June/2024

Feed additives: A focus on reducing enteric methane emissions

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Introduction

The primary source of methane emissions (CH_4) from ruminants or cattle (beef or dairy) is enteric fermentation; hence various feed additives have been developed or are under investigation for their potential to mitigate enteric CH_4 emission. This Fact Sheet reviews the basic background information, current research, challenges, and future research directions for feed additives which have potential to reduce enteric emissions.

What are feed additives?

A feed additive is a substance added to a basal diet of animals, usually in small quantities, to fortify it with specific nutrients, stimulants, or medicines other than as a direct source of nutrients. It is usually a non-nutritive product that affects the utilization of the feed or improves the product of animal origin or enhances the productive performance and health of the animals.

Why do we add feed additives to dairy cow's diet?

Feed additives aid cows in eating (consuming) more feed, digesting and absorbing it better, changing their metabolism and improving digestibility (Zhang et al., 2020; Hassan et al., 2020), which results in an overall improvement in performance and efficiency (Pandey et al., 2019; Kholif et al., 2021). In addition, they help to protect cows from stress during the period of transition from periparturient to neonatal period - thereby improving their health and productivity (Zhang et al., 2020; Lopez, 2023). Feed additives have also been found to be effective in preventing a variety of metabolic disorders, such as ketosis (Mammi et al., 2021), fatty liver (Zhang et al., 2020), acidosis (Cavallini et al., 2022), and milk fever (Marin et al., 2020). Furthermore, supplementation of certain feed additives, alongside effective management practices, has been found to be a preventive measure for mastitis, a substantial financial concern for dairy farm profitability (Mushtaq et al., 2018). Finally, some feed additives are used to improve environmental sustainability i.e., mitigation of enteric CH4 emissions (Roque et al., 2021; Kebreab et al., 2023) and manure ammonia emissions (Ti et al., 2019).

Why is there a growing interest in feed additives to cut enteric methane emissions?

Rumen modulation with feed additives has become an increasingly common approach to reducing CH_4 emissions. Effects of feed additives are immediate compared to genetic improvement which takes a long period of time to make improvements. It is more effective at reducing CH_4 emissions and is easy to use. There are several feed additives that have been reported to have the potential to reduce enteric CH_4 emissions. In terms of effectiveness, red seaweed has shown the highest CH_4 reduction rate of 71% (Machado et al., 2016), followed by 3-nitrooxypropanol (3-NOP) at 30% on average (Hristov et al., 2015) and nitrate at 29% (Jayanegara et al., 2011). The effectiveness of these additives is highly dependent on dose, forage levels and source, and fat percentages in dairy cows' diets. Seaweed contains active compounds called bromoform, which disrupts CH_4-producing microbes, 3-NOP inhibits the methanogenesis process, and nitrate reduces the availability of inputs (e.g., hydrogen) for CH_4 formation. Moreover, dietary lipids, probiotics, biochar, and ionophores have all shown moderate effectiveness, reducing CH_4 emissions by 13-27% (Garcia et al., 2018). The efficacy of tannins, flavonoids, saponins, and essential oils yielded inconsistent findings widely depending on the source and dose.

Does milk composition vary for supplementing these feed additives?

Based on recent studies, seaweed, 3-NOP, and nitrate supplementation have little to no effect on milk composition, e.g., fat, protein, or fatty acid (Muizelaar et al., 2021). Recent meta-analyses revealed that 3-NOP increased or tended to increase milk fat and protein percentage (Jayanegara et al., 2018; Kim et al., 2020). Nevertheless, nitrate supplementation had no effect on milk fat and total solid content at low doses (e.g., 0.11g nitrate /kg of body weight), but at high doses, it lowered milk fat and milk solids and increased lactose (Xie et al., 2022). Similarly, the supplementation of seaweed, reduced milk fat percentage to some extent and caused alterations in milk fatty acid composition. These changes ultimately led to an increase in omega-3 fatty acids, considered vital for human health (Altomonte et al., 2018). Few studies, including a short-duration study by Muizelaar et al. (2021), reported no accumulation of bromoform (the active component in seaweed) in animal tissue, but they traced bromoform in milk and urine of cows fed seaweed. Thus, feed additives warrant further longer-term studies focusing on how they are secreted in their natural or modified form in the urine or milk of the animals and whether they influence animal or human health through consuming animal-origin food from animals fed feed additives. Further long-term studies will be needed to understand how the flavors and processing techniques such as cooling or freezing, heating (thermalization, pasteurization, UHT, sterilization), homogenization, separation, fermentation, fractionation, concentration, and drying affect these secreted components in milk and milk products and whether there is a health hazard associated to it.

