Model-based design of optimal synergetic strategies for methane mitigation with fermentation co-benefits for ruminants

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PhD Supervisors

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Context

Ruminants play an important role in human nutrition and food security. Ruminants are able to harvest nutrients from forage diets rich in fibres and transform them into human-edible products with high-quality proteins. This transformation process occurs mainly in the rumen, thanks to the fermentation of feeds carried out by a complex microbial community (rumen microbiota) constituted by hundreds of species that include bacteria, archaea and eukaryotes. Microbial fermentation is mediated by the fate of hydrogen (H_2) within the rumen ecosystem. H_2 is as an electron carrier and energy source for the production of CH_4 by methanogenic archaea. This CH_4 contributes to the 44% of greenhouse gas emissions from the livestock sector [1].

Reducing CH_4 emissions from ruminants is a major challenge for the livestock sector to meet climate change mitigation targets agreed by the United Nations Framework Convention on Climate Change. Reduction of CH_4 production can be obtained by using feed additives exerting one of the following action mechanisms: (1) direct inhibition on the primary pathway of CH_4 production of methanogenic archaea or (2) promoting alternative pathways for H_2 redirection that result in metabolites that can be used by the animal host as energy source. Combining these two mechanisms into synergetic modulation strategies provides a promising approach to reduce CH_4 and, simultaneously, improve rumen function. The hypothesis of this project is that mathematical modelling can be useful to guide the design of optimal synergetic strategies to reduce CH_4. The objectives of the PhD project are (i) to develop mathematical models of rumen fermentation adapted to evaluate synergetic strategies for CH_4 reduction and (ii) to design optimal synergetic strategies for CH_4 reduction with fermentation co-benefits for the animal.

Methodology

The PhD fellow will extend and improve a series of mathematical models of rumen fermentation developed at MoSAR [2–4] to produce a mathematical framework with capabilities to evaluate synergetic feeding strategies under *in vitro* and *in vivo* conditions. One of the synergetic strategies to be studied is the combination of the macroalgae *Asparagopsis taxiformis* with phloroglucinol. *A. taxiformis* is a potent methane inhibitor. This anti-methanogenic power results from the action of its multiple secondary metabolites, bromoform being the most abundant anti-methanogenic halogenated compound. Pholoroglucinol is a phenolic compound that acts as electron acceptor. Phloroglucinol is degraded in the rumen resulting in the consumption of H_2 and in the production of additional short chain fatty acids (SCFA), the main source of energy for the ruminant. Model construction will exploit data from experimental studies conducted at CSIC and UMRH to evaluate the beneficial effect of synergism [5,6] and to quantify the degradation of bromoform by the rumen microbiota [7]. Next, the resulting model will be challenged and validated using data from ongoing and recently finished experiments conducted by the partners in the framework of national and international projects such as MASTER, HoloRuminant and Re-Livestock. Such studies include treatments with methane modulators such as 3-Nitrooxypropanol (3NOP), nitrate and monensin.

Finally, by using numerical optimization methods, the resulting modelling framework will be used to design optimal feed strategies with low CH_4 emissions and beneficial effects for the animal (*e.g.* high SCFA production).

The PhD project will be characterized by a full adoption of Open Science practices [8] such as bibliodiversity, Open Access, Open Data, Open Code.

Expected results

The project will contribute to a better understanding of the dynamics of the rumen ecosystem under different mitigation strategies. It will provide a mathematical framework to evaluate combination of strategies to reduce CH_4 emissions from ruminants with beneficial effects for the animal.

Objectives for promoting the doctoral student's research work: dissemination, publication and confidentiality, intellectual property rights

The work will be valorized in Open Access journals. The resulting model will be implemented using an open source interface to increase the use of the tool by the community. The PhD fellow will participate in international congress to disseminate her work.

Cotutelle program and collaboration environment

The PhD subject and the selected candidate will participate of the international doctoral Cotutelle programme (ADI) funding call of Université Paris-Saclay (France). If accepted, the PhD will be in cotutelle between Université Paris-Saclay and Universidad de Granada (Spain). The PhD will take place as follows:

1 year in the CSIC team in Granada to get knowledge on rumen fermentation using *in vitro* and *in vivo* approaches, collect existing experimental data in a common database, identify the gaps of data to build a complete database for the development of the models and run the necessary *in vitro/in vivo* tests to fill the identified gaps. The data to be collected include overall rumen fermentation pattern (gas production, volatile fatty acids, pH, ammonia), methane and hydrogen production, concentration for the main microbial groups (bacteria, protozoa, archaea and fungi).

2 years in the MoSAR team for the model developments. Frequent discussions and visits to the UMRH will be aimed at unravelling the biological relevance of the modelling results.

The PhD fellow will benefit of an interdisciplinary environment with a team of supervisors having expertise in mathematical modelling, rumen microbiology and ruminants nutrition. The three teams MoSAR, CSIC and UMRH have strong and long-term collaborations *via* the participation in national and international projects. The PhD fellow will benefit of a rich collaboration environment with networks such as Global Research Alliance, the Feed and Nutrition Network (FNN) and the Rumen Microbial Genomics Network (RMG) of which the partners are members. Milka Popova is the chair of the RMG network and David Yáñez-Ruiz is the chair of the FNN.

Conditions for carrying out the thesis (financial, technical and human resources) and professional development opportunities for the doctoral student (foreseeable professional outlets)

The PhD fellow will benefit of an interdisciplinary scientific project. The partners will provide a creative environment that will allow to the PhD fellow to build a competitive researcher profile to apply for scientific positions in the domain of applied mathematics to animal science and biology in general. The PhD fellow can furthermore capitalize her modelling skills in companies dedicated to optimize animal productivity. Financial resources for the participation of congress and publication fees will be covered with budget of ongoing projects of the partners. An ANR project focused on the study of strategies for CH_4 reduction and H_2 redirection using *in vitro* rumen fermentation systems was submitted last year and is under evaluation.

The funding to cover the personnel and lab costs in year 1 at CSIC is secured from Horizon Europe Re-Livestock project (coordinated by David Yanez-Ruiz, 2022-2027). The project has a specific task on assessing the combination of additives with potential synergistic activity (https://re-livestock.eu), which aligns with the activities included in this proposal.

Profile and skills required

The ideal candidate is driven by curiosity. She/he has excellent communication skills to integrate an interdisciplinary team. The desired skills are

- Expertise on dynamic modelling and programming
- Microbial metabolism basics
- Fluency in English
- Team player
- Good writing skills

Two types of profile are suitable for the project

(1) An engineer or mathematician with interest in microbiology
(2) A biologist (microbiologist, animal scientist) with strong interest in mathematical modelling

Non-conventional profiles are welcome.

To apply

https://adum.fr/as/ed/voirproposition.pl?site=PSaclay&matricule_prop=52598&langue=en

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