Global Methane Hub

ENTERIC FERMENTATION
R&D ACCELERATOR

STATE OF SCIENCE

3-Nitrooxypropanol Methane Inhibitor

Prepared By: Karen Beauchemin and Rolf Thauer, Updated July 1, 2024

3-Nitrooxypropanol (3-NOP, commercial name Bovaer®) is a methane (CH_4) inhibiting feed additive developed by DSM Nutritional Products. It is currently approved by regulatory authorities for use in the E.U. (for dairy only), Australia, Brazil, Canada, Chile, Mexico, Pakistan, Switzerland, Turkey, and the United Kingdom. A substantial body of research has been published indicating that adding low concentrations of 3-NOP to diets decreases enteric CH_4 emissions by 20 to 35% in dairy cattle and forage-fed beef cattle, and by 40 to 80% in feedlot cattle fed high grain diets. The mitigation effect is dose dependent and is negatively affected by increasing dietary concentration of fiber (Kebreab et al., 2023). Typical inclusion levels are: 125 to 200 mg/kg of dry matter in beef cattle diets and 60 to 80 mg/kg of dry matter in dairy diets. 3-NOP is most effective when added to total mixed rations fed to dairy cows or feedlot beef cattle reared in confinement. In its present form, 3-NOP is not applicable to grazing ruminants or animals that are self-fed hay and silage without supplementation (e.g., beef cows). More research is needed to produce a slow release form that could be used for grazing ruminants or added to a supplement offered once a day.

STATE OF SCIENCE

The mechanism of action of 3-NOP is well established (Duin et al., 2016); 3-NOP targets methyl-coenzyme M reductase, the enzyme that catalyzes the last step of methanogenesis in methanogenic archaea. Safety risks of using 3-NOP have been deemed as low by most experts (e.g., European Food Safety Authority, 2021). Once consumed by the animal, 3-NOP is rapidly metabolized in the rumen to nitrate, nitrite and 1,3-propanediol, which are naturally occurring products of ruminal fermentation (Duin et al., 2016).

Most of the research with 3-NOP has been limited to relatively short feeding periods (≤ 12 weeks), thus long-term effects on CH_4 mitigation, animal performance and health are not well known. Few studies have examined whether there is a loss of effectiveness of 3-NOP over time. Long-term studies that examine effects of 3-NOP over multiple lactations, or over entire backgrounding and finishing periods of beef cattle, are needed. In order to address this gap, a recent full lactation study (van Gastelen et a., 2024) with Holstein Friesian cows reported on average a 16%, 20%, 16%, and 26% reduction in CH_4 yield (g/kg DMI) for the dry period, early-, mid-, and late lactation diets, respectively. However, CH_4 mitigation potential of 3-NOP appeared to decline over time, and more research is needed to clarify the long term effects.

In most studies, 3-NOP has not resulted in consistent improvements in animal performance (milk yield in dairy cows or body weight gain in beef cattle), although there are some exceptions, as reviewed by Jayanegara et al. (2018), Kim et al. (2019), and Yu et al. (2021). Diet digestibility is typically unaffected (Jayanegara et al., 2018), or only slightly improved (Kim et al., 2020). Controlled field scale studies are needed for both dairy and beef cattle to determine whether mitigation effects observed in controlled research studies are reproducible in commercial settings that vary in environment, animal type, diet composition, and management.

The CO_2 emissions associated with the manufacture and transport of 3-NOP are very low. There is some inconsistency in the literature in terms of manure emissions when 3-NOP is added to diets, and thus, requires further research. No effects of feeding 3-NOP on manure emissions were observed in one field study, but a lab scale study found soil-dependent effects (Beauchemin et al., 2022).
The greatest limitations to widespread adoption of 3-NOP are: 1) the additional feeding cost from inclusion in animal diets, given the lack of consistent benefits in animal productivity, and 2) the difficulty of delivering the required dose to grazing ruminants in extensive production systems (Beauchemin et al., 2022).

LITERATURE CITED

Beauchemin, K. A., Ungerfeld, E. M., Abdalla, A. L., Álvarez, C., Arndt, C., Becquet, P., Benchaar, C., Berndt, A., Mauricio, R. M., McAllister, T. A,, Oyhantçabal, W., Salami, S. A., Shalloo, L., Sun, Y., Tricarico, J., Uwizeye, A., De Camillis, C., Bernoux, M., Robinson, T., and Kebreab, E. 2022. INVITED REVIEW: Current enteric methane mitigation options. J. Dairy Sci. 105:9297–9326 https://doi.org/10.3168/jds.2022-22091

Duin, E., Wagner, T., Shima, S., Prakash, D., Cronin, B., Yáñez-Ruiz, D., Duval, S., Rümbeli, R., Stemmler, R., Thauer, R., and Kindermann, M. 2016. Mode of action uncovered for the specific reduction of methane emissions from ruminants by the small molecule 3-nitrooxypropanol. Proc. Natl. Acad. Sci. USA, 113, 6172–6177.

European Food Safety Authority, 2021. Safety and efficacy of a feed additive consisting of 3-nitrooxypropanol (Bovaer® 10) for ruminants for milk production and reproduction (DSM Nutritional Products Ltd). E. J. EFSA Journal doi: 10.2903/j.efsa.2021.6905.

Jayanegara, A., Sarwono, K. A., Kondo, M., Matsui, H., Ridla, M., Laconi, E. B., and Nahrowi. 2018. Use of 3-nitrooxypropanol as feed additive for mitigating enteric methane emissions from ruminants: A meta-analysis. Ital. J. Anim. Sci. 17, 650–656.

Kebreab, E., Bannink, A., Pressman, E. M., Walker, N., Karagiannis, A., van Gastelen, S. and Dijkstra, J. 2023. A meta-analysis of effects of 3-nitrooxypropanol on methane production, yield, and intensity in dairy cattle. J. Dairy Sci. 106:927–936. https://doi.org/10.3168/jds.2022-22211

Kim, H., Lee, H., Baek, Y., Lee, S., and Seo, J. 2020. The effects of dietary supplementation with 3-nitrooxypropanol on enteric methane emissions, rumen fermentation, and production performance in ruminants: A meta-analysis. J. Anim. Sci. Technol. 62, 31-42.

Yu, G., Beauchemin, K. A. and Dong, R. 2021. A review of 3-nitrooxypropanol for enteric methane mitigation from ruminant livestock. Animals 11, 3540. doi: 10.3390/ani11123540

van Gastelen, S., E. E. A. Burgers, J. Dijkstra, R. de Mol, W. Muizelaar, N. Walker, and A. Bannink. 2024. Long-term effects of 3-nitrooxypropanol on methane emission and milk production characteristics in Holstein Friesian dairy cows. J. Dairy Sci. 107. https: //doi .org/10.3168/ jds.2023-24198.