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Review Article

Nutritional strategies to mitigate methane emission from livestock in India– A review

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Abstract

Greenhouse gases (GHGs) in the environment are released by a number of activities, the livestock sector being one among them. With the world's largest population of cattle or buffaloes, India is often described as the largest contributor to livestock-related GHG emissions. In order to mitigate this contribution, it is essential to understand the species-wise contribution of GHGs so that efforts can be channelized into major species responsible for this effect. The existing information suggests that ruminants, compared to non-ruminants, and large ruminants compared to their smaller counterparts, are the major contributors. The major component of livestock-borne GHGs is methane, which arises from digestion; hence, nutritional strategies play a major role in GHG mitigation. Accordingly, mitigation of methane emission through various feeding strategies has been developed in the laboratory, and some of these strategies were field tested for their impact. Major investigations revealed that, in order to reduce methane emission from enteric fermentation, tender grasses are preferred over mature grasses, concentrate feeds are preferred over high fiber rations, balanced rations are preferred over deficits/excesses of nutrients in the rations. Besides the composition of diets, many herbal products were tested, and some of them were found to have the properties of suppressing methane production. All such information is reviewed for researchers to choose objectives of future research.

Keywords: Crop residues, Greenhouse gases, Livestock sector, Methane

Highlights

- Maintaining lesser number of high-producing animals would make high concentrate rations profitable, thereby reducing methane production from rumen metabolism.
- Ration balancing is a practically feasible strategy for large-scale mitigation of methane, with field-tested results, and the results are consistent irrespective of the animal's genetic makeup of productivity.
- Year-round green fodder availability would prevent excess crop residues in the ration, thereby reducing methane emissions.
- Herbal feed additives need proper formulation, dose recommendation and commercialisation for mass-scale impact in terms of reduction in methane release by livestock farming.

INTRODUCTION

The twenty-first century has compelled global leadership to achieve environmental stability while meeting the goals of development. The price of development is often the pollution caused during the process. Pollution of any origin goes in one of the three spheres, viz. Lithosphere (land), Hydrosphere (Water) and Atmosphere (Air). The land pollution is largely local, affecting the immediate residents, and the water pollution is restricted to the extent of polluted water flow/percolation, but the air pollution has no boundaries, affecting the global environment. Greenhouse gases emitted from the development activity of one country would affect the people from the countries that do not share the fruits of development. In such cases, people enjoying the fruits of development and people paying the price for it are from different countries. Hence, the countries causing air pollution are more accountable to the international community than those causing land or water pollution. Accordingly, there had been a resolution to reduce the emission of greenhouse gases (GHG) into the environment, with a fixed time-bound target for each country during the Paris Agreement in 2015.

An unbiased assessment of responsibility in terms of the percentage contribution of global greenhouse gases vis-à-vis population keeps India in a very comfortable position, as evident from the fact that the United States of America, with her 400 million population, is responsible for 15% of GHG emissions, while India with her 1400 million population is responsible for only 6% of the same.

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In order to reduce GHG emissions from the Indian livestock sector, the available options have been reviewed hereunder.

Livestock sector and GHG emission

In terms of quantity of GHG in the environment, carbon dioxide is in the largest quantity. However, many trace gasses are proving to be more harmful than carbon dioxide in their longevity in the environment and potential to cause global warming. Methane is one among them (Lashof and Ahuja, 1990). The global warming potential of methane was estimated as 27-28 times to that of carbon dioxide (Boucher *et al.*, 2009). The molecular weight of methane is 16, which is lighter than carbon dioxide (44), nitrous oxide (46), carbon monoxide (28) and many other pollutant gases, which makes it rapidly reach higher strata of the environment. When we give a ranking to different sectors responsible for greenhouse gas emissions, the agriculture and allied sectors account for 10-12%, within which livestock accounts for 63.4% of the GHG emissions from the agricultural sector (Sharma, 2020). If we compare the US and India in terms of their livestock contribution to global GHG contributions, India, with 417.85 million cattle and buffalo, contributes 29.56 billion metric tons of CO_2 equivalent (GtCO2e), while the US, with 92 million cattle, contributes 175 million metric tons. The comfortable position of India in terms of total responsibility goes reverse when it comes to livestock production *vis-à-vis* GHG production, and hence, among Indians, the policymakers in general and livestock professionals in particular, have a responsibility to reduce GHG share of India in terms of unit livestock population or unit production of different livestock products like milk, meat and eggs. Any attempts to reduce GHGs from Indian livestock through reduction of livestock population would be detrimental to the national economy as well as livelihoods of masses.

