Forage Res., **47** (2) : pp. 139-146 (2021) **http://forageresearch.in**

NUTRITIONAL MITIGATION OF ENTERIC METHANE GAS EMISSION FROM LIVESTOCK SECTOR : A REVIEW

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(Received : 15 September 2021; Accepted : 29 September 2021)

SUMMARY

An environmental impact of livestock production has been given significant attention over the last few year. Besides increasing animal production and productivity, feeds are used to mitigate enteric methane production in the animal production sector. Enteric methane produced in the gastrointestinal tract of animals has direct effect on green house gas released from the livestock production. Enteric methane mitigation practices for animal production have been studied. Supplementation of roughage feed, concentrated feeds, addition of feed additives to animal feed are the major practice used to mitigate the enteric methane production from animal production sector. Decreasing roughage proportion with concentrate ration, while increasing the amount of crude fat (ether extract, EE) in dairy diet reduces enteric methane emissions. In the back knowledge, methane is mitigated through feeding animals diets with lipids due to its effectiveness in reducing CH_4, environmental safety, and animal health. Methane reducing strategies have their role to retention of energy in the animal body by dietary feed additives; plant extracts and chemical supplementation have been conducted to address their potential to reduce methanogenesis in the feed metabolism. Enteric methane emissions may be effectively reduced by manipulation of natural gastro-intestinal micro-floras and other micro-biota with various dietary supplementation and improved animal production efficiency.

Key words : Dietary manipulation, enteric methane, livestock sector

Global warming, caused by increasing atmospheric concentrations of greenhouse gases (GHGs), is a major worldwide environmental, economic and social threat. It is well acknowledged that livestock production responsible to this problem (Steinfeld *et al.,* 2006) of crucial concern for livestock production is the methane (CH_4) generated by ruminant livestock during the normal process of feed digestion or microbial fermentation of feeds, by methanogenic archaea. Despite of livestock production being an important basis of livelihoods for many communities around the globe, it is also an important provider to global greenhouse gas (GHG) emissions. Globally, about 95 million tons of CH_4 are emitted from enteric fermentation of domestic animals in 2010 with an annual growth rate of 0.90% (Patra, 2014). It is globally estimated that 18% of annual worldwide GHG emissions, are attributable to cattle, buffalo, sheep, goats, pigs and poultry (Steinfeld *et al.,* 2006); food production is also 26% of the total annuals global GHG emission (Hannah, 2019). Moreover, enteric methane supplies 17% and 3.3% of global methane and green house gas emissions, respectively, which mostly arises from Animal production sectors (Knapp *et al.,* 2014). The researchers Mekonnen and Hoekstra (2012); Ripple *et al.,* (2014) also pointed out that, livestock sector contributes ~14.5% of all anthropogenic greenhouse gas (GHG) emissions (7.1 giga tonnes of CO_2- equivalent per year). Internationally, the production, processing and logistics of feed contribute about ~45% of the green house gas emission from the animal production (Gerber *et al.,* 2013).

Many researches are directed towards methane emissions in the livestock production (Gill 2013; Hristov *et al.,* 2013) and some towards quantifying methane emissions as a result of feed production (land use and land-use change) and feeding practices (Gerber *et al.,* 2013). Numerous scholars like Hristov *et al.,* (2013); Gerber *et al.,* (2013); Hegarty *et al*., (2007) outline the methane mitigation strategies by genetic, dietary feed additives, plant extracts and chemical supplementation have been analyzed to address the capability to decrease methane synthesis. Mitigation strategies of enteric CH_4 are considered to be less expensive than carbon dioxide (CO_2) emissions (Patra, 2014; Knapp *et al.,* 2014). Inhibition of CH_4 emission by some technologies generally does not cause much detrimental effects on rumen fermentation, but may improve rumen fermentation efficiency.

The authors Sauvant and Giger-Reverdin, (2009) in their experiment showed that chemical composition and feed intake are main factors affecting methane production by ruminants. Animals consume roughage feed produce more methane than those fed the combination of concentrate and roughage diets. Improving the quantity and quality of forage produced will also improve animal feed efficiency, reduce CH_4 emissions per unit of animal product, and lead to production benefits for farmers. Numerous alleviation options have been projected such as vaccines, chemical additives, animal breeding, CH_4 capture and so forth but diet management is the most direct, and probably the most successful, means of minimizing enteric methane emissions from ruminants in most production and feeding systems. Therefore this review paper outlines or shows that the way of manipulation of animal diet to reduce enteric methane (CH_4) emission from animal production sector.

