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Nutritional Manipulation and Methane Emission in Ruminants-a Review

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ABSTRACT

Livestock emit large quantities of methane as part of their natural digestive processes. Livestock is a significant source of methane, a potent greenhouse gas, in agriculture. Carbon dioxide is much more abundant than methane in the atmosphere. Methane, on the other hand, traps 30 times more heat than carbon dioxide. Methane (CH4) is the main component of natural gas and a powerful greenhouse gas (GHG). After escaping into the atmosphere, greenhouse gases act as a shield, insulating the Earth and trapping energy while slowing the rate at which heat leaves the planet. The greenhouse effect has become stronger and more constant over the last few decades as greenhouse gas emissions have increased. It is leading to global warming, which is a concerning situation. As a result, methane production and emissions from the fermentation of feed and fodders in the ruminant digestive tract must be reduced. This analysis discusses nutritional manipulation in ruminants as the best method for reducing methane production and emissions.

***Key words**: Nutrition, Methane emission, Performance, Ruminants*

Introduction

Because of the increasing understanding of the negative effects of climate change, monitoring possible sources of greenhouse gas (GHG) emission has become a universal priority. One of the most common anthropogenic sources of GHGs is livestock farming (Kumari *et al*., 2014).

Livestock emissions exceed 7.1 gigatonnes CO2e per year1, accounting for 14.5 percent of total anthropogenic emissions (Kumari *et al*., 2016). If the economy grows and demand for livestock products such as meat and dairy products rises, so does the risk of climate change (Steinfeld and Gerber, 2010). As a result, reducing GHG emissions from livestock and promoting sustainable livestock farming will be critical in the future (Kipling *et al*., 2016).

In 2005, global anthropogenic GHG emissions from agriculture were 5.1 to 6.1 gigatonnes CO2-eq, with livestock accounting for approximately 9% of total emissions (IPCC, 2007). Ruminant supply chains are the major contributors to GHG emissions in the livestock sector, accounting for about 80% of total emissions (Opio *et al*., 2013), whereas non-ruminants, such as pigs and poultry, account for just around 9% and 8% of total emissions, respectively (Gerber *et al*., 2013). Beef and milk production account for around 35 and 30 percent of total global emissions, respectively, from the livestock sector. Buffaloes and small ruminant supply chains, on the other hand, contribute about 8.7% and 6.7 percent of sector emissions, respectively (Opio *et al*., 2013). According to another study (Gerber *et al*., 2013), GHG emissions from livestock supply chains account for around 14.5 percent of all human-induced emissions. The primary sources of GHG emissions in ruminant production are enteric fermentation and feed production-related operations, which account for approximately 39 and 45 percent of the total sector's emissions, respectively. Enteric fermentation, which accounts for approximately 47 percent of total CH4 emissions from ruminant production, is the largest source of GHG emissions from ruminant production (Opio *et al*., 2013). According to the US Environmental Protection Agency, enteric CH4 emissions accounted for roughly 20% of total CH4 emissions from anthropogenic sources in 2009 (EPA, 2011).

As a result, there is a strong demand for long-term and short-term mitigation techniques. The emphasis of this review will be on ruminant CH4 mitigation through dietary manipulation.

Methane production

Ruminant livestock with a fore-stomach (or rumen) that contains methanogens include cattle, sheep, buffalo, goats, deer, and camels. Methanogens are bacteria that can digest coarse plant matter and produce methane as a byproduct of enteric fermentation. The animal's belching releases the generated methane into the atmosphere (Curnow, 2020).

The rate and amount of methane released by livestock is largely determined by the number of animals present, the type and amount of feed consumed, and the digestive system of the animals. Ruminants are the main cause of livestock methane emissions, producing the most methane per unit of feed consumed.

Nutritional manipulation strategies are as follows.