The air pollution from the livestock sector arises due to a product of digestion, methane. In terms of global warming potential, methane is particularly the major greenhouse gas and accounts for 16% of the total global greenhouse gas emissions (Shivanna *et al.*, 2022). From livestock, most of the methane is produced from enteric fermentation, which is a natural process produced by ruminant animals and is responsible for one-third of methane from agriculture (Mirzaei-Aghsaghali and Maheri-Sis, 2011). The atmospheric methane concentration is believed to be on the rise at a rate of 22 megatons per year, primarily because of the disparity between estimated global annual emissions and removals (Singh *et al.*, 2021).

Enteric fermentation is responsible for emitting 10.09 million tons of methane, contributing to 73.3% of the total methane emissions from the agricultural sector in India (according to INCCA, 2010). Buffaloes, with their high methane emission coefficient of 50 kg/animal/year (as reported by NATCOM, 2004), stand out as the largest methane emitter within the livestock sector, comprising 42% of the total methane emissions in India for the year 2003.

The daily methane production from a large ruminant animal ranges from 250 to 500 litres by volume, with a weight range of 175 to 350 grams per day (Getabalew *et al.*, 2019). This substantial methane production has a significant impact on the contribution of cattle to global warming, making it quite substantial. Moreover, methanogenesis, besides adversely affecting the environment, also contributes to dietary energy loss for the animals, averaging around 7% (with a range of 2-15%) of their gross energy intake, as reported by Eugène *et al.* (2008). Hence, methanogenesis is considered an undesirable phenomenon from both ecological and economic aspects.

In the digestive system, bacteria responsible for methane production are called methanogens. The process is called methanogenesis, where carbon dioxide is reduced using the reducing power generated during bacterial fermentation. All the livestock species have methanogens in their digestive system, largely in rumen and in lesser number in large intestines. Methane-producing bacteria belong to the domain Archaea, which belongs to prokaryotes. They play a crucial role in the microbial community of the rumen and other anaerobic environments. The most significant methanogen found in the rumen is *Methanobrevibacter ruminantium.* These methanogens possess a unique cell envelope component called pseudo-murein, and they require coenzymes such as hydrogen, carbon dioxide, and formate for methane production. Examples of such methanogens include *Methanobrevibacter ruminantium*, *Methanobrevi bactermillerae*, and *Methanobacterium formicicum*, as reported by Baker *et al.* (1999). Methanogens are essential contributors to enteric methane production in the digestive systems of ruminant animals.

Moeletsi *et al.* (2017) conducted a study in South Africa and reported the species-wise contribution to methane emissions. Their findings indicated that large ruminants, such as cattle, contribute a significant portion, accounting for 78% of the total methane emissions from the livestock sector. In contrast, sheep and goats combined contribute to only 21% of these emissions, while all non-ruminant livestock contribute a mere 1%. Therefore, addressing methane mitigation from large ruminants would have the most substantial impact on reducing methane emissions and their environmental consequences.

Sources of methane from livestock rearing are,

1) Enteric fermentation and 2) Manure, of which the former accounts for 87-90% while the latter has only 7% share in methane emission from livestock sector (Zhang *et al.*, 2021).

Methane produced in the rumen constitutes 87% to 90%, while the rest of the 10% to 13% comes from the large intestine (Torrent and Jonson, 1994). Animals release methane into the atmosphere primarily by exhaling the gas through their mouth and nostrils. The concentration of methane in the breath varies, with lower concentrations when the breath originates from the lungs and higher concentrations when it consists of gases belched from the fore stomachs. It's important to note that even breath from the lungs contains absorbed methane and is inhaled together with air. In enclosed spaces such as barns or larger rooms, the concentration of methane is influenced by air exchange, but it represents a mixture of methane from breath, belching, and rectal expulsion, as explained by Getabalew *et al*. (2019).

Approaches to reduce methane production through enteric fermentation

The substances which can be used to inhibit methane production through different mechanisms include oils, microalgae, nitrate, ionophores, protozoa inhibitors, phytochemicals, essential oils and 3-nitro oxyproponol (Almeida *et al.*, 2021). Thus, the following are the approaches to reduce methane production through manipulation of enteric fermentation: nutrient supplementation, feeding greens and legumes, supplementation of fat/fatty acids, microbial interventions, plant bioactive compounds and essential oils supplementation.