Interaction of livestock production and environment

Livestock production has its link 30% to land surface and 8% to global water for feed crop irrigation (FAO 2009). According to Mekonnen and Hoekstra (2012); Ripple *et al.,* (2014) the area dedicated to feed-crop production represents 33% of total arable land. In Animal production, feed production contributes 36% and 28% of the total emissions, respectively feed production and use also impact on land use and land-use change, which leads to loss of sequestered carbon and biodiversity (Gerber *et al.,* 2013).

Methanogenesis and methane production in the rumen

Enteric methane is a natural a microbial by-product of feed fermentation within the rumen and, to some extent, in the subordinate digestive tract. The process of CH_4 synthesis in the rumen where H_2 reduced the CO_2 with the help of methanogenic archaea is called methanogenesis. The authors Stams, and Plugge (2009) stated that methanogensis is a dynamics process, in which methanogens strongly influence the metabolism of fermentative and acetogenic bacteria via interspecies hydrogen transfer. The produced H_2 and CO_2 are the major substrates that are used by methanogens, which is considered being the main pathway of CH_4 production in the rumen (Ellis *et al.,* 2008). Methane emission represents a significant metabolic use for decreasing equivalents hydrogen that would otherwise produced in much amount in the rumen and create an unfavorable environment for fermentative digestion processes (Morgavi *et al.,* 2010). Archaea bacteria in the Rumen play a crucial role for methanogenesis (Hook *et al.,* 2010). Because, neither of these microbes (Methanosphaera spp.) is abundant in the rumen (Janssen, Kirs 2008), the contribution of these substrates to total CH_4 production is expected to be lower (Morgavi *et al.,* 2010). Therefore, the inhibitors of this methanogenesis pathway may distinctively inhibit only methanogens without directly influencing other beneficial microorganisms within the rumen (Moate *et al.,* 2013).

Dietary Strategies to Mitigate Enteric Methane (CH_4) Emissions

Dietary strategies are often divided into two main categories: (i) improving the forage quality and changing the proportion of the diet and (ii) dietary supplementation of feed additives that either directly inhibit methanogens or altering the metabolic pathways resulting in a reduction of the substrate for methanogenesis. Among the nutritional strategies of CH_4 mitigation, dietary manipulation could be a simplistic and pragmatic approach that may ensure better animal productivity also as a lower CH_4 emission. Md Najmul Haque, (2018), also indicated that CH_4 emissions can possibly be reduced up to 75% through better nutrition. Several mitigation options and techniques are explored, which involve intervention at the animal level, dietary composition of animals, modulation of rumen fermentation, and inhibition of methanogenic archaea.

Efficiency of dietary Forage for enteric methane reduction

Forage quality has influences CH_4 production in the rumen (Boadi and Wittenberg, 2002). High-quality forage, e.g. young plants, can reduce CH_4 production by altering the fermentation pathway because this forage contains higher amounts of easily fermentable carbohydrates and fewer NDF, resulting in a better digestibility and passage rate. In contrast, more mature forage induces a higher CH_4 yield mainly because of an increased C:N ratio, which decreases the digestibility. Hammond, Burke (2013), found an inconsistent effect of the chemical composition of clover and ryegrass on CH_4 production. Beauchemin *et al.,* (2008) outline that legume forage contains a lower CH_4 yield, which is explained by the presence of condensed tannins, low fibre content, a high dry matter intake and a quick passage rate. Generally, C_4 grasses yield more CH_4 than the C_3 plants (Archimède *et al.,* 2011). Forage processing and preservation also affect CH_4 emission (Martin *et al.,* 2010). Similarly the study of Boadi *et al.,* (2004) showed that chopping or pelleting forages can reduce the CH_4 emission per kg of DMI, as smaller particles require less degradation in the rumen.

Efficiency of dietary concentrates for enteric methane reduction

Most of the researchers showed that there has a change in enteric methane production from livestock sectors when animals fed with dietary concentrate feed. High-producing dairy cows have a higher requirement that exceeds their capacity to ingest nutrients from forage only. Therefore, forages must be supplemented with concentrates with a better density of nutrients and less fibre. Because of less cell walls and readily fermentable carbohydrates (starch and sugar), concentrates favor propanoic acid production, decreasing CH_4 emission (Martin *et al.,* 2010). The increased dietary level of concentrate reduces CH_4 production because the energy proportions generally utilized by the animal products, like milk, egg and meat. Most energy rich concentrates are related to increase DMI, rate of rumen fermentation and feed turnover, causing a greater change in the rumen environment and microbial composition (Martin *et al.,* 2010). In beef cattle, the digestion of the cell wall results in better acetate: propionate ratio and CH_4 loss compared to other carbohydrate fraction; within non-structural components, sugar is more methanogenic than starch. The authors Tamminga *et al.,* (2007) show that all of the carbohydrate fractions contribute to CH_4 loss, of which the least contribution is that from starch, probably because of the maintenance of a propionate-dominating VFA profile. Feeding more starch to ruminants reduces enteric CH_4 energy losses compared to feeding a forage diet (Beauchemin *et al.,* 2009). Hindrichsen *et al.,* (2005) outline that, In contrast, sugar as a water-soluble carbohydrate is rapidly and completely degradable within the rumen, enhancing butyrate production at the expense of propionate, thereby making sugar concentrates more methanogenic than starch.