Forage Quality

Low-quality forage rations produced 16 and 33 percent more enteric methane per kilogramme of milk than medium and high-quality forage rations, according to Lascano and Cardenas (2010) and Mizeck *et al*. (2010), respectively. Furthermore, according to Mizeck *et al*. (2010), seasonal variation in forage quality influences the amount of enteric methane released by cows that graze on it. Molano and Clark (2007) conducted a study in lambs by feeding ryegrass at the reproductive and vegetative stages and discovered that CH4 emissions per unit of DMI were unaffected by DMI level or diet efficiency. Since high-quality forage, such as young plants, produces more easily fermentable carbohydrates and less NDF, it has a higher digestibility and passage rate, reducing CH4 output by changing the fermentation pathway. More mature forage, on the other hand, produces more CH4 due to a higher C:N ratio, which reduces digestibility (Haque, 2018). Methane production was lower in cattle fed corn silages than in cattle fed grass silages. The low fibre quality, improved digestibility, and feed efficiency may all be contributing to the lower methane output (Jenkins, 2014). Because of less energy loss as methane and a rise in ensiled forage intakes, ensiling of forages has proven to be a beneficial technique in the livestock industry for mitigating methane emissions and also increasing productivity. Maize silage is the most effective and simple method for reducing ECH4 emissions. Another technique that deserves more attention as a mitigation strategy is harvesting early cut swards (young stage) for ensiling (Evans, 2018). Gaviria-Uribe *et al*. (2020) also found that therapies with higher nutritional efficiency, such as higher digestibility, higher CP content, and lower FDN and FDA content, had higher DMI and lower CH4 emissions, and therefore lower CH4 energy loss. They also found that the intensity of CH4 emissions produced by the legume-based system was lower, making these systems a viable choice for transitioning to sustainable tropical cattle production. In comparison, Jonker *et al*. (2015) discovered that fresh pasture forage consistency, feeding level, and supplementation have small but important effects on CH4 yield in beef cattle. The results of Chaves *et al*. (2006)'s analysis indicated that cattle grazing alfalfa-grass pastures produced more DMI and CH4 than cattle grazing grass-only pastures. The higher digestibility of the alfalfa grass pasture was due to improved digestive ability, which was reflected in cattle grazing alfalfa-grass pastures losing less energy to CH4 output than those grazing grass-only pastures (7.1 vs. 9.5 percent of GEI). The findings of that study also indicated that using alfalfa to improve pasture quality could potentially reduce CH4 output by up to 10%. Trupa *et al*. (2015) found that the nature of the forage has a major impact on methane production. Improved forage quality could result in increased dry matter intake (DMI), milk yield, and a decrease in the proportion of energy converted to methane gas. According to Garg *et al*. (2014), ration balancing under tropical field conditions can be used to minimise enteric methane emission (g/d) by up to 10%. Reynolds *et al*. (2021) found that ruminant methane emissions are affected by changes in diet carbohydrate amount and form (i.e. starch vs. fibre). Cows fed higher maize silage diets had higher dry matter intake, milk production, and lower methane yield (g/kg of dry matter intake) than cows fed high grass silage diets (Reynolds *et al*., 2021). When goats ate cassava instead of Tithonia, Methane emissions in eructed gas were reduced by 50%, according to Phonethep *et al*. (2016). Diets low in soluble protein is thought to cause digestion in the cecum-colon region, where acetogenesis is thought to be more important than methanogenesis in the degradation of organic matter.

Forage/concentrate ratio

According to research conducted by Dong *et al*. (2019); Jiao *et al*. (2016) and Mizeck *et al*. (2010), increasing the proportion of concentrate in cow ration decreases the amount of methane generated per kg of milk produced. In general, this occurs since a high-concentrate diet contains more readily fermentable substances (e.g., starch) than a high-forage diet. Jenkins (2014) found that diets high in grains (for example, finishing diets used in beef feedyards) resulted in more body weight gain per pound of feed consumed and lower methane emissions than most forage-based diets.

Munoz *et al*. (2018), on the other hand, found that a higher level of dietary concentrate supplementation (8 kg) of dairy cows from pastoral systems in late lactation resulted in increased daily methane emissions, decreased methane yield, and had no impact on methane strength, compared to a more moderate level of dietary concentrate supplementation (4 kg).

Different microbes are involved in the digestion of cellulose-rich diets (grass or hay) or carbohydrate-rich diets (corn or distillers grains), resulting in varying amounts of methane output. More propionate production would take H2 away from methane production in carbohydrate-rich diets, resulting in less methane production. Methane production would be reduced as a percentage of dietary gross energy in cattle fed carbohydrate-rich diets with high intake (Jones, 2014).

