variation, suggesting strong potential for genetic selection, with sire having varying degrees of influence depending on the trait in question. Weak phenotypic correlations were found between the three traits studied, suggesting that selection for one of these traits will not heavily influence the others on a phenotypic level. This foundational work will contribute to the development of breeding strategies to reduce the carbon footprint of sheep production whilst maintaining and/or enhancing productivity and efficiency. The ultimate goal is to integrate these traits into a 'green' selection index for maternal sheep breeding programs in the UK, contributing to more sustainable, efficient and resilient sheep production. This work has been enabled by the 'Breed for CH4nge' industry-led research project which is funded by the Department for Environment, Farming and Rural Affairs (DEFRA) Farming Innovation Programme delivered by Innovate UK.

Carry-over vs acute heat stress effects on the behavior of dairy cows exposed to a GreenFeed system to measure enteric gas emissions

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Heat stress negatively affects the behavior and performance of dairy cows during all phases of lactation, but its impact on enteric methane (CH4) production is unclear. The objectives were to evaluate the carry-over and acute effects of heat stress on the behavior of 4 groups of cows, while exposed to a spot-sampling system (GreenFeed, USA; GF) to measure enteric gas emissions. The first group (G1) cows were either heat stressed (HS-G1; n=8) or cooled (CL-G1=9) during the entire dry period and the carry-over effects of HS on behavior and CH4 emissions were evaluated in the subsequent lactation. In the second group (G2), behavior and CH4 emissions were evaluated in cows that were either acutely heat stressed (HS-G2; n=23) or cooled (CL-G2; n=23) during lactation. Automated monitoring devices (Nedap, Netherlands) were used to assess behavior. A leg tag measured daily lying time, steps and standing bouts and a neck tag measured eating and rumination time. Behavior was recorded for 22 d for G1 and 30 d for G2. The GF units measured enteric gas output for 4 wks in G1 and two 4-wk periods in G2. In both groups, cows were housed in a sand-bedded free-stall barn. The CL cows had shade, soakers and fans, while HS had only shade. After calving, both HS-G1 and CL-G1 were cooled. Data was analyzed using the mixed procedure of SAS. In G1, there was no carry-over effect of dry period HS exposure on the behavior in the subsequent lactation. In G2, acute HS exposure resulted in decreases in eating ($P < 0.01$), rumination ($P = 0.05$), and lying ($P = 0.01$) time. The HS-G2 cows spent less time inactive ($P = 0.01$) and standing ($P < 0.01$). No differences in steps and standing bouts were observed between HS-G2 and CL-G2. In G1, daily CH4 did not differ between HS-G1 and CL-G1, but HS-G1 had greater CH4 intensity ($P < 0.01$). In G2, acute HS exposure decreased daily CH4 emissions ($P < 0.01$) while increased CH4 yield ($P < 0.01$). Results suggested that there is no carry-over effect of dry period HS exposure on behavior, while acute HS negatively affects behavior of lactating cows. HS carry-over effect increases CH4 intensity, while acute HS decreases CH4 yield and intensity in lactating dairy cows.

Methane Emissions and Productive Performance of Dairy Cows in Organic and Conventional Systems

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Methane emissions from dairy cattle are a key source of agricultural greenhouse gases. Understanding how different production systems influence CH_4 emissions is crucial for developing effective mitigation strategies tailored to specific farming practices. However, individual animal methane measurements under real field conditions remain scarce. This study shows preliminary results comparing methane emissions, milk yield and composition between conventional and organic dairy systems. The trial included four commercial dairy farms: two conventional and two organic. The GreenFeed system measured CH_4 emissions for at least one month per farm. Measurements in conventional farms were taken in autumn–winter, while organic farms were measured in spring–summer, coinciding with grazing. An official monthly milk recording was conducted throughout one year. For the calculation of CH_4 emission intensity, CH_4 emission records were combined with milk production data from the official milk recording performed during the month in which the GreenFeed system was installed. However, to compare production systems, the annual average per animal was calculated using all monthly milk recordings obtained throughout the entire calendar year. Mixed models evaluated the effect of production system, including fixed effects of system, random effects of farm, and age, parity, and days in milk as covariates. A total of 164 cows were enrolled: 89 conventional and 75 organic. Conventional farms showed higher CH_4 emissions (421 vs 299 g/d, $P<0.001$) and milk yield (35 vs 22 kg/d, $P<0.001$), likely reflecting higher dry matter intake and rumen fermentation. Methane emission intensity did not differ (11.4 vs 15.0 g/kg, $P=0.155$). Milk fat (3.85 vs 3.55%), protein (3.36 vs 3.09 %), and lactose (4.74 vs 4.64 %) were also higher in conventional cows ($P<0.01$). These differences may relate not only to a higher use of concentrates in conventional systems but also to a lower total dry matter intake in organic cows, whose diets rely more heavily on grazing and tend to be lower in energy and protein density. Conventional farms show higher CH_4 emissions and milk production, but CH_4 intensity is similar across systems. Differences in productivity and milk composition likely reflect contrasting feeding strategies, highlighting the challenge of balancing environmental impacts with production goals.

Whole-Farm Approaches to Advance Climate-Smart Livestock Systems

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Mitigating greenhouse gas (GHG) emissions from livestock production requires a systems-based, whole-farm perspective that accounts for interactions among animals, manure management, and crop and forage production. Livestock systems generate emissions from multiple sources, and meaningful mitigation therefore depends on the coordinated integration of multiple best management practices (BMPs) rather than isolated interventions. However, mitigation strategies implemented at one component of the farm may generate upstream or downstream trade-offs, highlighting the need for evaluation frameworks that capture cross-component effects on net GHG outcomes. This presentation will synthesize recent whole-farm approaches for advancing climate-smart ruminant production, with emphasis on the development and application of robust metrics across scales. Farm-level and life-cycle assessment (LCA)–based metrics will be discussed as tools to support on-farm decision-making, while also enabling alignment with regional and national incentive programs and policy frameworks. A series of case studies will be presented to illustrate the application of these approaches in Canadian livestock systems. These include evaluations of pathways toward net-zero emissions in national dairy systems, as well as assessments of selected BMPs with high mitigation potential. Practices examined include anaerobic digestion, manure acidification, and alternative field manure application strategies, with impacts quantified using advanced continuous greenhouse gas measurement techniques. Together, these case studies highlight both the mitigation potential and the trade-offs associated with integrated whole-farm strategies, underscoring the importance of systems-level metrics for guiding climate-smart livestock transitions.

Mapping Pathways to Reduce Greenhouse Gas Emissions in Canadian Dairies by 2030 and 2050.

