# Environmental impact of feed additives in cattle production

**Ermias Kebreab, PhD**
University of California-Davis, Davis, CA 95616

## Abstract

Cattle production is one of the main contributors to methane emissions globally. Although there are nutritional, genetic and other methods to reduce methane emissions from cattle operations, feed additives have the potential to substantially decrease emissions. These can be broadly categorized based on their mode of action into 2 main groups. Feed additives can either directly inhibit methanogens that are responsible for methanogenesis or modify the rumen environment to reduce the amount of methane produced. In general, inhibitors such as 3-nitrooxypropanol and macroalgae reduce emissions by 30 to 80%. Feed additives that work indirectly generally reduce emissions by less than 25%. However, a combination of the 2 types may increase the level of anti-methanogenic effectiveness. Some of the most effective feed additives are expected to be available commercially in 2022-2023 in some parts of the world contributing to methane mitigation efforts.

**Key words:** methane, feed additives, mitigation, climate change

## Introduction

Increased attention on methane emissions from ruminants has increased research in its mitigation. Although there are a number of proposed solutions, research on feed additives that have the potential to reduce enteric methane emissions has increased substantially. Anti-methanogenic feed additives can either directly affect methanogenesis in the reticulorumen or indirectly by modifying the rumen environment. Methane inhibitors target methanogens or other microbes associated with methane emissions. Indirect methods include providing the rumen with alternative hydrogen sinks or modify the rumen environment such that hydrogen production, hence, methanogenesis is reduced.

## Feed additives directly targeting methanogens

### 3-Nitrooxypropanol (3NOP)

3NOP is a small molecule with similar shape similar to that of methyl-coenzyme M, which is a substrate of coenzyme M reductase (MCR), the enzyme involved in the last step of methanogenesis.[1] MCR catalyzes the methane-forming step in the rumen fermentation. 3NOP preferably binds into the active site of MCR and effectively inactivates it. 3NOP is demonstrated to inhibit growth of methanogenic archaea at concentrations that do not affect the growth of nonmethanogenic bacteria in the rumen.[1] Several studies using 3NOP as an additive have reported reduction in methane emissions from beef and dairy cattle up to 60%. A meta-analysis [2] estimated the effectiveness of 3NOP to be an average of 32.5% reduction, however, 3-NOP dose and diet composition affected the level of methane mitigation achievable. Supplementation of 3NOP did not significantly affect feed intake or milk production.[3] 3NOP is now approved for use in the European Union, Brazil and Chile among other countries. It is still awaiting registration in the U.S. and Canada.

### Macroalgae

Some seaweed species, particularly *Asparagopsis* spp., contain bromoform and bromochlormethane as active ingredients that has been shown to be effective in vitro.[4] In vivo trial using *Asparagopsis* spp. in dairy cattle reported up to 67% reduction in methane production in dairy cattle.[5,6] Methane emissions in Brangus cattle declined 98% with inclusion of only 0.02% (on organic matter basis) of *Asparagopsis* taxiformis.[7] A longer-term study reported no evidence of microbial adaptation, however, the anti-methanogenic efficacy was dependent on fiber concentration.[8] The efficacy of methane reduction appears to correlate with the concentration of bromoform compounds, which appear to be the main active ingredients although other yet-to-be identified substances may contribute to methane reduction as well.[9] A formulation containing *Asparagosis taxiformis* (Brominata©) is now approved for use and sale in California. However, it will need to be approved by Food and Drug Administration to claim methane mitigation in the U.S.

## Feed additives that affect methanogenesis indirectly

### Nitrate

Nitrate (NO3-) is a strong inorganic anion and as a feed additive, acts as an alternative hydrogen sink in the rumen competing with methanogens for hydrogen utilization thereby reducing methane emission. Based on the stoichiometry for hydrogen consumption within the rumen, nitrate has a theoretical capability of reducing ruminal CH4 production 25.8 g/100 g of nitrate supplemented.[10] A meta-analysis that used only in vivo experiments indicated that nitrate supplementation reduced methane emission in dairy and beef cattle by an average of 13.9% in a dose-dependent manner.[11] The mitigating effect of nitrate on methane production and yield was greater in dairy than in beef cattle. However, effect of type of cattle appears to be related to slow-release nitrate use in beef cattle. Although an effective strategy, it is not recommended in commercial setting because feeding nitrate has the risk of nitrite toxicity resulting in methemoglobinemia. Furthermore, if nitrate is supplemented to a protein-sufficient diet, the extra nitrogen will be excreted and increase nitrous oxide emissions to the atmosphere and contaminate ground water with ammonia. Nitrate does not benefit animal productivity unless added to a protein-deficient diet.[12]

### Tannins

Tannins are soluble, phenolic compounds that accumulate within plant tissues likely due to ongoing metabolic processes and contribute to the plant defense system.[13] Tannins have affinity to bind to proteins and other compounds. They are classified as either condensed or hydrolysable, and both types of tannins have been shown to exert anti-methanogenic effects by directly inhibiting some methanogens and indirectly by decreasing protozoa population associated with methanogens. This decreases hydrogen production through inhibition of fibrolytic bacteria and fiber digestibility, and act as an alternative hydrogen sink to methanogenesis.[14] A meta-analysis[15] showed that low levels of inclusions of tannins in animal diets often yielded inconsistent results on methane production, but that variability seemed to diminish at higher doses. They estimated a linear decrease in methane emission per unit of feed intake of 3.65% with each 10 g/kg DM addition. However, reduction in methane production was often followed by a suppression in organic matter and fiber digestibility. Care should be taken when supplementing tannins as several studies have shown that tannins bind and interact with dietary proteins in the gastrointestinal tract, which reduces nitrogen availability to the animal.[16]

### Essential oils and blends

Essential oils are naturally occurring chemical compounds extracted from plants and used in fragrances and cosmetics and, to a lesser extent, pharmaceutical products for humans and animals.[17] Consumption of essential oils affects rumen microbial communities and fermentation patterns in a varying manner, depending on the source.[18] Many essential oils hold a high affinity for lipid and bacterial membranes, leading to disruption, but the broad antimicrobial effect is likely to be due to a combination of mechanisms.[19] Numerous plants such as cinnamon, lemongrass, ginger, garlic, juniper berries, eucalyptus, thyme, citrus, oregano, mint, rosemary and coriander have been screened in vitro.[20,21] However, only few have been studied in vivo. Some studies have used an essential oil "blend" or "complex" containing extracts from multiple plants. For example, Mootral, synthesized from natural products including garlic- and flavonoid-containing citrus extract, reduced methane emissions by 23% after 12-week supplementation at 1.58 g/kg DM.[22]

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