E

联合国粮食及农业组织 | Food and Agriculture Organization of the United Nations | Organisation des Nations Unies pour l'alimentation et l'agriculture | Продовольственная и сельскохозяйственная организация Объединенных Наций | Organización de las Naciones Unidas para la Alimentación y la Agricultura | منظمة الأغذية والزراعة للأمم المتحدة

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Item 6 of the Provisional Agenda

INTERGOVERNMENTAL TECHNICAL WORKING GROUP ON MICROORGANISM AND INVERTEBRATE GENETIC RESOURCES FOR FOOD AND AGRICULTURE

First Session

Rome, 25–27 September 2024

MICROORGANISMS RELEVANT TO RUMINANT DIGESTION

TABLE OF CONTENTS

I. INTRODUCTION

1. The Commission on Genetic Resources for Food and Agriculture (Commission), at its Seventeenth Regular Session, adopted its Work Plan for the Sustainable Use and Conservation of Microorganism and Invertebrate Genetic Resources for Food and Agriculture (Work Plan).[1] In line with the Work Plan, and based on the findings of a draft study,[2] the Commission addressed microorganisms of relevance to ruminant digestion at its last session.

2. The Commission welcomed the draft study and recommended that it be finalized, emphasizing the research gaps that need to be filled, and then published and disseminated as a background study paper.[3] It further recommended that FAO take the findings of the study into consideration in its work relevant to the conservation and sustainable use of microorganisms of relevance to ruminant digestion, as appropriate.[4] The study was subsequently published as Background Study Paper No. 75.[5]

3. The Commission invited Members to promote the conservation and sustainable use of microorganisms of relevance to ruminant digestion and ensure they are given due consideration in local, national and regional policies and policy-development processes. It recommended that FAO monitor policy-related developments in this field and report on them to the Commission. It also invited Members to manage and conserve the genetic diversity contained in local breeds, feeds and rumen microbes in an integrated manner at the national level.[6]

4. The Commission further encouraged relevant stakeholders, including scientific institutions, to collaborate on the conservation and sustainable use of microorganisms of relevance to ruminant digestion, especially on capacity development in developing countries and countries with economies in transition.[7]

5. It invited Members and stakeholders to intensify research on rumen microbiome management, in particular in relation to ruminant classification, breeding and husbandry, production efficiency, disease resistance and resilience to changing environmental conditions as well as on the potential effects of relevant microorganisms on animal and human health, but also on feed innovations for climate mitigation. It also noted the need for further study of the local diversity of rumen microorganisms.[8]

6. The Commission requested the Intergovernmental Technical Working Group on Microorganism and Invertebrate Genetic Resources for Food and Agriculture (Working Group), at its first session, to draft specific recommendations on microorganisms of relevance to ruminant digestion for consideration by the Commission.[9]

7. Drawing on previous work carried out for the Commission,[10] this document briefly summarizes the status and trends of conservation, use and access and benefit-sharing, maps regional and international organizations and other institutions most pertinent to microorganisms relevant to ruminant digestion and provides an analysis of gaps and needs in this area.

---

[1] CGRFA-17/19/Report, *Appendix E*.
[2] CGRFA-19/23/9.2/Inf.1.
[3] CGRFA-19/23/Report, paragraph 79.
[4] CGRFA-19/23/Report, paragraph 80.
[5] Huws, S.A., Oyama, L.B. & Creevey, C.J. 2024. *Sustainable use and conservation of microorganisms of relevance to ruminant digestion*. Background Study Paper No. 75. Commission on Genetic Resources for Food and Agriculture. Rome, FAO. https://doi.org/10.4060/cd0155en
[6] CGRFA-19/23/Report, paragraph 81.
[7] CGRFA-19/23/Report, paragraph 82.
[8] CGRFA-19/23/Report, paragraph 83.
[9] CGRFA-19/23/Report, paragraph 84.
[10] Huws, S.A., Oyama, L.B. & Creevey, C.J. 2024. *Sustainable use and conservation of microorganisms of relevance to ruminant digestion*. Background Study Paper No. 75. Commission on Genetic Resources for Food and Agriculture. Rome, FAO. https://doi.org/10.4060/cd0155en; McSweeney, C. & Mackie, R. 2012. *Micro-organisms and ruminant digestion: state of knowledge, trends and future prospects*. Background Study Paper No. 61. Commission on Genetic Resources for Food and Agriculture. Rome. FAO. https://www.fao.org/4/me992e/me992e.pdf.