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On-farm greenhouse gas (GHG) emissions, primarily carbon dioxide, methane, and nitrous oxide, represent the largest share of the carbon footprint of dairy products. Reducing these emissions is critical to lowering the dairy sector's contribution to climate change and addressing growing consumer concerns around environmental sustainability. Dairy Farmers of Canada have set a goal of achieving net-zero GHG emissions by 2050. However, specific, quantitative pathways to reach this target have not been fully explored. The objective of this project is to identify and evaluate potential pathways to reduce on-farm GHG emissions in Canadian dairy systems through the adoption of beneficial management practices (BMPs) under various implementation scenarios. The methodology used in Canada's National Inventory Report was adapted to estimate baseline and projected emissions from the main on-farm sources, including dairy feed production, enteric fermentation, manure management. Strategies for mitigation via soil and plant biomass carbon sequestration were also considered. For each emission source, the impact of selected BMPs combined with medium and high adoption rates by 2030 and 2050 was analyzed. Preliminary results indicate potential emission reductions between 38 and 58% by 2050 associated with manure management, primarily via manure acidification. Additionally, optimizing nitrogen use through 4R nutrient stewardship (right source, rate, time, and placement) showed potential reductions of 23-31% by 2050 on aggregated feed production emissions. Incorporating nutritional and genetic strategies to reduce enteric methane resulted in 30-48% reduction of baseline emissions by 2050. Across all sources considered, BMP implementation resulted in GHG emissions reductions between 34 and 54% by 2050.

LIFE Green Sheep project: Mitigation strategies reduce carbon footprint of European sheep production

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The LIFE Green Sheep project, involving 5 countries (France, Ireland, Spain, Italy, Romania), aims to reduce the carbon footprint of European sheep production by 12%. A total of 230 farms implemented carbon action plans, focusing on reducing greenhouse gas (GHG) emissions. Mitigation practices, identified by farmers, were grouped into five main management categories as follows: "flock", "nutrition", "land and crop", "energy and manure", and "carbon storage". On average, each action plan involved between 3 and 4 mitigation practices. Meat sheep farms focused on flock and land & crop management mitigation practices (48% and 27% respectively). In France, Ireland and Spain the practices focused on flock management, land & crop management and nutrition, respectively. Therefore, the mitigation practices are mainly country specific. On the other hand, dairy sheep farms mainly focused on nutrition and flock management mitigation practices (43% and 25% respectively). The French, Spanish and Romanian farms focused on nutrition management whilst Italian farms focused on energy consumption. Thus, the mitigation practices are mainly common between countries. While the action plans are still ongoing, the assessment tools facilitated estimating the potential changes of each farm mitigation plan. The potential average carbon reduction is estimated to be –10.3 ± 13.7%. Potential mean carbon gains are –117 ± 177 and –62 ± 84 t CO_2 eq per meat sheep farm and dairy sheep farm, respectively. It is concluded that targeted, practical mitigation actions can substantially decrease GHG emissions from the European sheep sector and the feasibility of aligning productivity with carbon neutrality goals through tailored farm-level strategies. Mitigation strategies also help reduce other environmental impacts, maintain or increase positive contributions, while resulting in economic gains.

Systems level and nationally aggregated climate smart development pathways in Kenya's beef sector

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Beef production in Africa is associated with high relative intensity of greenhouse gas (GHG) emissions, defined as kg CO2 equivalent emissions per kg carcass weight, with estimates ranging from a few percentage points to several factors higher than temperate systems of Europe, North America, and Latin America. Rising temperatures and increasing rainfall variability moreover pose increasingly severe stressors, forcing livestock farmers to adopt new practices or exit farming altogether. Using a multi-model, multi-data framework, this study quantifies national greenhouse gas mitigation potentials across Kenyan beef production systems considering climate variability in a forward-looking, 2020-2050 assessment. Simulations using GLEAM-I, the interactive online tool of the Global Livestock Environmental Assessment Model, are paired with liveweight simulations of the Rumen8 feed formulator to quantify GHG emissions and intensities across 5 beef production systems, distinguished by breed, agro-ecology, and farm types. Interventions based on feeding, breed improvement, health, and manure management are run, in relation to meat, milk, and GHG emissions at sectoral and national levels. Climate stressors are simulated via heat stress, forage scarcity, and periodic drought and with respect to animal feed intake and liveweight gain. Among interventions, the strategies with potential for reducing GHG emissions while increasing productive outputs under diverse climate stressors are highlighted as priorities to be promoted by stakeholders and policymakers. In addition to intervention selection for climate-smart development of African beef systems, a framework is proposed for upscaling GHG simulations using a GLEAM-Rumen8 interface.

Carbon balance of beef production: LCA-based estimation of emissions and carbon sequestration in silvopastoral systems

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The aim of the present study was to analyse the environmental footprint of beef production in extensive alpine grazing systems in northern Italy, with a specific focus on greenhouse gas (GHG) emissions and carbon sequestration in grassland soils and forest above-ground biomass. A LCA approach was applied to quantify emission flows throughout the production system. The functional unit adopted was one kilogram of live weight, allowing for standardized results and comparability with other production systems. Subsequently, models and local data were used to estimate carbon sequestration in soils and forest tree biomass. In particular, the RothC model was applied to simulate soil organic carbon (SOC) dynamics in alpine pastures. Soil data were obtained from the LUCAS database and integrated with local estimates derived through spatial interpolation. Carbon sequestration in forestland was calculated based on annual tree growth rates, taking into account pedoclimatic conditions and following the guidelines of the Italian National Forest Inventory. The results indicated an average emission of 19.13 kg CO_2 equivalent per kg of live weight, with substantial variability driven by differences in farm management practices. Farms that incorporate large forestland areas can offset up to 100% of their emissions, achieving carbon neutrality or even a net negative carbon balance. On average, 45% of total emissions were compensated through carbon sequestration in forests and pastures. However, the RothC model revealed an average annual SOC loss of 0.4 Mg per hectare, mainly due to mineralization under expected climate change scenarios as proposed by IPCC. The study also showed that producing one livestock unit for beef required nearly 4.15 hectares of utilized agricultural area for feed production, whereas 2.12 hectares of forestland would be sufficient to offset the associated carbon emissions. These findings suggested that integrating forestland into farm systems could significantly enhance the sustainability of the beef sector and support progress toward carbon neutrality.