Nutrient supplementation: An increase in the concentrate component of the ration was reported to reduce methane emission during enteric fermentation (Henderson *et al.*, 2015; Mikuła *et al.*, 2022). Supplementation of Urea-Molasses-Mineral Block (UMMB) reduced the emission of methane by 10% (Mohini and Singh, 2010). The methane emission was reduced from 40.9 to 28.01 g/kg digestible dry matter due to an increase of concentrate mixture from 25 to 75% in the wheat straw-based ration (Singh, 1997). Hindrichsen *et al.* (2003) also found that concentrates reduce enteric methane emission but increase methane in manure. On balance, there was still an overall reduction in methane. Increasing concentrates would enhance the cost of ration, and hence, it becomes economically viable for farmers if their animals are genetically superior high-yielding breeds. Hence, breeding activity indirectly supports methane mitigation.

The effect of balanced rations on methane emissions from crossbred cows under field conditions was reported by Garg *et al.* (2013). They found that field-level animal rations were imbalanced in terms of low protein, energy and calcium. They balanced the ration according to the requirements of the animals and recorded methane emissions from the animals receiving balanced rations for 30 days using the sulfur hexafluoride tracer technique. Their study found that by providing a balanced ration to the animals, there was a significant reduction in enteric methane emissions. This reduction was observed in terms of both grams per day (g/d) and grams per kilogram of milk yield (g/kg milk yield). Specifically, there was a reduction of 10.1% ($p<0.01$) in g/d and 13.5% ($p<0.05$) in g/kg milk yield. This reduction in methane emissions resulted in a decrease of 10.3% in the proportion of dietary gross energy that was lost as methane. These findings highlight the positive impact of balanced rations on mitigating methane emissions and improving the efficiency of energy utilization in livestock production.

The impact of ration balancing on methane emissions from lactating buffaloes and crossbred cattle under field conditions was studied by Kannan *et al.* (2010). The results showed that by balancing the rations at the farmer level, methane production was reduced by 10 to 11%. These benefits were consistent for both buffaloes and crossbred cows. This finding underscores the importance of properly balanced rations in mitigating methane emissions in livestock, leading to more sustainable and environmentally friendly farming practices.

Type of nitrogen source too has its effect on methane production. Nitrate (NO_3^-) had been proposed by Van *et al.* (2010) as a replacement for urea (non-protein N) as a source of rumen degradable N for the rumen microbes. Nitrate serves as an alternative hydrogen sink in the rumen, competing with methane synthesis. The stoichiometric relationship indicates that 1 mole of nitrate can potentially reduce methane synthesis by 1 mole. Additionally, nitrate can have the effect of decreasing the population of rumen protozoa, which, in turn, contributes to the reduction of methane production. This dual mechanism underscores the potential of nitrate as an effective strategy for mitigating methane emissions in ruminant livestock.

The type of nitrogen source and its effect on methane mitigation were also explored by some investigators. With traditional rations, protein degradation or non-protein nitrogen (NPN) ammonia is generated. Urea is used as pre-treatment to enhance forage quality and increase the availability of fermentable nitrogen thereby improves the feed intake and dry matter digestibility, microbial activity, microbial protein and volatile fatty acids (Shojaeian and Thakur, 2006). Replacement of urea with nitrate as a source of NPN was suggested by Leng (2011). Nitrate can be fed safely to goats at levels that supply all the requirements of rumen microbial protein synthesis in diets low in true protein. Growth rate and nitrogen retention were alike or even slightly better than urea-fed animals compared to the animals receiving nitrate as non-protein nitrogen source (Phuc *et al*., 2009). A linear reduction in methane production with an increased dose of nitrate was reported (Lee and Beauchemin, 2014). Their findings suggested that nitrate serves as a potent methane-mitigating agent, with a more pronounced effect on dairy cattle compared to beef cattle. They further concluded that in order to achieve a similar reduction in methane emissions for beef cattle as seen in dairy cattle, a higher nitrate dose is required. This underscores the potential of nitrate as a methane-reducing intervention in livestock, albeit with variations in effectiveness between different cattle types.

Feeding greens and legumes: Improving forage quality has several positive effects on livestock, one of which is an increase in voluntary intake. This, in turn, reduces the retention time in the rumen, promoting more efficient post-ruminal digestion. Additionally, improved forage quality also plays a role in reducing the dietary energy that is converted into methane production. These findings were initially observed by Blaxter and Clapperton (1965) and have been reaffirmed in recent studies.

