Global Methane Hub

ENTERIC FERMENTATION
R&D ACCELERATOR

STATE OF SCIENCE

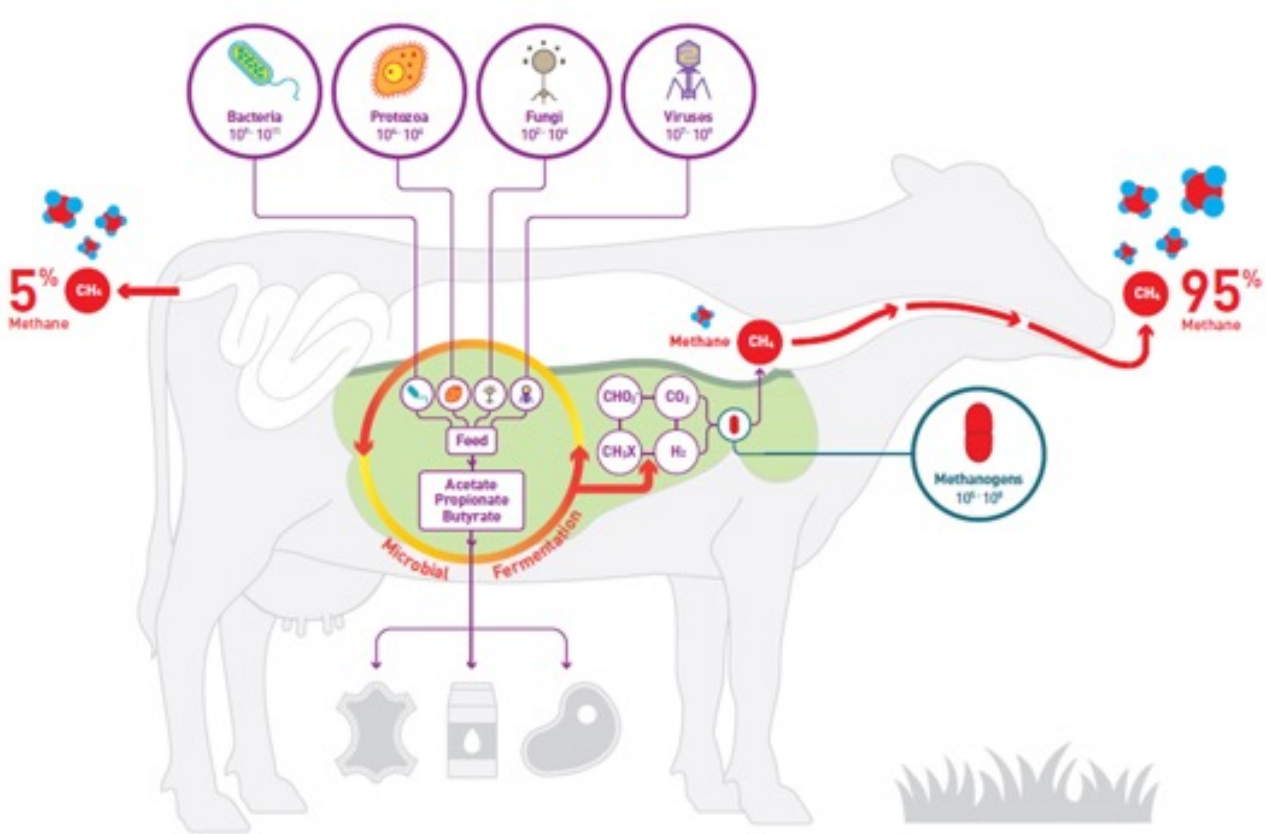
Rumen microbiology

Prepared By: Sinead Leahy

The Rumen and its Micro-organisms

The micro-organisms (bacteria, archaea, fungi, protozoa, and viruses) that live in the forestomach (reticulorumen or rumen) of ruminant animals have a major influence on feed digestion and the release of end-products into the environment. Ruminants are unable to produce the enzymes required to use the lignocellulose component of plant material as an energy source. This metabolic role is instead fulfilled by the rich and dense set of anaerobic microbes that inhabit the rumen (Figure 1). Ruminants and their microbial communities have evolved to thrive on a range of plant species, and this has enabled them to occupy many different habitats, spanning a wide range of climates. However, a global rumen census of rumen microbial communities found similar communities present in ruminants across the globe (https://www.nature.com/articles/srep14567).