Estimate carbon balance and financial viability for crop-livestock mixed farming and agrosilvopastoral systems: insights from the DIGITAF project

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As part of the implementation of the EU Carbon Removals and Carbon Farming (CRCF) Regulation (REG 2024/3012), approved on 27/11/24, agroforestry is gaining relevance as a potential practice to offset agricultural greenhouse gas emissions and to provide additional farm income through certified carbon credits. Within the DIGITAF HE Project (101059794), a free online tool was tested in the Italian Living Lab to evaluate the carbon balance of a long-term agroforestry experiment (Arnino LTE). The trial compares a mixed farming system (MIX) with an agrosilvopastoral system (ASP) characterized by poplar tree lines between plots, with a density of approximately 50 trees ha^{-1}. The experiment includes 28 plots (14 MIX, 10.19 ha, and 14 ASP, 12.01 ha) managed under a 7-year crop rotation with Triticum durum L., Sorghum bicolor L., Vicia faba L. minor, and 4 years of temporary multispecies grassland. Different rations based on crops produced within each system were formulated for beef suckler cows and growing beef cattle (6–24 months). System boundaries were clearly defined, and production data from 2022–23 were used to calculate the livestock units (LU) sustainably supported by each system, as well as the economic viability of the systems. Preliminary results show that the MIX system has a carbon balance of 8.32 Mg CO_2-eq LU^{-1} y^{-1} released to the atmosphere, with a financial balance of €344 from crop production. In contrast, the ASP system shows a carbon balance of 8.51 Mg CO_2-eq LU^{-1} y^{-1} and a financial balance of €1,642 from crop production. Further assessments are necessary to upscale the preliminary analysis and evaluate the potential contribution of agroforestry to emission mitigation and farm profitability. Results will be reviewed by Living Lab stakeholders. The novelty of this ongoing study lies in the integration of long-term experimental data, nutritional software, user-friendly analytical tools, and a participatory approach to support the implementation of the CRCF regulation in line with EU climate-mitigation commitments.

Implications of livestock FAO 2050 emissions projections on temperature change and carbon dioxide removal using GWP and GWP* metrics

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To keep global warming to 1.5°C above pre-industrial levels, countries and productive sectors must make a significant effort to decrease their Greenhouse Gas (GHG) emissions and to improve removals. However, the GHG mitigation goal of achieving 'a balance between anthropogenic emissions by sources and removals by sinks of GHG is open to interpretation. In particular, the choice of emission metric, particularly between Global Warming Potential over 100 years (GWP100) and Global Warming Potential Star (GWP*), can significantly influence how emissions and their contributions to global warming are represented in climate assessments. Indeed, metrics can affect interpretation of emissions' impacts, which, in turn, influences carbon dioxide removal (CDR) estimates and mitigation strategies. Livestock has an important role in GHG emissions, mainly due to the methane arising from enteric fermentation and manure management. This contribution is likely to increase due to the rising global demand for animal foods. According to several researchers, this poses challenges for net-zero climate goals. However, most of these assessments rely on GWP100, which does not account for the different behavior of methane compared to CO_2 and N_2O. The aim of this work was to apply both GWP100 and GWP* metrics to the FAO's 2050 scenarios (increasing production without mitigations or increasing production with mitigations. strategies) to determine how the choice of metric affects estimated temperature projections, and the estimated CDR required to achieve the temperature goal of no additional warming. Our findings highlight that GWP100 can overestimate or underestimate the cumulative warming impact of CH_4 emissions under different emission trajectories, whereas GWP* provides a dynamic approach that better aligns with temperature goals. These differences have critical implications for climate policy, as they influence the perceived effectiveness of mitigation strategies and the allocation of CDR requirements. This study highlights the need of selecting appropriate metrics when designing climate mitigation frameworks, particularly for methane-intensive sectors like livestock.

Engaging farmers in the climate change debate using a Citizens' Jury approach

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Farmer engagement is essential in achieving national climate and nature recovery goals, yet interventions advocated by policy-makers to reduce agricultural greenhouse gas emissions are frequently rejected by UK farmers as inappropriate or impractical. To explore whether deliberative democratic methods can help overcome this impasse, a novel approach based on the Jefferson Center's Citizens' Jury concept was applied. Sixteen farmers representing diverse enterprises, locations and farm structures were recruited from across the UK to form a 'jury'. Over two days, jurors heard evidence from more than 20 experts spanning climate science, policy, technology, retail and land use before deliberating on a set of 'charges' (i.e., questions) examining the role farmers should play in meeting government climate ambitions. The jurors agreed unanimously that farmers should contribute to national goals, but concluded that Net Zero is the wrong target for agriculture, being largely unachievable at farm level, poorly aligned with the sector's greenhouse gas profile—particularly short-lived methane—and likely to drive counterproductive trade-offs in biodiversity, welfare and water quality. Instead, they advocated outcome-based goals grounded in integrated land management and food security. Barriers to engagement included inconsistent emissions accounting, limited access to trusted baselining methods, unregulated carbon markets and weak cross-government coordination. Proposed solutions included establishing an independent food supply chain forum with embedded input from grassroots farmers, using existing farmer networks to test interventions in real-world conditions, removing technical roadblocks such as methane-metric disputes, and widening capital grant opportunities—e.g., to include second-hand equipment. They agreed that a shared understanding of the challenges alongside co-design would help to shift mindsets among both farmers and policy-makers. In conclusion, the 'Farmers' Jury' process demonstrates strong potential to reduce polarisation, build trust and generate pragmatic, farmer-led recommendations not only for climate action but for other nationally significant issues requiring action at farm level.

Motivations, constraints and incentives for adoption of climate-smart innovations: Evidence from UK dairy farmers

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Climate-smart innovations are essential for progressing toward net-zero. We identified 9 promising innovations to help dairy farmers reduce emissions and enhance system sustainability. Then we conducted a survey of UK dairy farmers (n=184) to assess current adoption levels and key constraints to implementation. A high percentage of farmers have adopted A) nature-based practices (herbal leys, cover crops or silvopasture; 66%); technology-based practices, including B) sexed semen and genomic selection (90%) and C) replacement of soy (62%). The main motivations chosen to implement them were: 27% to improve soil conditions and 22% to reduce environmental impact for A; 28% for markets requirements and 25% to reduce environmental impact for B, and to improve productivity, efficiency and animal health (32%, 25% and 24%, respectively) for C. Few farmers have adopted emission-based practices such as, D) usage of anti-methanogenic feed additives (7%), E) methods to reduce emissions from slurry and manure (25% of farmers) or F) technologies to capture CH4 and N (5%). The main constraints to adoption were: low return on investment (D:58% and E:82%); lack of information and awareness for D and E (D:57% and E:80%); and 42% due to the high initial cost for F. Farmers who did not adopt a certain innovation were asked their preferred option of financial reward schemes among a milk Price Incentive (PI), a Grant Scheme (GS), or an Income Reward Scheme (IRS). 56% preferred a PI to increase the uptake of anti-methanogenic supplements, but 64% preferred a GS for increasing adoption of technologies to capture CH4 and N from slurry or manure. To enhance the adoption of more sustainable innovations, targeted support mechanisms are needed. Tailored financial incentives may lower adoption barriers, making it feasible for farmers to implement innovative practices and contribute to achieving net-zero emissions.

