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Popular Article

Methanogenesis and manipulation of ruminal fermentation by physical means

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Abstract

Rumen is complex ecosystem of ruminant animal in which feed components first undergo fermentative digestion by microorganisms and then glandular digestion by the host. During fermentation the feed components i.e., carbohydrates, nitrogenous substances and lipids converted into volatile fatty acids (mainly acetic, propionic and butyric acids), carbon dioxide, methane and ammonia. Methane, a colorless, odorless gas, is produced predominantly in the rumen (87%) and to a small extent (13%) in the large intestines. Rumen methane is primarily emitted from the animal by eructation. In order to compare emissions of greenhouse gases GHG, the global warming potential (GWP) of the individual gases is used, with CO_2 as the reference gas. The GWP of methane is known to be 21-fold greater than that of CO_2 and the GWP of N_2O is 310-times greater than that of CO_2. However, since methane has no nutritional value to the animal, its production represents a loss of dietary energy to the animal. In general, methane production in cattle constitutes about 2–12% of dietary GEI (Gross Energy Intake). Reduction in methane production can result from a decreased extent of fermentation in the rumen or from a shift in the VFA pattern towards more propionate and less acetate. Hence, several rumen manipulation strategies have been used to reduce methane emission. Physical manipulation is one of the methane reduction strategies which included in this article.

Keyword: Greenhouse gases, methane, rumen manipulation, physical means

Introduction

Ruminant animals have two distinct metabolic systems with unique nutritional needs: microbial metabolism in the rumen and mammalian metabolism in the tissues. Enhancing ruminant productivity requires balancing the requirements of both systems adequately. In ruminants, feed undergoes fermentative digestion by microorganisms in the rumen before being further digested by the host. Various feed components like carbohydrates, nitrogenous substances, and lipids are degraded by the microbial population to different extents. The resulting end-products include volatile fatty acids (VFAs), carbon dioxide, methane, and ammonia (Owens and Basalan, 2016). Due to the anaerobic conditions in the rumen, ATP availability is limited, leading to most substrate energy being retained in the end-products of fermentation. Methane, an odorless and colorless gas, is primarily generated in the rumen (87%) and to a lesser extent in the large intestines (13%), mainly expelled by the animal through eructation. When assessing greenhouse gas (GHG) emissions, methane's global warming potential (GWP) is 21 times higher than that of CO2, and N2O's GWP is 310 times higher (Zhang *et al.*, 2016). However, methane production doesn't contribute to the animal's nutritional needs, representing a loss of dietary energy. In cattle, methane production typically ranges from 2% to 12% of the dietary gross energy intake (GEI). Reductions in methane production can occur by decreasing rumen fermentation or shifting the volatile fatty acid pattern towards more propionate and less acetate.

The ultimate goals of manipulating ruminal fermentation are to optimize feed utilization efficiency and enhance ruminant productivity. In simpler terms, the objectives of ruminal manipulation are to:

- Enhance beneficial processes;
- Minimize, alter or delete inefficient processes;
- Minimize, alter or delete processes harmful to the host.

The manipulation of rumen fermentation can be done in following nutrients:

I. Manipulation of carbohydrate fermentation
II. Manipulation of nitrogen fermentation
III. Manipulation of lipid fermentation

I) Manipulation of carbohydrate fermentation

Cellulose and hemicellulose constitute 15-70% of most ruminant diets. They are insoluble, structurally complex, and not completely physically accessible, the extent of their fermentation in the rumen is very less. Increasing fiber or starch fermentation will result in increased VFA production in the rumen. As end-products of microbial metabolism. So, the goal is to increase rate and extent of structural carbohydrate fermentation in the rumen to maximize nutrient intake and availability (Firkins, 2021). This can be done by the following methods:

1) Processing of roughages:

The core concept is that processing changes the physical and chemical properties of cellulose and hemicellulose in feedstuffs, making them more easily degraded by rumen microbes. This alteration results in a higher propionate to acetate ratio in the rumen (Owens and Basalan, 2016).

2) Chopping of roughages

Moreover, chopping roughages into smaller pieces reduces the degree of degradation needed in the rumen.

3) Pelleting

The voluntary consumption of pelleted forages is higher as the retention time is lesser, so efficiency of the animal increases with increase in propionate content. (Salinas-Chavira *et al.*, 2013)

4) Ammonia/ urea treatment of roughages

It breaks the lignocellulosic bonds of the roughage; hence the fermentation process is easier. pH is also stable, and it favours the production of propionate over acetate (Ma *et al.*, 2020)

5) Level of feeding

With increased DMI over maintenance, the production of propionate is favoured. For animals with a high production level, forages must be supplemented with concentrates with a higher density of nutrients and less fibre. Due to less proportion of cell walls and more non-structural (readily fermentable carbohydrates like starch and sugar), concentrates favour propionic acid production, helping the animal to cater its energy needs for high productivity.

6) Type of concentrates

The fermentation process of carbohydrates influences the composition of volatile fatty acids (VFAs) produced and, consequently, the amount of methane generated. Fermenting cell wall carbohydrates results in higher methane production than fermenting soluble sugars, which, in turn, produce more methane than fermenting starch. Diets rich in starch that promote propionate production can reduce methane emissions per unit of fermentable organic matter in the rumen (Tamminga *et al.*, 2007).