Grazing

Rotational grazing systems aim to minimise forage maturity, which increases forage digestibility and, as a result, lowers methane production (Jenkins, 2014). Furthermore, if cattle are feeding or grazing legume mixes, they produce less methane than when they are consuming or grazing grass-only forages. According to DeRamus *et al*. (2003), strenuous grazing is an effective management practise that has the potential to improve the conversion efficiency of forage into meat and milk by allowing for more effective use of grazed forage by managed rotational grazing. When opposed to constant grazing, best management practises for cows result in a 22% reduction in yearly CH_4 emissions. Raylene (2020) pointed out that an adaptive multi paddock (AMP) grazing process reduces methane emissions by using a great amount of paddocks stored at greater rates for short grazing times accompanied by prolonged rests.

Intake level

Pinto *et al*. (2020) found no effect of fibre intake (low vs. high NDF) on CH_4 concentration in their research, despite the fact that ruminants produce more CH4 when fed a fibrous diet. According to Gaviria-Uribe *et al*. (2020), high NDF and ADF intake increased CH4 emissions, although greater degradability of DM and OM resulted in lower CH4 emissions. Trupa *et al*. (2015) found that increasing feed consumption increases the amount of emitted methane gas. Higher TDN and DMI for rams resulted in lower methane output per unit TDN, methane output per DMI, and methane yield per ADG, according to Restitrisnani *et al*. (2016). However, increasing DMI not affects methane production, but affected by increasing TDN. Fischer *et al*. (2019) found that feed restriction applied to inefficient lactating dairy cows seems to improve their feed efficiency and to reduce their CH4 emissions.

Precision feeding

Fistcher *et al*. (2020) reported that precision feed restriction reduced daily methane emissions more for the least efficient cows by improvement of efficiency without impairing cow's performance. They also suggest that excessive consumption of feed can contribute to feed inefficiency by decreasing the mean retention time of feed in the rumen, resulting in reduced digestibility. Precision feeding, according to Andeweg and Reisinger (2013), will boost farm income by increasing feed production and productivity. In grazing dairy cattle systems, customised balanced feeding programmes have been shown to improve productivity while lowering enteric methane emissions intensity (15-20%) and nitrogen excretion (20-30%), resulting in lower manure emissions. Precision feeding and evaluation of livestock, according to Rooke *et al*. (2016), will minimise enteric emissions of methane by more accurately balancing specific animal demands to feed supply (e.g., by more regular and precise analysis of forage quality), by identifying animals with subclinical disease states, and by identifying animals at the optimal time for slaughter.

Feed additives

3-nitrooxypropanol (3NOP), bromochloromethane, coconut, chestnut, distillers dried grains and solubles, grape pomace, eugenol, linseed, nitrate, monensin, saifoin, nitroethane, fumaric acid, and tannins were found to have major effects on enteric emissions among many of the feed additives (Kebreab and Feng, 2021).

Oils

Boland *et al*. (2020) demonstrated that providing linseed oil-based concentrate enrichment in pasture-based dairy production systems is an efficient CH4 mitigation strategy while preserving dairy cow efficiency. In this study, the Linseed oil treatment had higher C18:3 (42 percent total FA) concentrations than the SO treatment (5 percent total FA). Since C18:3 has a higher degree of unsaturation than C18:1 and C18:2, it would be more probably to have undergone substantial rumen biohydrogenation, which rises as the degree of C18 FA unsaturation increases.

Fats and oils have shown to reduce methane emissions by 15–20 percent in farming systems (Curnow, 2020). Fats are a high-energy source that can be introduced to the diet in small amounts which have been shown to reduce methane emissions by inhibiting methane-producing microbes. Unsaturated fat can extract H2 from methane output by saturating the fat (H_2 sink) (Jones, 2014).

Sunflower oil decreased methane emissions per unit of gross energy (GE) intake by 22%, with 25% of this reduction due to a decrease in diet digestibility, according to Beauchemin and McGinn (2006). Canola oil, on the other hand, was found to decrease diet digestibility and minimise methane emissions per unit of GE intake by 21%.

In lactating cows, Zijderveld (2011) found that a blend of lauric acid, myristic acid, linseed oil, and calcium fumarate reduced methane production about 10%, negatively affecting fat and protein corrected milk production.

Klop *et al*. (2017) found a temporary decrease in CH4 yield and intensity over time, but no change in the degree or persistence of the fall in CH4. The rotational feeding of essential oils and C12:0 to lactating dairy cows is causing this.