Closing lecture

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Integration of 3D camera–based postural analysis for early lameness detection and methane intensity mitigation in dairy cows

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Lameness in dairy cows remains a major welfare and productivity constraint with implications for environmental sustainability. The objective of this study was to develop and evaluate a non-invasive, automated system for continuous lameness detection based on 3D imaging and artificial intelligence, and to explore its potential link with methane emission intensity. Using the Dellait 3D Vision System for Livestock Monitoring, depth images were processed to reconstruct the animal's dorsal topography and quantify spinal curvature and spatial displacement between the hook and pin bones. These morphometric features were used to identify postural asymmetries associated with musculoskeletal discomfort. The approach extends the concept first proposed by García (2024), linking automated 3D-based lameness detection with potential methane mitigation through improved welfare and feed efficiency. Postural indices were integrated with behavioral and performance data, including feeding activity, rumination time, and milk yield, to model energy use efficiency and enteric methane dynamics. Lame cows exhibited lower feed intake, longer idle time, and altered rumen efficiency—factors that, while reducing total methane output, increased emission intensity (g CH_4/kg milk) due to lower productive efficiency. The study demonstrates that combining 3D postural data with feed efficiency models allows identification of animals or management conditions contributing disproportionately to greenhouse gas intensity. This integration positions 3D imaging as a precision tool for early lameness detection, improved feed utilization, and climate-smart dairy management.

Linear and nonlinear relationship between global positioning system collars and enteric emissions for beef heifers grazing naturalized pastures

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Livestock greenhouse gas mitigation requires solutions reflecting the realities of extensive grazing systems. This study evaluated associations between GPS-derived parameters and daily enteric CO_2 and CH_4 emissions in 48 beef heifers (body weight [BW] 371 ± 25 kg; ~14 months) grazing naturalized pastures for 61 days. Linear and nonlinear associations between emissions and GPS parameters were evaluated through linear mixed models and generalized additive models (GAMs). Linear and nonlinear associations with animal altitude in pasture were detected for all CO_2 outcomes ($P < 0.05$), likely reflecting the fixed location of the emissions monitoring equipment. GAMs revealed nonlinear effects for grazing time (% head down, estimated degrees of freedom (EDF) = 4.20, P = 0.011) with predicted CO_2 increasing sharply as grazing time increased, especially at the highest observed levels. CO_2/BW was positively associated with travel velocity ($\beta = 1.97 \pm 0.89$, P = 0.027), tended to decrease with total distance ($\beta = -1.45 \pm 0.86$, P = 0.094), and decreased with greater daily temperature variability ($\beta = 0.23 \pm 0.07$, P = 0.002), indicating that faster but not necessarily farther-traveling animals tended to have higher CO_2 intensity. CO2/BW showed nonlinear responses to travel velocity (EDF = 1.67, P = 0.057) and temperature variability (EDF = 1.77, P = 0.034). For average daily gain (ADG) corrections, CO_2/ADG, grazing proportion showed a significant nonlinear effect (EDF = 3.72, P = 0.026), with low and very high grazing intensities associated with elevated emissions per unit gain. CH_4 and CH_4/ADG increased linearly with temperature variability ($\beta = 3.85 \pm 1.69$, P = 0.023; $\beta = 3.87 \pm 1.64$, P = 0.018) but otherwise showed no consistent links to GPS traits. Overall, daily distance, velocity, and grazing time emerged as behavioral correlates of CO_2 emissions, whereas CH_4 appeared less related to these GPS-derived metrics.

Methodological assessment of the Gas Endeavour device for real-time measurement of CO_2 and CH_4 emissions from sheep diets

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Agro-industrial by-products contain dietary fibre and bioactive compounds (polyphenols, flavonoids, and tannins), which can modulate the rumen microbiome, improving nutrient digestion and reducing methane emissions. Tannins may lower methane emissions either by limiting fibre degradation or by directly affecting rumen microbial populations without impairing digestion. To this end, in vitro trials were carried out in duplicate utilizing sheep diets containing different by-products: prickly pear silages or partially destoned olive cake. A series of four in vitro rumen fermentation trials were carried out using the innovative Gas Endeavour System, and the Gage R&R statistical approach was applied to assess the precision of the device in measuring total gas and methane production. For each diet, samples of the fermented liquor were analysed to determine the disappearance of organic matter and neutral detergent fibre. The parameters of repeatability and reproducibility obtained in these studies are promising, and the reproducibility data for total gas production were better than that for methane gas production as for diet with prickly pear silage, as for diet that include partially destoned olive cake. The inclusion of prickly pear silage in the sheep diet reduced both total gas and methane emissions, without altering the gas-to-methane ratio. Incorporating partially destoned olive cake lowered total gas production, while having no measurable effect on methane emissions. Regarding gas emission kinetics, methane production peaks during the early hours of fermentation, unlike total gas production, which follows a different temporal pattern. Finally, the inclusion of these by-products in the sheep diet reduced organic matter disappearance, likely due to the presence of seeds in the prickly pear silage and residual stone fragments in the partially destoned olive cake. In addition, the Gas Endeavour system provided reliable and consistent results, confirming its potential as a valuable tool in animal nutrition trials for the measurement of emissions from ruminants.

Evaluation of Laser-based spot measurements using ventilated hoods chambers for direct enteric methane emissions

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Spot measurements of enteric methane emissions using a hand-held Laser Methane Detector (LMD; Tokyo Gas Engineering Co. Ltd.) are increasingly proposed as a practical on-farm alternative to respiratory chambers, yet their accuracy and repeatability remain under evaluation. This study involved 8 lactating Sarda ewes, allocated to two productivity groups (1.6±0.55 and 2.8±0.47 L/d), and monitored using two ventilated hood chambers and three LMD devices across ten time points over 12 h. The trial lasted 4 days; each day, one ewe per group was assessed for methane emissions, while the remaining days was monitored for milk yield and feed intake. Inter-operator repeatability (with simultaneous measurements on the same ewe while in the chamber, with one LMD per operator; crossover 3×3) and agreement between methods were evaluated. LMD measurements showed high concordance among operators (CCC 0.88–0.91), indicating strong repeatability. The predictive ability of LMD relative to hoods measurements was variable: linear models based on single-time-point LMD readings explained up to 60% of the variability, and only when feed intake was included in the model. The best-performing model (R^2=0.92) included LMD data, feed intake, and body weight, whereas simplified models relying only on LMD, and body weight showed limited predictive performance, with the highest accuracy at three and four hours after feeding (R^2=0.50). Overall, while the LMD proved highly repeatable in a confined environment, its ability to estimate chamber-derived methane emissions depended strongly on measurement timings and inclusion of additional animal variables. Funded by the project GreenSheep LIFE+19 CCM/FR/001245.