II. BACKGROUND

8. Ruminant livestock production is highly relevant to two of the most important challenges facing the world: improving the food security and nutrition of a growing world population and mitigating climate change. The microorganisms that live in the rumen – the main compartment of the fore-stomach of ruminant animals – are key both to ruminants' digestive capacities and to their role as emitters of methane.

9. The characteristics of the rumen microbiome (the assemblage or community of microorganisms within the rumen) affect both the supply of nutrients to the animal and the amount of methane produced as feed is digested. This raises the possibility that manipulating the rumen biome could be a means both of improving animal nutrition and of reducing methane emissions.

III. OVERVIEW, STATUS AND TRENDS

10. The rumen is a complex, dynamic ecosystem composed of anaerobic bacteria, protozoa, anaerobic fungi, methanogenic archaea and bacteriophages. While technological advances in recent years have allowed considerable advances in rumen microbiology to be made, the taxonomy and functions of these organisms remain poorly understood overall.

11. Analysis of rumen microbiomes from different host species and different parts of the world has revealed that they are dominated by a core community of microorganisms. Variations are driven primarily by host diet, but they are also influenced by the species, breed and individual genetics of the host. The presence of geographically specific minor groups of rumen organisms is probably linked to climate-related variations in the plant material consumed or to the presence of locally adapted breeds of ruminants. It is likely that the microorganisms in such "minor" groups play important roles in allowing their hosts to cope with local environmental conditions, and represent pools of genetic diversity that need to be maintained and might be further exploited.

12. Trends towards the industrialization and homogenization of animal management practices globally mean that the risk of losing the localized diversity of rumen microorganisms is high. For instance, diet supplementation with easily digestible carbohydrates, as is common in more industrialized systems, has been observed to be associated with a simplification of the rumen microbial community, resulting in lower bacterial diversity and lower concentrations of fibrolytic microbes. Similarly, increased feed efficiency in ruminants (a key goal in ruminant agriculture given the need to sustainably feed a growing world population) has been linked to a reduction in the diversity of the rumen microbiome. Strategies involving the use of feed additives to reduce methane production from ruminants have been linked to alterations in ruminant microbiomes that may drive their further homogenization globally.

IV. CHARACTERIZATION AND CONSERVATION

13. The trends described above highlight the need to capture and catalogue communities of rumen microorganisms. There have been major steps forward in this regard, such as the Hungate Collection,[11] a flagship project for the Global Research Alliance on Agricultural Greenhouse Gases (GRA), which provided 501 rumen bacterial and archaeal genomes. However, many rumen microbial genomes remain unavailable.

14. Recent technological advances have been useful in terms of correlating the rumen microbiome to the host phenotype. However, they have not resulted in major progress in terms of confirming the functions of particular microorganisms. This would require an enhanced catalogue of pure rumen microbial cultures.

15. Openly accessible culture collections, such as those of the Leibniz Institute DSMZ-German Collection of Microorganisms and Cell Cultures[12] in Germany and the American Type Culture

[11] https://genome.jgi.doe.gov/portal/HungateCollection/HungateCollection.info.html
[12] https://www.dsmz.de/

Collection[13] in the United States of America, are pivotal to the maintenance of global microbial genetic diversity and in ensuring open access for stakeholders. However, many isolates are not deposited in culture collections, as there is no legal obligation to do so. Concerns about intellectual property mean that many microbes that have potential commercial use remain in individual storage facilities even after patenting and publication.

