

Understanding the rumen microflora to enhance nutrient utilisation and reduce methane emissions in beef and dairy cattle

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Summary

- Internationally, agriculture is faced with the major challenge of feeding a rapidly increasing human population, while adhering to strict environmental legislation.
- In cattle, the complex population of micro-organisms that inhabit the animals' 'rumen' or forestomach influences the efficiency with which feed is utilised as well as the quality of both meat and milk.
- Feed efficient animals have lower daily methane emissions. A core group of 'methanogens', or methane emitting micro-organisms, exists in the rumen of cattle regardless of feed efficiency potential. However, there are specific differences evident at both a species and genotype level between feed efficient and inefficient cattle.

Challenges facing the agri-food industry

The Food Harvest 2020 report has set ambitious growth targets for the Irish beef and dairy industries, with increases in output value of 40% and 50%, respectively, by 2020. However, currently in Ireland, agriculture accounts for a higher proportion of national greenhouse gas emissions than any other EU country. Methane emissions resulting from fermentation in the rumen of cows and sheep are responsible for approximately 50% of this. Consequently, if projected increases in beef and milk output are to be met in an economically and environmentally sustainable manner, major improvements in the efficiency of these production systems at farm level are necessary.

Nutrient digestion and utilisation is enhanced by the rumen microbiome

The microbes in the rumen, or forestomach, play a central role in aiding the animal to effectively digest fibrous material like forages in a process called fermentation. The volatile fatty acids generated through this process can contribute up to 70% of the energy requirements of the animal. The rumen 'microbiome' is a complex and dynamic ecosystem of thousands of species of microbes. Consequently, a deeper understanding of the rumen microbiome will facilitate development of new strategies to manipulate rumen fermentation and improve nutrient utilisation. Recent advances in DNA technology now allow us to analyse the rumen microbiome in much greater depth than was previously possible. Using this technology, we and other researchers have been studying the extent to which the rumen microbiome influences the efficiency of feed utilisation by cattle.

Rumen methanogenesis, feed efficiency and the rumen microbiome

Despite being central to the ability of cattle to digest forages and other fibre containing materials, fermentation by the rumen microbiome is accompanied by the production of methane, a potent greenhouse gas. Methane is produced by methanogenic archaea (bacteria-like micro-organisms) which convert the hydrogen produced by ruminal

fermentation into methane. Although this process helps maintain rumen pH (i.e. avoiding acidosis) by preventing accumulation of hydrogen ions in the rumen, it also results in high methane emissions from cattle production. In addition, methane production in the rumen is an energetically wasteful process, accounting for up to 15% of dietary gross energy.

Feed accounts for up to 80% of the direct costs in beef cattle production. Therefore, improving the efficiency of utilisation of ingested feed by cattle is central to economic sustainability. The objective of Irish beef production systems is to maximise the utilisation of forage-based diets to reduce reliance on expensive purchased feedstuffs. Recently, residual feed intake (RFI) has become the measure of choice for feed efficiency in beef cattle. Feed efficient animals are those that consume less feed than their contemporaries of similar body weight and growth performance. There is some emerging evidence to suggest that feed efficient cattle may emit less methane, though the biological mechanisms involved are not fully understood. A study at Teagasc Grange was conducted to examine the relationship between phenotypic RFI and methane emissions in beef heifers. Simmental heifers were offered a grass silage diet over 120 days and methane production was measured. Heifers were ranked on the basis of RFI and divided into low (efficient), medium or high (inefficient) groupings. Mean live weight (485 kg) and daily live-weight gain (0.6 kg) did not differ between the groupings; but high RFI heifers (inefficient) consumed 9% and 14% more than medium and low RFI heifers (efficient), respectively. Similarly, daily methane emissions were lower for low RFI than for high RFI heifers (Figure 1).

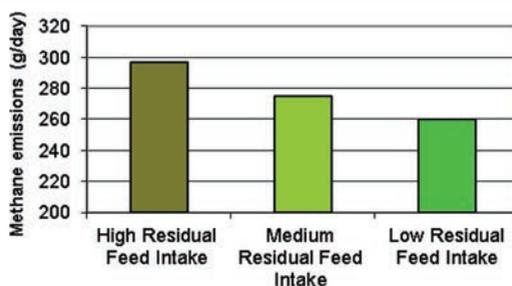


Figure 1 — Methane emissions (g/d) of heifers differing in Residual Feed Intake offered grass silage.

In a further experiment at Teagasc Grange, we examined the composition of the ruminal microbial population in low RFI and high RFI heifers and how this was affected by whether a forage-based or a concentrate-based diet was offered. Rumen digesta samples were collected sequentially from high RFI and low RFI animals fed both the forage and concentrate diets and analysed using a range of DNA sequencing technologies. We found that *Methanobrevibacter* spp. was dominant amongst methanogens in the rumen, with *Methanobrevibacter smithii* the most abundant species detected. Although the abundance of either total or specific methanogenic species did not differ between animals divergent in RFI, their relative abundance was affected by diet type. At the genotype level, however, we found that various genotypes of *Methanobrevibacter smithii* were more abundant in cattle of high compared to low RFI across diet. It is possible that these differences in genotype abundance may drive the observable changes in methane emissions between animals of high and low RFI.

Conclusions and implications

Our studies conducted to-date suggest that variation in the ruminal fermentation process affects the animal's ability to efficiently utilise feed and that this is mediated to some extent through the composition and activity of the ruminal microbiome. We will also examine interactions between, and the functional capacity of, these microbes. Such an approach will better facilitate the development of strategies focused on improving feed efficiency and methane abatement without compromising animal performance. This will ultimately give beef and dairy producers a competitive advantage by reducing the environmental footprint of Irish agriculture.