Evaluating the Accuracy of ZELP Sense™ Against Respiration Chambers for Methane Emission Measurement in Cattle

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Introduction Methane production by ruminants is a critical factor driving the ongoing climate crisis. Accurate methane measurement allows for better methane management. Currently, respiration chambers are the gold standard technique for measuring livestock methane emissions. Whilst precise, they are also costly, restrictive and stressful for the animal, which can lead to a reduction in feed intake and an alteration in natural methane emission patterns (Llonch et al., 2018). ZELP Sense offers a solution to these drawbacks, as a wearable device that provides continuous, real-world, emissions monitoring. The aim of this study is to compare the methane measurements provided by ZELP's device with those provided by respiration chambers. Methods A trial was carried out over three weeks at AgResearch in New Zealand, using four Kiwi cross dry cows. Adaptation to the device took place over the first week. This was followed by two three-day test periods with a rest period in between. Feed intake was restricted for the second test period. The device uses sensors to track ventilation rate and methane concentrations in gas exhaled by the animal. The company's Machine Learning models then use this data to calculate daily emission totals. Results There was a moderate positive correlation between the methane measurements provided by the device and those provided by the respiration chambers (R^2 = 0.4726 , p = 0.0006). The daily emission totals showed an RMSE of ~18% when compared to chamber totals. The device was also shown to be sensitive to CH4 emission variations resulting from the restricted diet (p = 0.0452). All animals adapted well to the device. Conclusions For accurate measurement and monitoring of methane emissions from cattle, we conclude that this device offers a good alternative to respiration chambers. Moreover, the device addresses some of the disadvantages of respiration chambers, as it is field-deployable and can be worn for longer time periods. Further work will allow the device's accuracy to be improved and for its performance across a broad range of conditions to be demonstrated.

Comparison of procedures for estimating enteric methane emissions in dairy herds

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Enteric methane (CH4) is a main driver to greenhouse gas emission (GHGE) in dairy herds, but its direct measurement is complex. This study aimed at comparing estimations of enteric CH4 due to lactating cows obtained with equations based on 1) milk fatty acids (FA) predicted by mid-infrared spectra (MIR) and 2) estimated cows' feed intake and diet composition. Data originated from 174 farms enrolled in the Parmigiano Reggiano Consortium. For each farm, data on milk yield (MY), feed allowance and composition of diets fed to lactating cows were collected. Individual milk composition, milk MIR spectra (MilkoScan FT6000), days in milk (DIM) and parity were retrieved from the official Italian milk recording systems over a period of almost two years. Editing of spectra included outliers' detection by mahalanobis distance. Prediction of six informative FA were obtained using equations previously developed to calculate enteric CH4 emissions. Farm-based least square means were obtained using a linear model (fixed effects: farm, DIM (12 classes of 30 days) and parity (5 classes); random effects: individual cow, test-day). These were compared with the values obtained from eight diet-based equations retrieved from the literature using Pearson correlation analysis. On average, farms herded 148±135 cows, with a MY of 27.8±5.7 kg/cow/d (3.38% protein, 3.76% fat). Feed intake averaged 25.2±2.3 kg dry matter/cow/d (mean forage-concentrate ratio of 58:42). MIR-based CH4 values averaged 405±79 g/cow/d, whereas estimates from diet-based equations ranged from 361±37 to 478±40 g, with an overall average of 432±36 g. Correlation factors between MIR-based and diet-based CH4 ranged from 0.08 to 0.58: three equations showed low values (0.08-0.37) and five equation (plus the overall average) higher and significant ones (0.48-0.58, $P<0.01$). In conclusion, enteric CH4 estimated using milk MIR spectra could be an interesting alternative method to compute farm GHGE.

Effect of feed additives on in vitro gas production kinetics

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Strategies such as dietary adjustments and the use of feed additives have been investigated to mitigate greenhouse gas (GHG) emissions. Therefore, this study aimed to evaluate three additives—a tannin-based product, biochar, and a mycotoxin adsorbent—and their potential effects on gas mitigation. The experiment was conducted at the Applied Nutrition Laboratory of the Department of Animal Science at UFMS and approved by the Ethics Committee on the Use of Animals (1.385/2025). Wheat straw was used as a fermentation substrate. It was dried in an air oven at 55 ± 5 °C until it reached a constant weight, ground through a 1 mm sieve using a Wiley stationary mill, and subsequently mixed with the additives before being subjected to the in vitro gas production technique. For each sample, 1 g of wheat straw and 0.005 g of additive were incubated with 100 mL of solution and 25 mL of ruminal fluid. The samples were saturated with CO_2 and incubated in a water bath at 39 °C. Interference was monitored for 24 hours using the automated ANKOM RF system, with pressure recording every 5 min. Cumulative gas production profiles were estimated using the non-linear model proposed by Ørskov (1979). The final gas production volumes differed ($P > 0.01$) between the additive treatments and the control. The total gas production in the control treatment (wheat straw only) was 7.16 mL/100 mg of DM. Treatment with biochar showed a reduction of 8.19 mL/100 mg of dry matter, treatment with mycotoxin adsorbent showed a reduction of 7.28 mL/100 mg of dry matter, while treatment with tannin showed a reduction of 6.39 mL/100 mg of dry matter. The use of tannins in ruminant nutrition can modulate the ruminal microbiota, significantly improving animal performance and contributing to the mitigation of greenhouse gases. It is concluded that tannin supplementation can reduce total gas production in vitro. Acknowledgments: FAPEMIG, INCT-CA.