What are the challenges in adopting the most promising feed additives?

One of the challenges is that feed additives are expensive. For instance, harvesting and purifying seaweed is costly, rendering it burdensome for some producers, especially small farmers. However, producing it in a laboratory setting raises questions about the sustainability of the production system and the unreasonable cost. Additionally, when used in lower doses (e.g., 0.25% inclusion as dry matter), it did not improve milk production. In fact, milk production decreased when doses exceeded 0.50% (Stefenoni et al., 2021). This raises concerns about the value of using this substance. Furthermore, the fact that it has little to no effect on animal productivity and increases production costs discourages farmers from using this additive (Kebreab et al., 2023).

Another challenge is that these additives do not have regulatory approval in every country. Seaweed releases bromoform during cultivation and depletes ozone. Ozone can convert it to bromate, a potential carcinogenic agent (Jia et al., 2022). Some research demonstrated that feeding bromoform also causes inflammation in the rumen epithelium, negatively affecting absorption (Muizelaar et al., 2021). It also requires logistical support for handling and storage since efficacy depends on the amount of bromoform present, necessitating long-term efficacy and practicality studies of this additive. The European Union and the Food and Drug Administration (FDA) have already approved the 3-NOP but countries such as New Zealand, have not. More data must be collected on the 3-NOP's long-term safety and potential effects on animal health and productivity (Clemens et al., 2020). Nitrate also requires additional research concentrating on animal and human health and safety, as high doses cause severe toxicity in animals. There is a need for quantitative assessment tool for feed additives in assisting adoption decisions by the producers or dairy nutritionists or other stakeholders along the dairy value-chain. This assessment tool should consider safety, efficacy, benefits, and tradeoffs.

What should be the focus of future research on feed additives?

Some recent studies reported interactions between feed additives and diets, e.g., 3-NOP has better efficiency in cutting down CH_4 in corn-silage than in grass-silage diets (van Gastelen et al., 2022). Whereas other studies demonstrated the tradeoffs between animal performances and emission sources, i.e., some feed additives can effectively reduce enteric CH_4 but decrease feed intake, efficiency, or digestibility of nutrients (Uddin et al., 2021). Feed additives may sometimes increase manure greenhouse gas emissions, though they can reduce enteric emissions (Uddin et al., 2022). A recent study indicated that manure from cows fed 3-NOP altered the soil microbiome and enzyme activities when applied to agricultural fields (Lupwayi et al., 2023). Thus, further study should particularly focus on 1) interactions between feed additives and diets, 2) holistic evaluation of feed additives using life cycle assessment to capture tradeoffs between emission sources, avoiding misleading conclusions, 3) potential consequences in soil health through manure, 4) the additive's secretion or transfer to milk, 5) whether these additives get transferred or modified or reactivated during processing and manufacture of various milk, milk and food products and 6) the short as well as long term health and safety of both animals and humans.

Safety aspects of these additives

FAO (2023) has recently published a paper on inhibitors, possibly identifying human health concerns linked to methane reducing additives fed to dairy cows. The IDF Standing Committee on Residues and Chemical Contaminants has also identified methane reducing feed additives as an area to monitor for possible contamination of the milk. Given the diversity of additives that have been investigated for their effect on enteric methane production, assessing food safety aspects from methane reducing additives will require a case-by-case approach, identification of risks, knowledge gaps and monitoring developments in this area.

Concluding remarks

At this point, it could be concluded that feed additives might be an effective approach to cut down the enteric CH_4 emissions from dairy cows. However, existing additives need to be redesigned to accomplish synergy with CH_4 emissions and milk production, with cow and human safety concerns and long-term efficacy needing to be addressed under various dairy cattle dietary and production scenarios.

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Acknowledgements

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