Robertson and Waghorn (2002) conducted a study on dairy cows grazing pastures and found that methane production as a proportion of Gross Energy Intake (GEI) was 4.5–5.3% in September (spring) but increased to 6–7% of GEI when cows grazed in December (summer) within the same lactation period. They attributed this increase to the maturity of the grass being grazed over the lactation period. Vlaming *et al*. (2008) also confirmed the reduction of methane emissions with the inclusion of legumes in the feeding regimen, highlighting the importance of forage composition in mitigating methane production.

Supplementation of fat/fatty acids: The introduction of a hydrogen acceptor other than carbon dioxide can effectively reduce methane production. Consequently, unsaturated fat in the diet has the potential to compete for available hydrogen, which would otherwise be utilized for methane production. The impact of dietary fat on methane production has been observed positively, although the extent of this benefit may vary among different researchers.

Several studies have provided a consensus on the role of dietary fat in inhibiting methane emissions. For every 1% increase in fat in the diet on a Dry Matter (DM) basis, methane reduction was estimated at approximately 5.6% according to Beauchemin *et al.* (2008), 3.8% according to Martin *et al*. (2009), and 3.5% according to Moate *et al*. (2011). These findings collectively suggest that dietary fat plays a significant role in mitigating methane emissions.

Microbial interventions: This includes suppression of methanogenic bacteria as hydrogen sink. This mechanism would stimulate the growth of reductive acetogenic bacterial growth in the rumen. Feed additives such as antibiotics, ionophores, fats rich in USFA etc. proved to modify the rumen microbial fermentation to decrease methane production. Examples of ionophores are lasalocid, salinomycin, niacin, lysocellin, etc. Feeding 50-100 mg Rumensin/day/animal significantly decreased methane production of about 14-23% on maintenance, 30-35% in medium milk producers and 22-32% in high yielders (Singh, 2010). Use of antibiotics was not recommended as their residues were present in milk. Use of ionophores is also not recommended as their effect is not long-lasting.

Instead of synthetic additives, natural antimicrobials like plant extracts are recommended. These extracts have anti-methanogenic and antimicrobial properties attributed to the presence of secondary metabolites such as saponins, terpenoids, phenylpropanoids, tannins, and more. Saponins, for example, have been found to effectively reduce methane and ammonia production.

For a cost-effective approach, it's advisable to supplement the animal ration with a mixture of fractions from various parts of plants, including seeds, bark, leaves, roots, fruits, and so on. This approach, as noted by Goel and Makkar (2012), can be more affordable and provide the desired antimicrobial benefits.

Yeast cultures of *Saccharomyces cerevisiae* stimulate acetogenic bacteria which consume H_2 to form acetate. Enzymes like cellulases and hemicellulases added to the diet improve ruminal digestion and reduce methane production (Jain *et al.*, 2011).

Abdelbagi *et al.* (2021) studied the effects of probiotics and encapsulated probiotics on enteric methane production and nutrient digestibility in ruminants (*Lactobacillus plantarum* TSD10 strain). The results of the study indicate that both the probiotics and the encapsulated probiotics had a significant impact. They reduced methane production by 6.1% and 33.1%, respectively, compared to the control diet. Additionally, they increased total gas production by 15.7% and 23.3%, respectively, in comparison to the control. These findings suggest that probiotics, particularly when encapsulated, can effectively reduce methane emissions while also enhancing overall gas production.

Plant bioactive compounds: Plant bioactive compounds such as tannins and saponins serve as valuable antimicrobial feed additives, and their extracts have been employed to reduce methane emissions (Table 1). Forage legumes that contain condensed tannins (CTs) have shown a direct inhibitory effect on methanogens. The inclusion of dietary CTs has led to a reduction in methane production by approximately 13-16% on a Dry Matter Intake (DMI) basis, as observed in studies conducted by Carulla *et al*. (2005) and Grainger *et al*. (2009). These