Evaluation of the Kleiber index in dairy Gyr heifers fed diets with different associations of wheat silage

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Animals exhibiting lower feed intake and reduced metabolizable energy production have lower maintenance energy requirements, which consequently results in reduced rates of enteric methane emissions. Therefore, the objective of this study was to evaluate the feed efficiency of dairy Gyr heifers using the Kleiber Index (KI). The experiment was conducted at the Agricultural Research Company of Minas Gerais (EPAMIG), in Uberaba, Minas Gerais, Brazil, under the approval of the Animal Ethics Committee (CEUA/EPAMIG; protocol 03/2022). A total of 32 dairy Gyr heifers, with an initial body weight of 357 kg and an average age of 797 days, were used. Animals were housed in group pens in an automated feedlot system equipped with feed bunks and waterers coupled to an animal weighing platform. Treatments consisted of diets containing different proportions of wheat silage replacing corn (0%, 33%, 67%, and 100%). The experiment lasted 112 days, and the Kleiber Index was calculated according to the equation proposed by Kleiber (1936). Data were analyzed using the PROC MIXED procedure (SAS Institute), with the selection of the best (co)variance structure based on the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). The Kleiber Index was higher ($P < 0.05$) in animals fed diets containing 0% (12.8) and 33% (11.74) wheat silage replacing corn, whereas inclusion levels of 67% (9.78) and 100% (8.87) wheat silage resulted in lower KI values. Higher KI values are desirable for feed efficiency, as they indicate greater body growth without increasing maintenance energy costs, reflecting physiologically more efficient animals. Thus, diets containing 0% and 33% wheat silage showed superior feed efficiency due to higher KI values. In conclusion, the partial replacement of corn with wheat silage at 33% represents a favorable nutritional strategy to promote efficient growth, reduce energy intake, and potentially contribute to lower enteric methane emissions throughout the animal's productive cycle. Acknowledgments: FAPEMIG, INCT-CA, CAPES.

Ability of faecal NIRS for predicting methane emissions in cows supplemented with antimethanogenic additives.

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Current methods for quantifying methane (CH4) emissions from individual ruminants are difficult to apply on commercial farms. Near-infrared spectra (NIRS) can be obtained from bovine faecal samples, which are an unabsorbed product of digestion and a universal matrix. Since CH_4 and faeces are produced during digestion, these spectra could potentially be used to detect the use of antimethanogenic additives (AMA) and predict CH_4 emissions. This work aimed to: i) evaluate the potential of faecal NIRS to detect effects of AMA supplementation in cows' diets; ii) test predictive models of CH4 emissions from faecal NIRS of cows supplemented or not with AMA. This work was based on three previous experiments on dairy cows (n = 43; Experiments 1 and 2) supplemented with 3-nitrooxypropanol (3-NOP; 60 mg/kg DM), and beef cows (n = 20; Experiment 3) supplemented with Asparagopsis taxiformis macerated oil (Bromoil; 25 mg/kg DM). Individual data on CH4 were acquired using GreenFeed units or respiration chambers. Faecal samples for NIRS analyses were collected during the same week as CH4 measurement. Individual faecal NIRS from the three trials were used to test an existing predictive model of CH4 emissions. The results demonstrated that faecal NIRS successfully identified diet differences. A local NIRS model for predicting CH_4 emissions was tested. A specific prediction model was developed for 3-NOP treatment in each experiment. For the Bromoil trial, the model is still being calibrated. This work should highlight the potential of faecal NIRS to predict CH4 emissions from cows supplemented with AMA.

Effect of nitrate supplementation on the in vitro gas production profile of grass and maize silage

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Enteric methane emissions from ruminants represent an major source of greenhouse gases emissions. Alternatives to minimize emissions are a research priority, feeding manipulation represent a viable option amongst which Nitrate supplementation has been proposed. The in vitro gas production technique is widely utilised to evaluate the nutritional potential of feedstuffs and feeding strategies. Therefore the aim of the present study was to evaluate the effect of nitrate supplementation on the gas production profile of grass (GS) and maize (MS) silages. Samples of GS and MS were obtained and supplementation of 2 levels of nitrate inclusion 10 and 15mg were evaluated. Samples (GS0, GS10, GS15, MS0, MS10 and MS15) were incubated in rumen liquor in airtight syringes according to Menke and Staingass (1988) as modified by Palmer (2006). Gas measurements were taken every 0.5h for the first 4h, hourly up to 6h, every 2h up to 12h, then at 16, 20, 24, 28, 32, 36, 40, 44, 48, 56, 64, and 72h. Total gas (ml) and gas profiles were used to calculate fermentation characteristics of the carbohydrates (CHO) fractions: quickly degradable (QCHO ml), and rate of degradation (QCHOrate h), slowly degradable (SCHO) lag (SCHOlag h) and rate (SCHOrate h), by regression on the corrected gas volumes using known stoichiometry. Nitrate supplementation affected total volume, QCHO, SCHO, SCHOrate and SCHOlag for GS and MS. For GS higher rates of supplementation inversely affected total gas (GS0=58,GS10=52, GS15=50ml), QCHO (GS0=24, GS10=21, GS15=18ml) and SCHO rate (GS0=0.17, GS10=0.15, GS15=0.09h) in GS samples. However, for MS the biggest reductions were observed at 10mg nitrate total gas (MS0=91, MS10=80, MS15=86ml), QCHO (MS0=26, MS10=24, MS15=25). Our results showed that nitrate supplementation effectively reduced gas production from grass and maize silages by mainly affecting the quickly degradable fraction of the carbohydrates. Future research should study, optimal supplementation rate, long term effect and dose-rate effect in vivo of nitrate supplementation

Sniffer sensors vs. SF_6 gas-tracer technique: A field comparison in pasture-based dairy systems

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Uruguayan dairy sector is a major export-oriented industry predominantly based on grazed pastures. Although the country contributes only ~0.03% of global greenhouse gas (GHG) emissions, around 70% originate from agriculture, with enteric methane (CH_4) being the main source. Due to its short atmospheric lifetime and strong warming potential, reducing CH_4 emissions is a key mitigation target under national commitments aligned with the Paris Agreement. Improving accurate and scalable CH_4 measurement tools is therefore essential to support mitigation strategies, refine national inventories, and inform selection programmes for lower-emitting animals. This study compares the performance of two techniques for measuring enteric CH_4 emissions in grazing dairy cows: the sulphur hexafluoride (SF_6) gas-tracer technique, used as the reference technique in pasture-based systems, and sniffer-type sensors, a lower-cost and potentially scalable alternative. The experiment was conducted at INIA La Estanzuela's (Colonia, Uruguay) robotic milking system during winter and spring, 2025. Individual CH_4 emissions were monitored along with milk production, feed intake, live weight, and body condition score. Preliminary results show an average sampling efficiency of 60% for the SF_6 technique. Mean daily CH_4 emissions measured with the SF_6 tracer were 404 (± 59) g/d. A positive correlation (Pearson, r = 0.58) was observed between the two techniques, indicating good potential for sniffer sensors to provide reliable emission estimates despite expected variability due to environmental and behavioural factors. These results suggest that sniffer sensors may represent a promising, practical approach for large-scale CH_4 monitoring in pasture-based dairy systems. Further data collection and analysis are underway to improve the comparison and fully assess agreement and repeatability between methods.