Lipid Supplementation

Dietary lipids modify the rumen environment in several ways, including (1) toxic characteristics on microbes in rumen such as methanogen and protozoa, (2) hydrogenation of unsaturated fatty acids (3) shifts to propionic production, resulting in reduction of enteric CH_4 production (Beauchemin *et al.,* 2008, 2009b). Several meta-analyses were conducted to estimate the impact of dietary lipids on CH_4 production (Beauchemin *et al.,* 2008; Eugène *et al.,* 2008; Martin *et al.,* 2010). In recent times, lipid has been used for enteric CH_4 reduction. Several studies have showed that addition of fats or fatty acid to the diets of ruminants can decrease enteric CH_4 emissions (Williams, 2014, and Patra, 2013). In another study, Patra (2013) states that percentage increase in supplemental dietary fat decreases CH_4 emission by about 4.30%. Fat concentrations of up to six of diet DM can also increase milk production and lower enteric CH_4 emissions appreciably (15%) in cattle. Fat concentration beyond this concentration may decrease production efficiency because of adverse effect on rumen fermentation. In dairy cow, Eugène *et al.,* (2008) reported a decrease of 9% through lipid supplementation (average 6.4%) compared with control diets (average 2.5%), mostly as a consequence of reduced DMI. Similarly, Patra (2013) reported that 3.77% decline in CH_4 emissions for every percentage inclusion of lipid in milk cow diets. According to Williams (2014) the by-products containing high concentration of lipids (brewer's grains, grape marc, hominy meal, etc.) appear to be promising in mitigating CH4 emission in a cost-effective manner. Moate *et al.,* (2011) reported the subsequent relationship between dietary fat and CH_4 production per unit of DMI: CH_4 (g/kg DM) = 24.51 (±1.48) – 0.0788 (±0.0157) × fats (g/kg DM). Grainger *et al.,* (2010) showed that supplementary feeding of whole cottonseed, brewer's grains, cold-pressed canola, and hominy meal (Moate *et al.,* 2011), to dairy cows could cause a substantial decrease in CH_4 emissions without adversely affecting milk production. Secondary compounds like tannins, p-Coumaric acid and resveratrol can also inhibit enteric methanogenesis to some extent (Moate *et al.,* 2014). Methanogenesis decreases with the application of volatile oil, especially by reducing microbial populations. However, no-effect has been observed to date on the most important aspects of rumen fermentation. Limited studies have investigated the effect on CH_4 reduction *in vivo*.

Medium-chain fatty acids

These include lauric, myristic, capric and caprylic acids (Hollmann *et al.,* 2012). In vitro studies have reported coconut oil, which contains 75% of MCFA, to reduce CH_4 production by 43–85%. In *in-vivo* trials, application of coconut oil also showed similar patterns for CH_4 reduction (Hollmann *et al.,* 2012). Inclusion of myristic acid @ 50.0 g/kg DM in dairy cow diets reduced CH_4 production by 36%, but also reduced milk fat by 2.4%, with a tendency to scale back DMI (Odongo *et al.,* 2007). lauric acid had no-negating effects on methanogenesis in dairy cattle even @ 10.0 g/kg DM (Hristov *et al.,* 2009). Therefore, if fewer amounts of medium-chain fatty acids supplied to animals, no-effects were observed in enteric methane production.

Efficiency of Feed additives to mitigate methane production

***Probiotics* :** The use of probiotics for CH_4 mitigation has recently been described (Schmidt *et al.,* 2019). The CH_4 reduction potential of probiotics has not been well documented precisely because of the unsuccessful introduction of acetogens to the rumen (Lassey, 2007). Probiotics supported by *Saccharomyces cerevisiae* were increasingly employed in ruminant diets and in dairy cattle production to enhance rumen fermentation; dry matter intake and milk yield (Lassey *et al.,* 2001). In contrast, Jeyanathan *et al.* (2019) observed no-effect on methane output while feeding *Lactobacillus pentosus* D_{31} and *L. bulgaricus* D_1 *in-vivo*.