Table1. Plants containing secondary metabolites help to reduce methane emission

Name of the plant	Plant part	Active principle	Reference
Acacia concinna (Shikakai)	Seed pulp	Saponins, tannins	Balamurugan *et al.*, 2022
Allium sativum (Garlic)	Bulb	Volatile oil- alicin, diallyl disulphide, diallyl trisulfide	Mateos *et al.*, 2013
Azadirachta indica (Neem)	Seed pulp, leaves	Nimbin, nimbidin, azadirachtin	Taethaisong *et al.*, 2023
Bergenia crassifoila	Leaves, roots	Tannins	Jayanegara *et al.*, 2009
Emblica officinalis (Amla)	Seed pulp	Tannins, chebulinic acid (astringent), gallic acid and resin	Chaturvedi *et al.*, 2015
Eucalyptus globulus (Eucalyptus)	Oil, leaves	α and β Pinene, limonine, α- phellandrene,1,8- cineole, terpinene- 4-ol	Sallam *et al.*, 2009; Sallam *et al.*, 2010
Foeniculum vulgare (Fennel)	Seed	Pinene, fenchone, trans-anethole, camphene, methyl 1 chevicol, 1,8-cineole, anisic aldehyde	Agarwal *et al.*, 2020
Mentha piperita (Peppermint)	Oil	Menthol, menthone,1,8-cineole, methyl acetate, methofuran, isomenthone, α pinene, trans sabinene hydrate	Agarwal *et al.*, 2009; Patra *et al.*, 2012
Moringa oleifera (Drumstick)	Seeds, leaves	Saponins, phenols, tannins	Soliva *et al.*, 2005; Leitanthem *et al.*, 2022
Ocimum sanctum (Tulsi)	Leaves	Essential oil like eugenol, terpenes etc. and camphor	Chaturvedi *et al.*, 2015
Peltiphylum peltatum	Leaves	Tannins	Jayanegara *et al.*, 2009
Populus deltoides (Poplar)	Leaves	Essential oil, tannins, flavonoids and resin	Kumar *et al.*, 2022
Psidium guajava (Guava)	Leaves and fruit	Selinene, caryophyllene, squalene, oleanolic acid, urosolic acid etc.	Al-Sagheer *et al.*, 2018
Quercus incana (Oak)	Leaves	Catechin, hyperin, astragalin, kaempferol, triterpene, saponin, gallic acids etc.	Lohan *et al.*, 1983
Rheum undulatum	Leaves	Tannins	Jayanegara *et al.*, 2009
Rhus typhina	Leaves	Tannins	Jayanegara *et al.*, 2009
Sapindus mukorossi/ Saponaria (Soapnut, Reetha)	Seed, pulp	Saponins (mukoroside)	Agarwal *et al.*, 2006; Kamra *et al.*, 2000
Syzygium aromaticum (Clove)	Flower buds/ oil	Volatile oils like eugenol, pinene acetyleugenol, methyl salicylate, vanillin etc.	Kamra *et al.*, 2012; Pawar *et al.*, 2014
Terminalia bellerica (Bahera)	Seed pulp	Gallic acid, ellagic acid etc.	Agarwal *et al.*, 2020
Terminalia chebula (Harad)	Seed pulp	Tannins, chebulinic acid, gallic acid and resin	Agarwal *et al.*, 2020
Vaccinium vitis	Leaves	Tannins	Cieslak *et al.*, 2012; Cieslak *et al.*, 2014
Zingiber officinale (Ginger)	Ginger	Essential oil like zingerone zingiberene, linalo oil etc.	Altincekic *et al.*, 2021

findings highlight the potential of plant bioactive compounds, particularly CTs, in mitigating methane emissions in livestock. According to the work done by Animut *et al.*, 2008 a decrease in methane production is seen when the CTs in dietary level is 140-150 g/kg DM or daily intake of about 115-139 g in goats. Plant saponins attributed to their anti-protozoan activity to reduce methane.

Harit Dhara, a feed supplement developed by ICAR-NIANP from natural phyto sources through extensive research spanning a decade, has proven to be highly effective in reducing enteric methane emissions in livestock. When incorporated into their feed, it can lead to a significant reduction of up to 17-20% in methane emissions. This innovation holds great promise in addressing the environmental impact of methane production in the livestock industry. This feed supplement is rich in saponins and tannins. Saponins have the ability to cause defaunation through binding with sterols present on the protozoal surface, while tannins have the ability to inactivate ruminal enzymes (Kataria, 2016). The dose of this product varies according to the animal's type and age. An average requirement of 150-200 g daily for adult cattle and available at rupees 6/kg makes it a low-cost technology. The propionic acid formed in the fermentation process after the consumption of HD will give more energy-stimulating lactose formation and body weight gain. There is a need to prepare similar products from other herbal products for large-scale promotion, including commercialization. Since methane mitigation at the farmer level is not economically encouraging, the Government needs to promote the industries preparing methane-mitigating products.

In a study conducted by Alves *et al.* (2017), the impact of *Acacia mearnsii* tannin extract supplementation on grazing dairy cows was examined in terms of Dry Matter Intake (DMI), enteric methane emission, and overall performance. The study involved 12 Holstein cows divided into two groups, each receiving different treatments. These treatments consisted of millet pasture (*Pennisetum glaucum* L.) and either a 6 kg concentrate supplement with or without 120 g of tannin extract. The findings of the study concluded that the supplementation with tannin extract had a significant impact. Specifically, methane emissions were significantly reduced by 32% (with a p-value less than 0.05) in the animals that received the tannin extract, as compared to the non-supplemented animals.