In vitro gas production kinetics of feed-grade urea and protected urea

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Environmental concerns have intensified the need to reduce greenhouse gas emissions from livestock systems. Thus, the objective of this study was to evaluate the total gas production of two nitrogen (N) sources. The experiment was conducted at the Applied Nutrition Laboratory of the Department of Animal Science, Federal University of Mato Grosso do Sul, under approval of the Institutional Animal Care and Use Committee (n° 1.385/2025). Wheat straw (WS) was used as the substrate. It was oven-dried at 55 ± 5 °C with forced-air circulation until constant weight, ground through stationary Wiley-type mill (1-mm screen), and mixed with the N. For each sample, 1 g of wheat straw and 0.005 g of the N source were incubated with 100 mL of buffer solution and 25 mL of rumen fluid. Samples were saturated with CO_2 at 39 °C. Fermentation was monitored for 24 h using the ANKOM RF automated system, with pressure recorded every 5 min. Cumulative gas-production curves were fitted using the model proposed by Ørskov (1979). Total gas production for the control treatment WS was 7.16 mL/100 mg dry matter DM. Feed-grade urea yielded 5.44 mL/100 mg DM, whereas protected urea produced 9.57 mL/100 mg DM. Feed-grade urea undergoes rapid hydrolysis, releasing large quantities of ammonia within minutes. This rapid N release may impair fermentation efficiency and result in reduced gas production in in vitro incubations due to decreased microbial synthesis. Protected urea consists of feed-grade urea coated with polymer layers and/or vegetable waxes, which slow the rate of N release in the rumen. Consequently, protected urea promotes more efficient fermentation and tends to increase cumulative gas production over time, whereas conventional urea releases N too rapidly, potentially compromising microbial activity and reducing total gas yield. In conclusion, protected urea shows potential to enhance fermentative efficiency, which may contribute to strategies aimed at mitigating greenhouse gas emissions in ruminant production systems. Acknowledgments: FAPEMIG, INCT-CA.

Advantages and limitations of the Use of Laser Methane Detector for Ranking Enteric Methane Emissions: practical recommendations.

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LMD is a portable, absolutely non-invasive and versatile tool for estimating enteric methane (CH_4) emissions. Its use for ranking animals has gained interest, but its reliability remains uncertain. Evidences from cattle, buffaloes and sheep show that LMD can detect daily CH_4 patterns and treatment-related trends, such as post-feeding peaks, and can stratify animals for emission. However, comparisons with respiration chambers (RC) revealed low to moderate correlations/poor accuracy, even after data correction. Environmental variability, animal behavior, and operational conditions influence LMD readings, along with other factors, limiting its standalone use for precise quantification. Nevertheless, LMD can be applied for detecting relative changes rather than absolute quantification. Measurements should be standardized for fixed factors and repeated across multiple days. Combining reference techniques (e.g., RC) is essential for quantification or validation after a mass screening using rapid methods (e.g., LMD, sniffer). Practical recommendations: Perform single measurements lasting at least 2–3 minutes to represent a full rumen cycle.Maintain fixed distance and angle from the animal.Measure at consistent time (preferably ≥3 hours after feed).Record animal activity (i.e. feeding, rumination etc.) and environmental conditions (T°C, humidity, solar radiation, wind speed/direction).Note instrument and operator identity; include these in models. Quantify baseline environmental CH_4.Take multiple measurements per day over several days per animal.Document deviations or contingencies.For diet/treatment trials, pre-test under controlled conditions to select animals balanced for emissions.Include any potential effect in statistical models (eg., body condition score, liveweight, production level, coat color, activity, containment type, season, parity/age, stable position, milking order, feeding operator).LMD is suitable for preliminary or comparative studies on large sample sizes and for efficiently ranking animals or experimental groups, whereas quantitative determinations should be validated using standard methods. Nevertheless, applying rigorous protocols can significantly reduce bias and minimize external influences.

In vitro gas production of different forages and their implications for greenhouse gas mitigation

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When forages are properly managed and animals exhibit greater productive efficiency, livestock systems can act as agents of greenhouse gas mitigation rather than merely potential pollution sources. Therefore, the objective of this study was to evaluate differences in total gas production among three forage sources: in natura forage peanut, forage peanut hay, and wheat straw. The experiment was conducted at the Applied Nutrition Laboratory of the Department of Animal Science, Federal University of Mato Grosso do Sul, under approval of the Ethics Committee on Animal Use (Protocol no. 1.385/2025). Samples were oven-dried at 55 ± 5 °C with forced-air circulation until reaching constant weight. The pre-dried material was ground through a 1-mm screen using a stationary mill. For each incubation, 1 g of sample was combined with 100 mL of buffer solution and 25 mL of rumen fluid. The samples were saturated with CO_2 at 39 °C. Fermentation was monitored for 24 h using the ANKOM RF automated system (ANKOM Technology, NY, USA), with pressure recorded every 5 min. Cumulative gas-production profiles were fitted using the model proposed by Ørskov (1979). Total gas production for wheat straw was 7.16 mL/100 mg dry matter (DM), for in natura forage peanut was 6.85 mL/100 mg DM, and for forage peanut hay was 4.41 mL/100 mg DM. Legumes contain tannins, compounds known to modulate ruminal fermentation and reduce methane production. Among the forages evaluated, forage peanut hay yielded the lowest gas production, indicating greater fermentative efficiency. Thus, its inclusion in ruminant diets may improve overall nutritive value while contributing to greenhouse gas mitigation. Consequently, the use of forage peanut preserved as hay demonstrates potential as a sustainable strategy to reduce greenhouse gas emissions in ruminant production systems. Acknowledgments: FAPEMIG, INCT-CA.