7) Increasing frequency of feeding

Reducing meal frequencies in dairy cows has been shown to increase propionate production, decrease acetic acid levels, and consequently lower methane emissions. This effect is associated with a decrease in methanogens due to the heightened diurnal fluctuations in ruminal pH caused by infrequent feeding.

8) Replacing grass silage with maize:

Grass silage, typically harvested later in maturity, contains lower levels of digestible organic matter, reduced sugars, nitrogen, and some lactate due to the ensiling process (Tamminga *et al.*, 2007). On the contrary, maize silage or other whole-crop small-grain silage offers higher dry matter content rich in easily degradable carbohydrates like starch and sugar, which enhances both dry matter intake (DMI) and animal performance [Beauchemin et al., 2007] and upon fermentation promote propionate production over acetate.

II) Manipulation of nitrogen fermentation:

The logical strategy for manipulating nitrogen metabolism in the rumen is to enhance ruminal escape of dietary protein by minimizing its degradation and optimizing microbial protein production from NPN (Ipharraguerre, 2004). This can be done by providing NPN sources to ruminants, so that the loss of N in the formation of microbial protein can be covered from urea, instead of the dietary protein. By subjecting proteins to specific chemical treatments, their solubility can be altered, providing an advantage in preserving high-quality proteins from rumen degradation. Formaldehyde has been extensively used in the production of bypass protein feed. Similarly, heating protein sources to withstand rumen pH (around 6.5) is a common method to prevent loss to microbial protein synthesis. Typically, crude protein from protein meals has a rumen degradability ranging from 50-75%, However, treating these protein meals with suitable chemicals to lower rumen degradability to 25-30% could increase the net availability of amino acids for milk synthesis (Schwab, 1995)

III) Manipulation of lipid fermentation

In the rumen, the unesterified fatty acids are adsorbed onto the particulate matter, either feed particles or microbial cells, and are not degraded further because the anaerobic conditions in the rumen are unfavorable for oxidation of fatty acids (Naik, 2013). They may be incorporated into microbial lipids. The unsaturated fatty acids are hydrogenated in the rumen primarily by bacteria and ciliated protozoa. Manipulation of ruminal lipid metabolism can be done to control of antimicrobial effects of fatty acids to minimize disruption of ruminal fermentation and control of biohydrogenation to alter the absorption of selected fatty acids that may improve nutritional qualities of animal food products. The manipulation of biohydrogenation and loss of lipids to microbial lipid synthesis can be done by providing bypass fat to the animal.

Bypass fats can be prilled fats, or prepared by heating oils to a temperature that they get solidified and become undegradable at rumen pH. Calcium salts of fatty acids are also used as bypass fats as they are only disintegrated at acidic pH, i.e, the abomasum. In the abomasum at acidic pH, it dissociates and set free fatty acids and calcium for absorption (Naik, 2013). Feeding bypass fat to early lactating animals increases milk and fat yield and ensures early conception. The recommended practice is to include bypass fat in the diet of dairy animals for 10 days prior to calving and for 90 days post-calving. This fat can be added to the ration at a rate of 15-20 g per kg of milk production or 100-150 g per animal per day (Singh and Babu, 2021). Importantly, bypass fat supplementation does not interfere with fiber digestion and consistently proves more beneficial compared to feeding ghee or oil.

Conclusion

Various physical strategies can be used to manipulate rumen function, increase the level and efficiency of animal performance, and minimize methane production and its adverse effects animal health and the environment.

References

Beauchemin, K.A., Kreuzer, M., O'mara, F. and McAllister, T.A. 2008. Nutritional management for enteric methane abatement: a review. Australian Journal of Experimental Agriculture, 48: 21-27.

Firkins, J.L. 2021. Invited Review: Advances in rumen efficiency. Applied Animal Science, 37: 388-403.

Ipharraguerre, I.R. 2004. Nutritional strategies for optimizing nitrogen utilization by dairy cows. University of Illinois at Urbana-Champaign.

Ma, Y., Chen, X., Zahoor Khan, M., Xiao, J., Liu, S., Wang, J., He, Z., Li, C. and Cao, Z. 2020. The impact of ammoniation treatment on the chemical composition and in vitro digestibility of rice straw in Chinese Holsteins. Animals, 10: 854.

Naik, P.K. 2013. Bypass fat in dairy ration-a review. Animal nutrition and feed technology, 13: 147-163.

Owens, F.N. and Basalan, M., 2016. Ruminal fermentation. Rumenology, 63-102.

Salinas-Chavira, J., Alvarez, E., Montaño, M.F. and Zinn, R.A. 2013. Influence of forage NDF level, source and pelletizing on growth performance, dietary energetics, and characteristics of digestive function for feedlot cattle. Animal feed science and technology, 183: 106-115.

Schwab, C.G. 1995. Protected proteins and amino acids for ruminants. Biotechnology in animal feeds and animal feeding, 141.

Singh, S. and Babu, A.S. 2021. Effects of Bypass Fat and Prilled Fat Supplementation on Nutrition and Performance in Milch Animals: A Review.

Tamminga, S., Bannink, A., Dijkstra, J. and Zom, R.L.G. 2007. Feeding strategies to reduce methane loss in cattle (No. 34). Animal Sciences Group.

Zhang, X., Xu, X., Liu, Y., Wang, J. and Xiong, Z. 2016. Global warming potential and greenhouse gas intensity in rice agriculture driven by high yields and nitrogen use efficiency. Biogeosciences, 13: 2701-2714.