Effect of essential oils on methane production: Essential oils extracted from various sources, including thyme, oregano, cinnamon, garlic, horseradish, rhubarb, and frangula, have been found to effectively reduce methane emissions in a dose-dependent manner. This means that as the dosage of these essential oils increases, their ability to decrease methane production becomes more pronounced. These natural extracts have shown promise in mitigating methane emissions in livestock and other contexts (Benchaar and Greathead, 2011).

As per the *in vitro* studies conducted by Patra and Yu (2015), garlic oil alone or in combination with nitrate and/or saponin reduced methane production as well as methanogen population. However, as per the latest available results, the beneficial effects of garlic compounds in rumen metabolism, as reported by different investigators, were found to be inconsistent, and more studies were recommended (Sari *et al.*, 2022). Methanol extract and ethanol extract of clove buds reduce the methane emission but also reduce digestibility (may be because of tannin). Peppermint oil's role in methane reduction can be attributed to its anti-protozoa activity. At high doses of 1.0-2.0 mL/L, it demonstrated a direct effect on the activity of both methanogens and protozoa, as observed in the study by Pawar *et al.* (2014).

Garlic, when included at a rate of 135 mg/g of substrate, resulted in more than a 20% inhibition in CH_4 yield (mL/g DM), without affecting total gas production. It even slightly increased in vitro DM degradability by 2%, according to García-González *et al.* (2008).

Patra (2010) reported that tannins decrease the digestibility of organic matter and neutral detergent fiber with a decrease in methane production, but in the case of saponins, essential oil and organo-sulphur compounds, there was no effect in digestibility with a decrease in methane production.

In a study conducted by Beauchemin and McGinn (2006), the effects of feed additives, specifically fumaric acid (at 175 g/d) and canola oil (at 4.6% of DM intake), on methane emissions from beef cattle were examined. The study's findings indicated that canola oil has the potential to reduce daily methane emissions by as much as 32%, leading to a 21% reduction in gross energy loss due to methane. However, the investigators cautioned that while canola oil has the potential to reduce methane production, there were associated risks, including decreased fiber digestibility and dry matter intake.

Patra and Yu (2012) conducted a study to examine the impact of five different essential oils, namely clove oil (CLO), eucalyptus oil (EUO), garlic oil (GAO), origanum oil (ORO), and peppermint oil (PEO), each administered at three different doses (0.25, 0.50, and 1.0 g/L), on methane production. The results of their study showed that all the tested oils had a significant effect in reducing methane production as the doses increased. At a dose of 1.0 g/L, the reductions in methane production were substantial, with CLO reducing it by 34.4%, EUO by 17.6%, GAO by 42.3%, ORO by 87%, and PEO by 25.7% compared to the control group.

Beauchemin *et al.* (2009) conducted a study to investigate the impact of crushed oil seeds as a source of long-chain fatty acids on methane production, rumen fermentation, and milk production in lactating dairy cows. The number dietary treatments were four viz. a commercial source of calcium salts of long-chain fatty acids (CTL), crushed sunflower seeds (SS), crushed flaxseed (FS), and crushed canola seed (CS). All 3 oilseed treatments decreased methane production (g/d) by an average of 13%. After adjusting for variations in Dry Matter Intake (DMI), it was observed that when compared to the control group (CTL), methane production per kilogram of DMI was reduced by 18% when feeding FS, 16% when feeding CS, and showed a numerical decrease of 10% when feeding SS. Consequently, it was determined that only CS had the effect of lowering methane production per unit of digestible dry matter intake.

Conclusion

Based on the information provided, it is evident that ruminants play a significant role as the primary methane producers in livestock. Addressing the reduction of ruminal methane production in ruminants is a complex challenge. It's clear that farmers are unlikely to adopt these measures unless there is a positive economic impact on animal production. Some strategies can simultaneously reduce emissions and enhance farm profitability, but the extent of this impact often depends on market conditions and varies from region to region. Nonetheless, we can make significant strides in diminishing methane production through the adoption of biotechnologies, enhancing the efficiency of animals, cultivating high-quality forages and pastures, incorporating alternative feeds with high levels of ingredients like tannin and saponin, and leveraging the benefits of probiotics.

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