



A conceptual model of the synergetic effect of combining the anti-methanogenic macroalgae *Asparagopsis taxiformis* with the hydrogen acceptor phloroglucinol: a strategy for methane mitigation with fermentation co-benefits for ruminants

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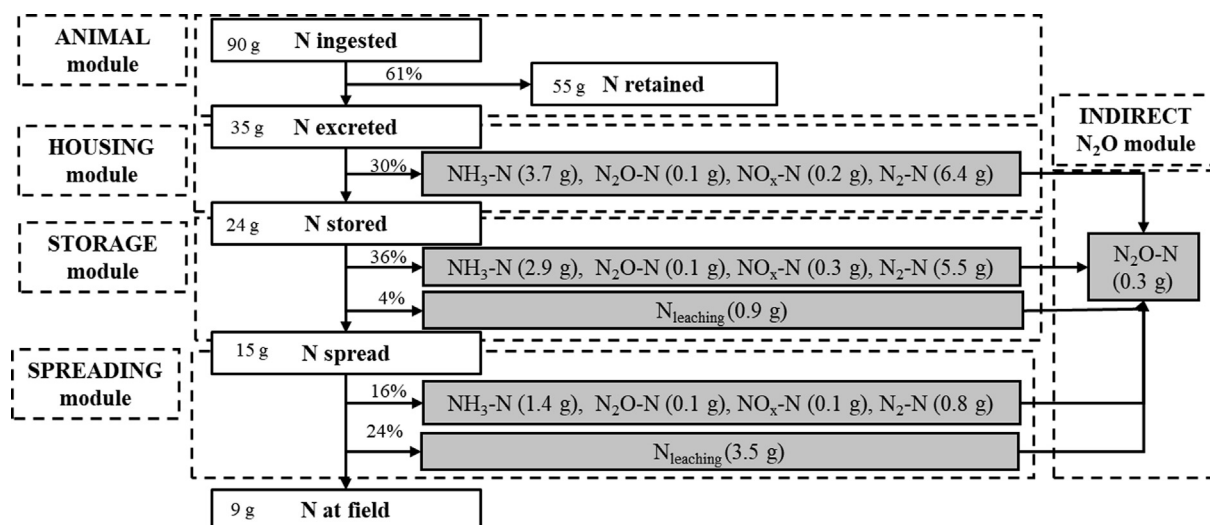


Fig. 1. Nitrogen (N) flows simulated with the AVINEM model for the production of one chicken.

Results and discussion: N excretion was estimated to 35 g per chicken (Fig. 1), of which a total of 26 g were lost, mostly as gas emissions (22 g). These N losses were mainly under N_2 -N (13 g) and NH_3 -N (8 g) forms, and originated from housing (40 %), storage (37 %), and spreading (23 %). In comparison with AVINEM, N losses estimated with the EMEP model were lower for total N (21 vs 26 g), N_2 -N (6 vs 13 g), N_2O -N (0.2 vs 0.3 g), NO_x (0.4 vs 0.6 g) and leached N (0.6 vs 0.9 g), but not for NH_3 -N (14 vs 8 g). This confirms the importance of both taking into account N_2 -N losses in all stages for an accurate estimate of NH_3 -N emissions, and regularly updating EFs used in emission inventory models, such as EMEP. Experiments are underway to validate the model.

Conclusion and implications: The AVINEM model simulates N losses based on the most recent data for broiler chickens. In particular, it highlights the contribution of non-reactive N_2 -N emissions relatively to total N losses.

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68. A conceptual model of the synergetic effect of combining the anti-methanogenic macroalgae *Asparagopsis taxiformis* with the hydrogen acceptor phloroglucinol: a strategy for methane mitigation with fermentation co-benefits for ruminants

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Introduction: The rumen microbiota harbors a highly diverse microbial community, leading to a complex metabolic network including key processes such as fermentation and methanogenesis. Fermentation is essential for the degradation of fiber and is coupled with methane (CH_4) production via interspecies hydrogen transfer. CH_4 mitigation is a central target for the ruminant sector. An alternative for CH_4 mitigation is the supply of antimethanogenic feed additives (AMFA). An optimal CH_4 mitigation strategy should also induce co-benefits such as enhanced animal productivity and health. Such co-benefits can be attained by complementing AMFA with modulators that favour alternative pathways. Mechanistic modelling can be instrumental for the design of optimal synergetic strategies (Pressman and Kebreab, 2024). To date, very few models integrate AMFA and complementary modulators. The objective of this work was to set the conceptual basis of a mechanistic model that integrates the synergetic effect of the combination of two modulators on the fermentation and CH_4 . The first modulator is the macroalgae *Asparagopsis taxiformis*, which contains the anti-methanogenic compound bromoform. The second modulator is the phenolic compound phloroglucinol, which is a hydrogen (H_2) acceptor and thus have the potential to redirect H_2 to alternative beneficial pathways such as acetate production.