16. There is a general lack of knowledge of rumen microorganisms associated with particular local areas, and very few of them are in culture.

V. SUSTAINABLE USE

17. As noted above, effective management of the rumen microbiome can contribute to the mitigation of methane emissions from ruminant production systems. Changing the host animal's diet is the easiest way to bring about an immediate change in the rumen microbiome and the amount of methane produced. Potential interventions include those that decrease emissions per unit of product and those that lead to absolute decreases in emissions. The former include increasing feeding levels, reducing the maturity and increasing the digestibility of the forage fed, and decreasing the ratio of forage to concentrate in the diet. The latter include supplementing the diet with methane inhibitors (e.g. 3-nitrooxypropanol [3-NOP, commercially known as Bovaer®], which inhibits the last step in rumen methanogenesis), tanniferous forages, electron sinks (chemicals or microbes that utilize hydrogen so that there is less available for methanogenesis), oils and fats, or oilseeds. While promising results have been obtained, the mechanisms through which many dietary approaches operate remain unclear.

18. The host genome has been shown to influence the rumen microbiome, and recent global data show the potential to breed ruminants with decreased methane emissions. Such an approach can potentially reduce methane emissions by up to 30 percent based on daily methane emissions (g/day), methane yield (g/kg of dry matter intake) and methane intensity (g/kg or litre of product produced), Again, further work is needed to confirm the potential of such approaches and to clarify the mechanisms underlying the effects observed.

19. In addition to its significance to climate change mitigation, the rumen microbiome (and the microbiome of the ruminant gastrointestinal tract more generally) is also significant to efforts to implement the "One Health" approach.[14] Rumen bacteria have antimicrobial resistance genes that can easily transfer to other bacteria. The rumen is also a source of novel bioactive compounds that can potentially be used to enhance human, animal and environmental health.

20. For many years antibiotics were used as growth promoters in animal feeds because of the benefits they can provide in terms of animal health and feed efficiency. With the banning of use of antibiotics as prophylactics and growth promotors in many countries, alternative approaches have risen to prominence, including the use of direct-fed microbials (sources of live naturally existing microorganisms). While the use of this approach in ruminants is still under development, it has been linked with improvements in the health of young animals, increased milk production and enhanced growth, suggesting that it may be a viable alternative to the use of antimicrobials.

VI. POLICY, LEGAL AND INSTITUTIONAL FRAMEWORKS

21. Policy and legal frameworks of relevance to the management of rumen microorganisms include those related to climate change, those related to the conservation, use and exchange of

[13] https://www.atcc.org/

[14] "One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent." One Health High-Level Expert Panel (OHHLEP), Adisasmito, W.B., Almuhairi, S., Behravesh, C.B., Bilivogui, P., Bukachi, S.A. *et al*. 2022. One Health: A new definition for a sustainable and healthy future. *PLoS Pathogens*, 18(6): e1010537. https://doi.org/10.1371/journal.ppat.1010537

biodiversity for food and agriculture, those related to food and feed safety, and those related to marketing.

22. Climate-related policies are increasingly influencing the availability of funding for work on rumen microorganisms, with many funders prioritizing efforts to optimize the rumen microbiome to achieve reductions in methane emissions. However, regulatory frameworks can act as a barrier to the adoption of such technologies because of the time required to obtain approval for their release. Labelling of products as having been produced with reduced methane emissions is often a grey area in regulatory terms. Where consumers are unable or unwilling to bear the costs of such innovations via increased market prices, there may be a need for governmental intervention to support them or make their introduction mandatory. The cost implications of policies for the approval and use of feed additives may be a deterrent in some countries. Strategies such as promoting the use of legumes and tanniferous forages as animal feed may be less costly alternatives but have less impact on emissions.

23. The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity (Nagoya Protocol) has increased the level of bureaucracy involved in the exchange of ruminant microorganisms and this has raised concerns among those involved in their use and conservation globally.