***Biochar* :** Biochar as organic matter and has been utilized for generations as a remedy for digestive disorders and is sourced by the livestock industry to deal with issues surrounding farming, metabolism and waste management (Kalus *et al.,* 2019; Schmidt *et al.,* 2019). Considering that there's already an existing market for biochar as a beneficial feed additive, *in- vivo* evidence for GHG mitigation are significant (Schmidt *et al.,* 2019). Biochar supplemented at 8 g/kg DM reduced CH_4 production by 9.5% in growing steers and 18.4% in finishing steers (Winders *et al.,* 2019). Biochar supplemented @ 8 g/kg DM reduced CH_4 production by 9.5% in growing steers and 18.4% in finishing steers (Winders *et al.,* 2019). However, the mechanisms of action for CH_4 mitigation in cattle aren't well understood (Terry *et al.,* 2019; Man *et al.,* 2020).

***Exogenous enzymes* :** Enzymes, like cellulase and hemicellulase, arecurrently being employed in ruminant diet. Enzymes that improve fibre digestibility typically lower the acetate: propionate ratio in the rumen, ultimately reducing CH_4 production (Eun *et al.,* 2007). Subsequently, in a review, Beauchemin *et al*., (2008) suggested the possibility of developing a commercial enzyme additive to scale back methane. However, attempting to find potential enzymes for methane abatement warrants future research.

***Plant Secondary Compounds* :** Several plant secondary metabolites present in forages and plant extracts are identified to be potential for CH_4 inhibition in the rumen by directly affects the methanogenesis bacteria. The CH_4-suppressing effect of PSM is especially related to anti-microbial properties that kill the bacteria (Bodas *et al.,* 2012), protozoa (Hristov *et al.,* 2003) and fungi (Patra and Saxena, 2009) in the rumen. Forage plants rich in tannins and saponins are potentially promising to reduce methane directly by inhibiting methanogenic bacteria production in ruminants (Li *et al.,* 2014).

***Halogen* :** Gribble (2004) define halogens as elements that hold an oversized, negative electron affinity and seek to combine with other compounds to achieve stability through satisfaction of the valence shell in the rumen environment. The B_{12}-dependent methyl-transferases also play a crucial role in one carbon metabolism in acetogenic bacteria (Banerjee and Ragsdale, 2003). Roque *et al.,* (2019a, 2019b) outline that, *Asparagopsis taxiformis* and *A. armata* are evaluated for their mitigation potential both *in-vitro* and *in-vivo*. And the study show that Steers dosed daily with 0.267 g/kg DM of chloroform were shown to decrease 94–95% of CH_4 production within 4-5 days of treatment.

***Tannins* :** Tannins are soluble, phenolic compounds that accumulate within plant tissues likely because of ongoing metabolic processes and contribute to the plant defense system (Swanson 2003). Methane measurements from goats fed Kobe lespedeza, forage containing condensed tannins at 151, 101 and 49.9 g/kg of DM led to a 54, 52 and 32% methane reduction compared with the control group respectively (Animut *et al.,* 2008). Investigating different tannin-containing hays, Stewart *et al.,* (2019) found small burnet (Sanguisorba minor) fed to Angus cows and heifers to 209 vs 289 g CH_4/day reduce CH_4 production as compared to a diet containing alfalfa hay respectively. More recently, Caetano *et al.,* (2019) fed ensiled grape marc @ 31.2 g/kg DM, 3-4 kg/day of ensiled grape marc (estimated on the basis of reported DMI).

Ionophores : A research analysis showed by Appuhamy *et al.,* (2013) investigates the impact of monensin in livestock production. Beef cattle delivered with ionospheres at an average dose of 0.032 g/kg DM, methane production was decrease by 19 g/day. Similarly In dairy cattle, methane production was decreased by 6 g/day animals take the same average dose. On the other side, Benchaar (2020) observed non-significant effect of monensin on methane when animals took 0.024 g/kg DM.

CONCLUSION AND RECOMMENDATION

A Number of methane alleviation ways are presented and currently put into practice. Use of synthetic chemicals, plant metabolites or such applications attributes momentary effects on methane diminution. However, overall dietary management by selecting and utilizing quality forages, planned supplementation of forages, changing concentrate proportion with roughage composition should be considered as an immediate and sustainable methane alleviation approach of enteric CH_4 emitted from ruminant livestock. Use of locally available feed additives provides a promising option that can increase the sustainability of animal-sourced foods by substantially reducing enteric CH_4 emissions.

As a recommendation, very limited information is outline on the consequences of bypass starch on methane reduction mechanism; therefore research should be conducted on the issue of bypass starch to mitigate the methane production. Biochar has proven feed additive to reduce enteric methane emission now a days. More research should be conducted, mainly *in-vivo*, is required to grasp the conditions under which biochar can mitigate methane production.

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