Figure 1. Rumen microbial fermentation

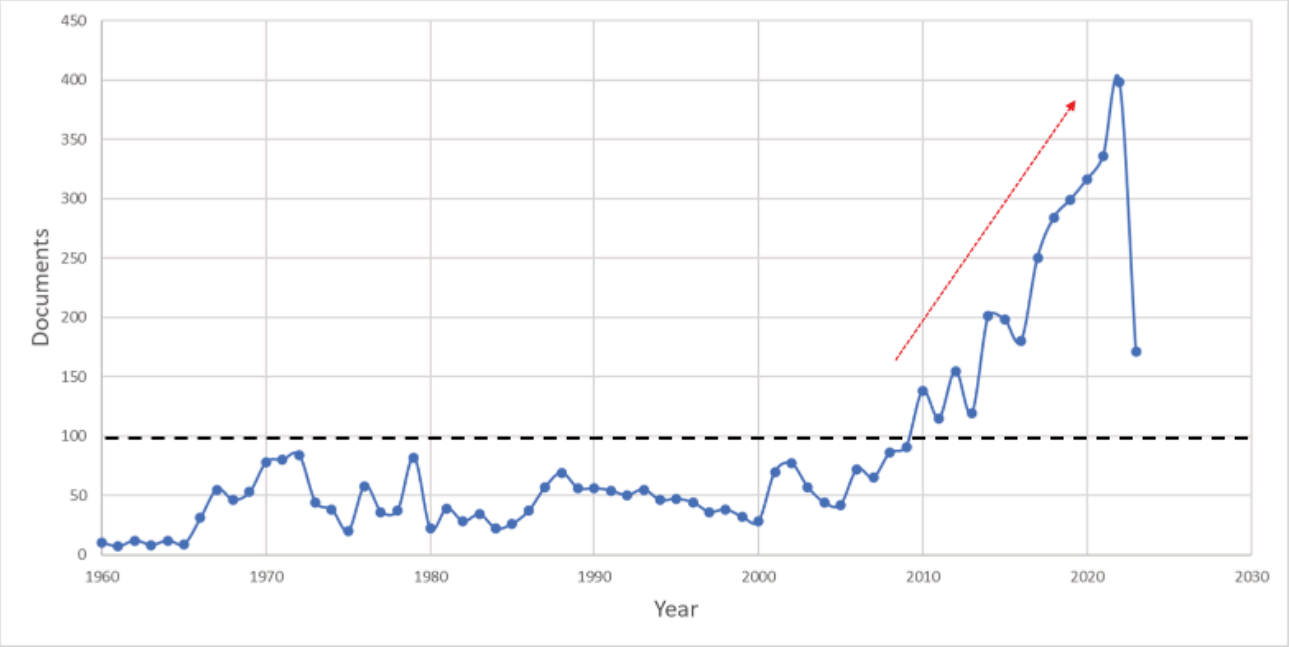


Bacteria, fungi, and protozoa all contribute to the microbial degradation of lignocellulose and other plant polymers. Fermentation of the released soluble sugars produces short-chain fatty acids (acetate, propionate, and butyrate) that are absorbed across the rumen epithelium and used by the ruminant as a source of energy. Microbial cells pass from the rumen to the lower digestive tract where they become the main source of protein and amino acids for the animal. Other fermentation end-products, including hydrogen, carbon dioxide, formate, and methyl-containing compounds, are important substrates for the methane-forming archaea (methanogens). The viruses infect the other microbial groups in the rumen, probably influencing their population balances and hence the structure of the rumen community.