24. Most funding agencies and journals have an open-access policy that ensures that when articles are submitted for review, all the data on which they are based must have been made publicly available. However, publications involving research on novel microbial isolates do not have to ensure open access to the isolate through deposition in a culture collection before publication. This means that open-access sharing of isolates for continued research and societal benefits is limited. This is a major challenge, and changes are needed. However, it also needs to be noted that such changes will require enhanced infrastructure for existing culture collections to enable the organizations responsible for them to maintain and make available the increased number of isolates.

25. Key institutions and networks related to the conservation and sustainable use of microorganisms of relevance to ruminant digestion include the culture collections discussed in Section IV, the GRA (also discussed in Section IV), the GRA's Livestock Research Group and Rumen Microbial Genomics Network, and a number of universities and research institutes around the world that have major capacity to isolate and maintain ruminant microbes and have their own collections. The private sector probably also holds collections, but details of these are not publicly available. In addition to the GRA projects mentioned above, a number of other major projects promote stakeholder collaboration internationally, including the EU Horizon 2020 projects MASTER (Microbiome Applications for Sustainable food systems through Technologies and EnteRprise) [15] and Holoruminant.[16] Some stakeholders from developing countries report that a lack of funding is a constraint to their participation in collaborative activities.

VII. GAPS, NEEDS AND POSSIBLE ACTIONS

26. Based on Background Study Paper No. 75, the following gaps and needs can be identified.

- *Research*. Much still needs to be done to improve knowledge of the rumen microbiome and its functions. Priorities include improving techniques for culturing rumen microorganisms and exploring the potential for using isolates as direct-fed microbials to reduce methane emissions.
- *Culture collections*. There is a need for journals to insist that microorganisms used in the research they publish are deposited in open-access culture collections. The capacity of culture collections needs to be improved, so that they can accommodate the additional deposits.
- *Policy frameworks*. Relevant policies, legislation and institutional arrangements, including those related to access and benefit-sharing and to intellectual property, need to be reviewed, and where necessary, updated, with a view to ensuring an appropriate enabling framework for research and collaboration on rumen microorganisms and their

[15] https://www.master-h2020.eu/
[16] https://holoruminant.eu/

management. There is also a need to put in place policies that will promote the uptake of innovations emanating from research in this field that can help reduce methane emissions.

27. Similarly, the following potential actions can be identified:

- establishing a global expert group to work on the prioritization of activities related to the management of microorganisms of relevance to ruminant digestion and on the identification of threats to the sustainable use and conservation of these organisms;
- ensuring adequate resourcing for global research initiatives related to the culture, cataloguing, characterization and management of rumen microorganisms;
- promoting policies that ensure that all pure culture microbial isolates are deposited in open-access culture collections prior to the publication of any data related to the respective organism(s);
- enhancing the capacity of the organizations managing publicly accessible culture collections so that they are able to deal with the increased demand that a policy requiring isolate deposition would bring;
- promoting the funding of research on the management of the rumen microbiome, particularly with respect to ruminant breeding and dietary innovations;
- promoting policy and legal innovations that facilitate the exchange of rumen microbial samples globally; and
- providing stimulus to encourage global collaboration, especially collaboration involving low- and middle-income countries.

VIII. GUIDANCE SOUGHT

28. The Working Group may wish to make recommendations to the Commission as to whether:

(i) existing global institutional frameworks addressing the sustainable use and conservation of microorganisms of relevance to ruminant digestion – including with regard to the priority setting and with regard to the promotion of global collaboration – should be strengthened and improved;

(ii) existing legal and policy frameworks related to the approval of methane inhibitors and those related to the exchange of rumen microbial samples should be improved to facilitate their approval and exchange;

(iii) FAO should support countries in the establishment or strengthening of national policies, legal and institutional frameworks related to the management of rumen microorganisms;

(iv) resourcing of global research initiatives related to the culture, cataloguing, characterization and management of rumen microorganisms should be improved; and

(v) incentives should be created to encourage the deposition of rumen microbial isolates in open-access culture collections and increase the capacity of such collections to deal with increased demand.