Nutritional Strategies to Reduce Methane Emission in Ruminants

A. Swain, K. Sethy*, A. K. Das and S. L. Kolhe, P. N. Badnayak
Department of Animal Nutrition, C.V.Sc and AH, Odisha University of Agriculture and Technology, Bhubaneswar, 751003, Odisha
DOI:10.5281/Vettoday.15538513

Introduction

Methane production by ruminants can reach 250 to 500 liters each day. As a result of this much production, cattle are thought to make a significant contribution to global warming. Many conditions can lead to this methane emission from farm cattle. The amount and kind of carbohydrates and processing of feed helps to bring down methane production in cattle. Ruminal action of microorganism's causes feed to release acetate, propionate, butyrate, methane and carbon dioxide. These VFAs are used by the animal for energy and the gases discharged through eructation process. All of these gases are formed in the rumen by a process known as methanogenesis. Apart from hurting the environment, it results in the loss of 2-15% of the animal's gross energy. An option to modify this procedure includes removing protozoa, administration of antibiotics (monensin and bacteriocins), using different sources of lipids, organic acids, gases and ionophores. According to experts concerned with global warming, methane is the main greenhouse gas as it offers a global potential 23 times greater than carbon dioxide and contributes to 16% of all global emission of greenhouse gases.

Process of Methane Production in the Rumen

Hemicellulose, cellulose and starch are the main carbohydrates in the diet of ruminants. Feeds are carried to the rumen after being eaten and fermentation happens there. Rumen provides an environment where microbes such as bacteria, protozoa, fungi and archaea exist. Cellulolytic bacteria and anaerobic fungi found in the chamber convert cellulose and hemicellulose into glucose and similar simple sugars. Certain bacteria use the sugars to produce acetate, propionate and butyrate together with gases carbon dioxide and hydrogen gas. When fermentation is happening in the rumen, hydrogen is stored there. Because this build-up interferes with fermentation, hydrogen needs to be extracted. In the rumen, archaea bacteria conduct methanogenesis, taking carbon dioxide and hydrogen from the diet, using both as their fuel to create methane and water. Methane is released from the rumen to the environment directly by eructation, the action commonly known as belching.

Different Strategies to Reduce Methane Production

Dietary Manipulation

By altering the ratio of non-fiber carbohydrate (NFC) and neutral detergent fiber (NDF) in the diet, it is possible to reduce both the number of methanogens and methane emission by adjusting hydrogen production, dry matter intake (DMI), nutrients leaving the rumen and their digestibility. Liquid carbohydrate fermentation results in the creation of acetate and butyrate and hydrogen are a resulting co product that can be used for forming propionate. For this reason, methane production can be assessed using the ratio of acetate to propionate (C_2/C_3). If C_2/C_3 is close to 0.5, maximum hydrogen produced by the acetate pathway can be used for making propionate which lowers methane emission. According to theory, NDF fermentation results in higher acetate and lower propionate than in NFC. As a result, making adjustments to the mix, like increasing the starch or lowering the amount of roughage could support more propionate formation and a reduction in the quantity of methane produced (sun *et al.,* 2023).

Forage Feeding

Plants that are young are important forage options. By modifying the way forage is fermented, methane production is reduced because young forage contains more easily fermentable carbohydrates and less NDF which helps with digestibility and speed of passage. Rather, older forage results in greater methane emission due to its higher C:N ratio which decreases digestibility of feed. The chemical components in forage varieties can lead to changes in methane emission. The presence of condensed tannins, small amounts of fibre, high amount of dry matter eaten and a fast rate of digestion explains why legume forage releases less methane than other forages. C4 grasses as a rule produce more methane than C3 plants. Dividing the forages into smaller particles can help decrease methane amounts per kilo of feed digested. Presumably, ensilaged forages may also produce less methane in the rumen because some fermentation took place during the ensiling. Feeding young forages with more soluble carbohydrates and less fibre is better along with a small amount of grain helps in controlling the methane production (Haque, 2018).

Fat Supplementation

When fat supplementation was given, methane levels fell in both cattle and sheep by 3.77% and 4.30%, respectively. Reduction in methane production was greater in sheep compared to cattle because DM digestion was less affected with the addition of fat in sheep than in cattle. The fatty acids $C_{12:0}$ and $C_{18:3}$ along with other polyunsaturated fatty acids (PUFAs) are stronger than most saturated fatty acids. Fats still seem to prevent methane production efficiently in most cases with suppression lasting 72 days or beyond in cattle. Fats provided up to 6% of the diet (DM) can boost milk production and decrease methane emission by 15% in cattle, yet higher levels of fats in the diet lowered the efficiency of feed digestion and fermentation which affected milk production. Feeding ruminants medium chain fatty acids (MCFA) and poly unsaturated fatty acid (PUFA) can reduce the number of methanogens (Haque, 2018). PUFA can also suppress the growth of protozoa by going through hydrogenation to become biological hydrogen. It seems that MCFA and PUFA harm the cell membrane which causes it to lose its selective properties, a key requirement for the survival and development of methanogens and other microbes. When cattle are fed concentrates and fat then it more strongly prevents methanogenesis than it does when they are given forages. The better anti-methanogenic effect of MCFA and PUFA at high concentrate levels is lower pH that occurs in these diets (Patra *et al*., 2017). Adding medium and long-chain fatty acids in the diet can be managed by including garlic oil, corn oil, canola oil, peppermint oil, eucalyptus oil and commercial mixtures.