Literature perspective

A search of the literature related to rumen microbiology published between 1960 and 2023 (Scopus keywords: Rumen AND Microbiology OR Microbiota) revealed 5,460 documents (Figure 2). Between 1960 and 2009, the number of documents remained below 100, since 2010 there has been a steady increase in the number of documents available reflecting the increased awareness of the environmental impact of ruminants and the emergence of omic technologies which

Figure 1. Number of documents available identified via Scopus (14th July 2023)



have formed the content for a significant number of publications since the early 2000s. The most cited paper identified through this search was the 1995 paper by Johnson and Johnson titled "Methane emissions from cattle". An analysis of the top 10 most significantly cited articles (number of years since publication/citation count) revealed three key themes of documents, reviews of rumen microbiology and methane emissions, publications related to the microbial degradation of complex carbohydrates and studies looking to characterise the microbiome community of ruminants.

Some current global efforts in rumen microbiology

Funded by Global Methane Hub – Global Research Alliance Flagship: Rumen Gateway

Led by Prof Sharon Huws, Queen's University Belfast. The project has recruited 13 'culture hubs' across the globe, with a key focus on culturing rumen micro-organisms to support increased understanding of rumen microbial function, mechanistic understanding of the action of feed interventions to mitigate methane, provision of potential direct-fed microbials to re-direct hydrogen away from methanogenesis, and microbial resource availability for bioactive compound discovery.

Greener Cattle Initiative

An international research study on how diets and different additives affect hydrogen production and utilization in the rumen of both beef and dairy cattle and how these changes in hydrogen dynamics affect the amount of enteric methane produced.

New Zealand-Ireland (2023-2027). RU_Mining

RUmen microbiome MINING for bacterial cultures to reduce methane. This involves AgResearch and Teagasc rumen microbiology teams through the DAFM IE-NZ Joint Call 2022. The project has a focus on trying to fundamentally understand the key rumen microbes who contribute to methane emissions in ruminants.

Holoruminant (2021-2025)

Understanding microbiomes of the ruminant holobiont. Horizon 2020. Multiple European research teams whose focus is to undertake a multi-omics approach to analyse the microbiome and the host, as well as the impact of their interaction at key stages during ruminant life. The goal of the project is to characterise and identify ruminant-associated microbiomes associated with improved production efficiency, health, and welfare.

Priority research needs with respect to methane

Two recent publications have looked at this

Huws et al, 2023 (https://www.fao.org/3/cc6629en/cc6629en.pdf) draft report identified a key gap area being in the culturing and conservation of rumen microbes.

Leahy et al., 2022 (https://www.sciencedirect.com/science/article/pii/S0966842X21002985) tried to identify through the engagement of a small expert team some of the key advancements needed in rumen microbiology to advance methane mitigation technology development. The group felt there were three main areas that advancement was needed (1) develop new tools, methodologies, and experimental designs to provide better quantitative measurement of fluxes of key ruminal intermediates and associated microbes and use these data to develop a detailed mechanistic understanding of the key steps in ruminal microbial processes (2) develop small-scale synthetic rumen microbial communities that can be used to study rumen microbial mechanisms under controlled experimental conditions. And (3) renewed effort focused on the isolation, microbiology, physiology, and biochemistry of key microbial species.

Key messages from this activity

Currently. there is no consistent evidence for increased production with current methane mitigation approaches. Making a breakthrough in fundamental understanding of rumen microbial processes will be needed if production co-benefits from enteric methane mitigation strategies are to be achieved. Co-benefits will be key to driving uptake on the farm.

An extensive array of enteric methane mitigation strategies has already been explored by the global scientific community. If novel mitigations are to be discovered, then they will need to emerge from a non-obvious basis. New advances in fundamental knowledge will be required to stimulate new ideas.

Rumen Microbiology Global Resources

The Global Research Alliance Rumen Microbial Genomics network is a voluntary network of the key rumen microbial groups globally or scientists with an interest in rumen microbiology.