In Vitro Gas Production Kinetics of Protein and Energy Concentrates Used in Bovine Nutrition

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Methane(CH_4) production during ruminal fermentation is directly influenced by feed intake, nutrient digestibility, and the type of cattle feed. Reductions in CH_4 emissions can be achieved through strategies that modulate rumen fermentation, such as altering forage to concentrate ratios, yielding environmental benefits by mitigating methanogenesis.Therefore, the objective of this study was to evaluate the in vitro gas production of protein and energy concentrates commonly used in bovine diets. The experiment was conducted at UFMS, and approved by the Ethics Committee on Animal Use (1.385/2025). Ingredient samples, including cottonseed, citrus pulp, dried distillers' grains (DDG), ground corn, high-moisture corn, and feed-grade urea were pre-dried and ground.For each ingredient, 1 g of the total diet was incubated with 100 mL of buffer solution and 25 mL of rumen fluid, under CO_2 flux at 39 °C.Fermentation was monitored for 24 h using the ANKOM RF automated system, with pressure recorded every 5 min. Pressure data were converted into cumulative gas production (mL/100 mg dry matter DM).The Logistic (1994) model provided the best fit. The highest observed and estimated gas production values occurred for high-moisture corn (15.08 vs. 15.50%) and ground corn (12.68 vs. 13.09%),reflecting their greater supply of fermentable carbohydrates, which tend to increase total gas production, including precursors of CH_4. Citrus pulp presented a moderate increase (6.23 vs. 6.43%), whereas DDG showed lower values (5.22 vs. 5.52%), likely due to its reduced digestible carbohydrate fractions.Cottonseed yielded the lowest fermentation (2.11 vs. 2.24%), consistent with its higher lipid content, which can depress methanogenic microbial activity. These results demonstrate that ingredient composition affects fermentative processes and greenhouse gas production. Thus, selecting feedstuffs that reduce gas formation can enhance overall diet efficiency. Acknowledgments: FAPEMIG, CAPES, INCT-CA.

Mathematical model for adjustments of in vitro gases production at different inclusion levels of wheat silage

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The production of silage is essential to ensure a continuous and high-quality feed supply for cattle, particularly during periods of forage scarcity. In the context of increasing demand for more efficient and environmentally sustainable livestock systems, the wheat cultivar MGS 3 Brilhante has emerged as a promising forage option for the off-season due to its agronomic and nutritional advantages. Evaluating ruminal fermentation kinetics through in vitro gas production enables the estimation of feed degradability and nutrient availability, as well as a better understanding of the potential impacts of enteric fermentation on greenhouse gas emissions. Therefore, this study aimed to analyze gas production kinetics of diets containing different inclusion levels of wheat silage (WS). The experiment was carried out at UFMS, and approved by the Ethics Committee on Animal Use (N°1.385/2025). Samples of total diet containing 0, 15, and 30% WS, were pre-dried and ground. For each sample, 1 g of the total diet was incubated with 100 mL of buffer solution and 25 mL of rumen fluid under CO_2 at 39 °C. Fermentation was monitored for 24 h using the ANKOM RF automated system (Technology, NY, USA), with pressure recorded every 5 min. Data were converted into cumulative gas production (mL/100 mg dry matter DM) and fitted to the Orskov (1980) and logistic (1994) mathematical models. The Orskov model showed higher precision in explaining in vitro digestion. Estimated and observed gas production values were similar among the three inclusion levels, ranging from 11.03 to 11.65 mL/100 mg DM, indicating good model precision and no significant effect of WS inclusion on ruminal fermentation. These findings demonstrate that the inclusion of up to 30% wheat silage in the diet does not meaningfully alter in vitro gas production kinetics, suggesting that this forage can partially replace corn silage without compromising ruminal fermentation. Acknowledgments: FAPEMIG, CAPES, INCT-CA.

In vitro gas production dynamics of forage peanut cv. BRS Mandobi

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Given the global relevance of livestock production, a major nutritional challenge is to enhance animal performance while simultaneously reducing the environmental impacts associated with the activity. Incorporating legumes into production systems has been proposed as an alternative strategy to mitigate these impacts. Therefore, the objective of this study was to evaluate the cumulative in vitro gas production of forage peanut, assessed in its in natura form and as hay dried under rain-protected conditions (LON) or dried in a roofed barn (GAL). The experiment was approved by the Animal Use Ethics Committee protocol 1.385/2025. Wheat straw was used as the substrate. It was oven-dried at 55 ± 5 °C with forced-air ventilation until constant weight, then ground through a 1-mm screen of a stationary Wiley-type mill. After grinding, additives were incorporated into the straw, and the samples were subsequently submitted to the in vitro gas production technique. For each treatment, 1 g of sample was incubated with 100 mL of buffer solution and 25 mL of rumen fluid. Samples were saturated with CO_2 at 39 °C. Fermentation was monitored for 24 h using the ANKOM RF automatic system ANKOM Technology, NY, USA, with pressure recorded every 5 min. Cumulative gas production profiles were estimated using the Logistic model (1994). The final cumulative gas volume was lower when forage peanut was preserved as hay, with no differences between drying methods. In natura forage peanut produced 6.85 mL/100 mg DM of total gas, while GAL hay produced 4.41 mL/100 mg DM, and LON hay produced 4.37 mL/100 mg DM. The forage conservation method in the form of hay reduced total gas production. Intensified use of forage legumes has potential to reduce environmental impacts, as legumes may decrease nitrous oxide emissions associated with the nitrogen cycle and lower enteric methane production by ruminants. Thus, haymaking can reduce the fermentation time of legume forages, contributing to the mitigation of greenhouse gas emissions generated by ruminants. Acknowledgments: FAPEMIG, INCT-CA.

In vitro gas production kinetics for different inclusion levels of wheat silage

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The use of wheat silage (WS) diets has the potential to enhance bovine performance. Additionally, appropriate nutritional strategies may contribute to more efficient production systems with reduced environmental impact, given that ruminal fermentation is associated with greenhouse gas emissions. Although the in vitro gas production technique does not quantify methane in isolation, evaluating different inclusion levels of this forage is essential to understand its effects on ruminal fermentation, particularly through in vitro gas production kinetics. The experiment was conducted at UFMS and approved by the Ethics Committee on Animal (1.385/25). Diet samples containing 100% and 67% WS produced with the cultivar MGS3 Brilhante, as well as 100% and 67% corn silage (CS), were pre-dried and ground. For each sample, 1 g of total diet was incubated with 100 mL of buffer solution and 25 mL of rumen fluid under CO_2 and maintained at 39 °C. Fermentation was monitored for 24 h using the ANKOM automated system. Data were converted into cumulative gas production (mL/100 mg dry matter—DM) and fitted to the Ørskov mathematical model (1980). Predicted and observed values of gas production were similar, indicating adequate model precision. Diets containing 67% WS showed higher predicted and observed gas production (10.09 and 9.77 mL/100 mg DM, respectively), suggesting greater fermentability at this proportion. The 100% WS total inclusion resulted in lower predicted and observed values (7.28 and 7.14 mL/100 mg DM, respectively), likely due to reduced availability of fermentable carbohydrates. A similar pattern was observed for CS treatments, with the highest gas production at 67% WS inclusion. These findings indicate that intermediate proportions of the different forages favor microbial activity. Thus, WS represents a promising alternative, maintaining fermentative efficiency and aligning with nutritional strategies aimed at mitigating environmental impacts in livestock systems. Acknowledgments: FAPEMIG, CAPES, FINEP, INCT-CA

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