Material and methods: This work used as scaffold a previously mechanistic dynamic model we developed to represent the effect of *A. taxiformis* on rumen fermentation and CH₄ under *in vitro* batch conditions (Muñoz-Tamayo et al., 2021). On the basis of recent *in vitro* experiments (Huang et al., 2023) performed in our groups to investigate the combination of *A. taxiformis* with phloroglucinol, we identified key biological processes to be integrated in the model structure to account for the synergetic effect.

Results and discussion: The model has 20 state variables: 3 polymer components, 9 soluble components, 3 microbial groups, 3 gas-phase components, 2 methanogen modulators (1 methanogen inhibitor and 1 hydrogen acceptor). The state variables are interconnected through mass fluxes from microbial substrate utilization and microbial growth. The bromoform contained in *A. taxiformis* has a direct inhibitory effect on the methanogen microbial group resulting in H₂ accumulation. H₂ exerts thermodynamic control on the fermentation. A fraction of accumulated H₂ is used in combination with phloroglucinol by sugar utilizers to produce acetate and butyrate.

Conclusion and implications: The conceptual model is the first step to identify key processes to represent synergetic strategies for CH₄ mitigation. The exercise enabled us to identify model parameters that need to be incorporated into stoichiometry and reaction rate functions in order to account for synergetic scenarios. The next step is to produce a numerical simulation model with parameters estimated from available *in vitro* experimental data (Huang et al., 2023). We expect that the resulting model can guide the identification of optimal conditions for CH₄ mitigation while maintaining or improving volatile fatty acids production.

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69. Integrated crop-livestock systems: mechanisms and strategies to improve nitrogen utilization efficiency

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Introduction: Integrated crop-livestock systems (ICLS) represent a sustainable agricultural model that synergistically combines crop production, livestock husbandry, and agricultural waste management. By integrating these components, ICLS enhance nutrient cycling, particularly carbon, nitrogen (N), and phosphorus, within agroecosystems. In ruminant-based ICLS, manure is strategically utilized to fertilize croplands and forage production, closing nutrient loops and reducing agricultural pollution. The objective of this study was to elucidate the ecological benefits of ICLS by comparing N utilization efficiency (NUE) between conventional separated crop-livestock systems and integrated approaches.

Material and methods: Two mechanistic models were developed to simulate N flows in separated versus integrated crop-dairy systems. The separated model tracked N across five pools (soil, crop, diet, cow, and manure), with manure either being improperly discarded into the environment (e.g., rivers and lakes) or left in unmanaged stacks. The integrated model incorporated a sixth organic fertilizer pool, treating manure through composting before being recycled to the soil. Both models were parameterized for a dairy cow producing 12 tons of milk annually at 25 % feed-to-milk NUE and 3.2 % milk protein content. This configuration exports 62 kg N via milk annually, requiring 248 kg of dietary N intake. Dietary N was originated from crop residues, forages, cereal grains, protein supplements, and cereal by-products. Meanwhile, N losses from raw crop feedstuff to animal diet were accounted for. By reverse tracing milk N across the crop production chain, crop N uptake efficiency from soil, soil N input (synthetic fertilizers, biological N fixation, and atmospheric deposition) and losses (runoff, leaching, ammonia volatilization, and denitrification) were quantified.

Results and discussion: Model simulations revealed that dairy cattle-based ICLS achieved a whole system NUE of 10.3 %, compared to 6.8 % in the separated systems, representing a 51 % increase under integration. Within ICLS, 132.5 kg of N was effectively recycled via organic manure, reducing synthetic N fertilizer demand by 41 % (from 610.6 kg to 360.7 kg of N). This improvement stems from both optimized nutrient cycling and reduced reliance on external N inputs. Together with synthetic fertilizers, biological N fixation, and atmospheric deposition, the total N input into the soil was 911.4 kg in the separated systems compared to 736.2 kg in ICLS. Although organic manure still contributes to N losses via runoff, leaching, and ammonia volatilization, these losses were lower than those from synthetic fertilizers. In