With increasing doses, Patra and Zhongtang (2012) found that all essential oils (five essential oils (EOs), including clove oil (CLO), eucalyptus oil (EUO), garlic oil (GAO), origanum oil (ORO), and peppermint oil (PEO)) considerably lowered methane emission. However, the potency of different EOs in modulating rumen microbial communities and fermentation differs. Furthermore, a single EO can not effectively and functionally reduce methane emission in ruminants unless combined with other antimethanogenic compounds at low concentrations.

Organic acids

Trupa *et al*. (2015) proposed that feed additives that inhibit methane production, such as plant extracts (e.g., tannins, saponins, and oils) and organic acids could minimise methane emissions.

When one form of seaweed was fed to cattle at a rate of 3% of their diet, methane emissions were reduced by up to 80%. (Curnow, 2020). According to Fletcher (2020), the methane released by steers fed 0.10 percent and 0.20 percent Asparagopsis in their diets was reduced by 40% and 98 percent, respectively, with a 53 percent and 42 percent weight gain, respectively.

Asparagopsis taxiformis, a red algae species, is added to an animal feed to minimise enteric methane intake, according to Rawat (2021). Bromoform, a powerful inhibitor synthesised and stored by the seaweed, inhibits the methyltransferase enzyme, which is needed for methane production.

Gallic acid has the ability to reduce CH4 and N2O emissions from beef cattle without decreasing feed digestibility in cattle fed a high-protein fodder diet, according to Aboagye *et al*. (2019).

Methane inhibitor

Hristov *et al*. (2015) demonstrated that the methane inhibitor (3-nitrooxypropanol) 3NOP, applied at 40 to 80 mg/kg feed dry matter, reduces methane emissions by 30% with increased body weight gain without affecting feed intake or milk yield in high-producing dairy cows. McDonald (2021) observed that including the feed ingredient in steam-flaked or dry-rolled barley finishing diets at 125 mg/kg of feed dry matter reduced enteric methane emissions by 70% on average. The methane reduction in steam-flaked corn-based finishing diets was 31% to 80% at the 125 mg/kg stage. Increasing the dose from 150 to 200 mg/kg in diets, on the other hand, reduced methane yield by 17 to 26 percent. According to Kebreab and Feng (2021), 3-NOP decreases enteric methane output by 41% in dairy cattle and by 22% in beef cattle.

Plant extracts/Phytogenics

Rawat (2021) reported that the plant extracts/phytogenics reduce the production of methane via one of several ways such as inhibiting methane-producing bacteria, the protozoans that live in synergy with them, or altering/promoting the metabolic pathways involved in using the hydrogen that would otherwise be turned into methane.

Bovaer effectively inhibits the formation of methane, according to Bannink (2021). The effectiveness of the treatment is determined by the cow's diet. When a low dose of Bovaer (60 mg/kg DM*) was added to a diet without maize silage in the roughage, methane was decreased by 27% in cows. The methane reduction was up to 35% at a low dose in a diet containing 80 % maize silage in roughage dry matter. With the addition of a medium dose of Bovaer (80 mg/kg DM), methane reductions ranged from 29% to 40%. Despite their effectiveness in vitro, Zijderveld (2011) found that Diallyldisulfide, yucca powder, calcium fumarate, an extruded linseed product, and a combination of capric and caprylic acid had no effect on methane emissions in lactating cows. He also found that adding nitrate and sulphate in sheep diets reduced in vivo methane emissions by 32% and -16%, respectively, probably by serving as hydrogen sink in the rumen.

Probiotics

Probiotics have been shown to shift the ruminal microbial population away from methanogens and toward microbes that produce more volatile fatty acids. Ruminants use certain volatile fatty acids as an energy source, which helps to minimise methane emissions. According to Lathum *et al*. (2019), using Paenibacillus 79R4 reduces enteric methane emissions while also preventing microbial environment inhibition of fermentation performance. The use of probiotics in deccani ram lambs decreases enteric methane emission by 21.9 percent by enhancing digestibility, according to Thota *et al*. (2017). In contrast, Chen *et al*. (2020) noticed that by enhancing the production of Norwegian dairy cows, propionic acid bacteria reduced methane production by up to 20%. By altering rumen fermentation, Astuti *et al*. (2018) discovered that addition L. plantarum strains U32 and U40 as probiotics resulted in increased propionic acid and reduced methane output. In Ongole cross breed cattle, Anggraeny *et al*. (2021) discovered that using a mixture of organic components and probiotics resulted in the greatest reduction in CH4 development from enteric fermentation.