Concentrate Feeding

Lower emission of methane was detected with 80 or 90% concentrate feeding, but 35% or 60% concentrate supplementation had no effect. Feedlot cows fed a concentrate diet of 90% showed a low methane loss of just 2–3% of their gross energy intake. In beef cattle, eating cellulose affects the digestion, leading to a bigger acetate: propionate ratio and higher methane emission compared to other carbohydrates; inside non-structural components, sugar produces more methane than starch (Haque, 2018). Methane loss is influenced by all of the carbohydrate fractions, as starch has the least effect likely because its metabolism favors dominant propionate production. Giving ruminants more starch as their main diet brings methane energy losses down compared to feeding a forage diet. The advantage is that starch provides demand for hydrogen, reducing its availability for methanogens which makes the rumen less acidic thus discouraging the growth of rumen methanogens.

Ionophores

In the livestock industry, most ionophores used are monensin, salinomycin and lasalocid. Ionophores are able to attach to the cell membranes in gram-positive bacteria and protozoans which reduces the H^+ difference across the cell membrane and causes apoptosis of the cells. Consequently, ionophores could improve propionate production and lowers hydrogen emission for gram-negative bacteria in the rumen. In high-fiber ration, adding ionophores to the feed can lower methane emission by decreasing the action of cellulose-breaking bacteria. Ionophores can control the presence of cocci bacteria which leads to reduced production of acetate and methane. High levels of monensin drop methane production (g/d) in dairy and beef cattle by 4–10% and also result in a 30% decrease in methane emission from beef cattle when 33 mg/kg of monensin are given, likely due to changes in protozoan populations (Haque ,2018). Over time, the inhibitory action of ionophores on methane may wear off as microorganisms adapt themselves. Yet, because ionophores may only help for a limited time and there is more public pressure to see fewer antimicrobials in animal feed, there is likely a small chance of methane emission being controlled for the long term.

Plant Secondary Metabolites

Plant secondary metabolites, mainly condensed tannins and saponins and their active property of phenolic compounds makes the metabolites antimicrobial and therefore help suppress methane production in the rumen.

Tannins

There are many ways tannins help like they prevent the growth of methanogens and reduce the number of protozoa, decreasing the amount of hydrogen these microbes produce during fiber digestion. The amount of methane produced dropped (up to 55%) when tannin-rich forages, including lucerne, red clover, chicory and lotus were fed to ruminants (Haque,2018). Experts believe that, excess tannins get in the way of digesting plants and hinder animal productivity so, they are less likely to be used for methane reduction on a large scale (Patra *et al.,* 2017*).*

The presence of flavonoids, saponins and organic sulfur compounds in vegetable oils may help reduce emission of methane. The number and number of methanogens, dry matter degradation and methane emission all decreased due to oregano oil. They might reduce gram-positive bacteria and improve the ability of bacteria involved in propionate fermentation to take in hydrogen. Greater concentrations of saponin resulted in fewer protozoa and hence a fall in methane production of up to 29% (Sun and Li, *2023*).

Nitrates as Alternate Hydrogen Sink

When nitrate is present, it lowers the amount of hydrogen formed and so decreases the production of enteric methane. The rumen uses hydrogen from the rumen more for removing nitrates than for producing methane. More hydrogen is given off by cattle when they are fed food containing large amounts of nitrate. A newly discovered fact is that dairy cattle produce less enteric methane if fed high amounts of nitrate. The amount of methane created was up to 25% lower in g/ DM at a nitrate level of 21 g of nitrate /kg DM (Olijhoek *et al*., 2016). Methane formation is decreased because nitrate takes the place of CO_2 in accepting electrons and nitrite and nitrous oxide directly interfere with the actions of both methanogens and some hydrogen-producing bacteria (Patra *et al.,* 2017*)*. None of the total volatile fatty acids or their individual amounts such as butyrate, propionate and acetate varied but formic acid amounts increase. Tests showed that nitrate addition did not affect milk yield or the chemical structure of milk (Olijhoek *et al*., 2016).

Conclusion

Both the environment and farm budgets are threatened by enteric methane produced by cattle. The right diet can cut back the pollutants and does not have to reduce animal performance. Nitrates and ionophores added in concentrates will lead to significant cuts in greenhouse gas emission. Furthermore, using both genetic selection and precision nutrition supports the long-term sustainability in reducing methane production by farm animals.

References

Haque, M.N. 2018. Dietary manipulation: a sustainable way to mitigate methane emission from ruminants.*Journal of Animal Science and Technology*, 60: 1-10.

Olijhoek, D.W., Hellwing, A.L.F., Brask, M., Weisbjerg, M.R., Højberg, O., Larsen, M.K., Dijkstra, J., Erlandsen, E.J. and Lund, P. 2016. Effect of dietary nitrate level on enteric methane production, hydrogen emission, rumen fermentation, and nutrient digestibility in dairy cows. *Journal of Dairy Science*, 99(8) : 6191-6205.

Patra, A., Park, T., Kim, M. and Yu, Z. 2017. Rumen methanogens and mitigation of methane emission by anti-methanogenic compounds and substances. *Journal of Animal Science and Biotechnology*, 8: 1-18.

Sun, J., Zhao, G. and Li, M. M. 2023. Using nutritional strategies to mitigate ruminal methane emission from ruminants. *Frontiers of Agricultural Science and Engineering*, 10(3): 390-402.