Prebiotics

Ghosh and Mehta (2012) revealed that mannan-oligosaccharide (MOS), fructo-oligosaccharide (FOS), and galacto-oligosaccharide stimulate Selenomonas, Succinomonas, and Megasphera while inhibiting acetate producers Ruminococcus and Butyrivibrio, resulting in increased propionate production. Methane intake is reduced by 11% when galacto-oligosaccharides are fed to the animals. In *S. fusiforme*, valuable metabolites and nutrients play an important role as prebiotics. Choi *et al*. (2020) performed an in vitro analysis on *S. fusiforme*, which indicates that using S. fusiforme in animal rations could minimise methane emissions.

Tannin

According to Hess *et al*. (2006), much extracted tannins can be useful in minimising methane emission without significant losses in feeding value of the diet, while very tannin-rich shrub legumes like C. calothyrsus, despite being successful in limiting methanogenesis, are limited in their utilization due to the simultaneous depression of the feeding value of the diet. Stewart *et al*. (2019) observed that cows consuming the hydrolysable tannin-containing hay (SML) at lower intake levels had reduced CH4 yield (g/kg DMI), while heifers receiving the same hay at higher intake levels did not have lower CH4 yield. Tannin-rich hays also decreased nitrogen excretion, increased nitrogen retention, and transferred nitrogen excretion from urine to faeces. In contrast, Aboagye *et al*. (2018) discovered that including both condensed and hydrolysable tannins in the diet reduces methane production without compromising efficiency.

Methane yield was decreased when cottonseed oil (14%) or tannin (11%) were added directly to the rumen, and when both were used together, methane production was decreased by up to 20%. The mechanism of fat and tannin's anti-methanogenic effects is unknown, but both tend to cause a reduction in overall fermentation rather than a switch in the form of fermentation (Williams *et al*., 2020).

Saponins

According to Jayanegara *et al*. (2014), increasing the amount of a saponin-rich source reduced ruminal CH4 emissions in vitro while having no effect on digestibility or total SCFA intake.The decline in CH4 with rising saponin levels is thought to be due to a lower acetate-to-propionate ratio and lower protozoal counts. Galindo *et al*. (2016) discovered that combining saponin with star grass increases invitro methane production. Belanche *et al*. (2016) used a rumen simulation technique to show that ivy fruit saponins can decrease methane production by up to 40%. The ensiled forms of both the Verko and Kometa alfalfa varieties appear to be good sources of saponin, capable of reducing methane production (P 0.05) without hampering the basic fermentation parameters, according to Kozlowska *et al*. (2019).

Inophores

Monensin decreased methane emissions in beef cattle by about 9% without decreasing diet digestibility, according to Beauchemin and McGinn (2006). Vyas *et al*. (2018) found that NOP (nitrooxypropanol) is a potent CH_4 inhibitor that can be added to traditional feedlot diets containing Monensin without causing efficiency or carcass characteristics to suffer. As per Odongo *et al*. (2007), medicating 60:40 TMR with 24 mg Monensin Premix/kg dry matter is a viable strategy for reducing CH_4 output in lactating Holstein dairy cows. De *et al*. (2012), found that adding monensin to urea molasses mineral block or concentrate mixture could reduce methane output by 10.11 to 16.33 litre/kg DDMI or 10.76 to 17.01 litre/kg DOMI, or 32 to 60 litres per day. Gupta *et al*. (2018) suggested that feeding 24 mg/kg DMI of monensin on high forage diets has the potential to minimise enteric methane emissions in lactating buffaloes without affecting nutrient use, reducing buffaloes' contribution to the global methane inventory and its negative impact on the environment while increasing environmentally sustainable milk production in the country. Monensin use in dairy and beef cattle, as per Appuhamy *et al*. (2013), decreases dry matter intake and methane emission without affecting milk production in dairy cattle. When the impact of monensin on methane mitigation in dairy cows and beef steers were adjusted for monensin dose variations, the results were identical.

DHA (docosahexaenoic acid), Nitrate

Klop *et al*. (2016) revealed that the nitrate but not DHA reduced enteric CH4 production, and there were no interaction effects on CH4 production per kilogramme of DMI or per kg of FPCM. With the use of nitrates in cattle, Kebreaband and Feng (2021) announced reductions in methane emissions of up to 14.4%.

Conclusion

It is infered that the nutritional manipulation strategy could be beneficial to mitigate methane production and emission in ruminants that decreases untoward effects on environment and human health.

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