

Is cattle welfare affected by the methane-reducing feed additive 3-Nitrooxypropanol (3-NOP) ?*

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Overview

To meet climate change targets, countries including Scotland are taking steps to reduce greenhouse gas emissions. Agriculture contributes around 10% of UK emissions, of which methane from ruminant livestock contributes around half. Across sectors, mitigation methods are being explored. The feed additive 3-Nitrooxypropanol (3-NOP, Bovaer) can reduce cattle methane emissions by up to 30% by inhibiting the final enzyme in methane synthesis in the rumen microbiome. Although now licensed for use in various jurisdictions including the UK and EU (for dairy and suckler cows), the possible impact of 3-NOP use on cattle welfare has not been fully investigated.

Main Findings

This brief examines possible effects of 3-NOP on cattle welfare, the existing evidence concerning animal welfare impacts and identifies knowledge gaps.

- 3-NOP summary
 - Feed additive, effective at reducing methane emissions from ruminants.
 - Feed intake and milk yield are slightly reduced, although milk fat and protein increase.
- Feed intake reduction
 - Seen in some but not all studies, shows as a small effect in meta-analysis of many studies.
 - Reason is unknown- not necessarily bad for welfare but might be.
- Controversy over roll-out in Denmark
 - Danish dairy farms since October 2025 must add 3-NOP or increase dietary fat in cow rations, anecdotal reports of health and production problems have led to negative press.
 - Arla's trial in the UK 2025 has yet to report.
- Animal welfare studies are lacking.
 - No major production, health or welfare problems are apparent after multiple trials.
 - Studies using physiological markers and behavioural observations and tests aimed at assessing welfare are lacking and would be valuable.

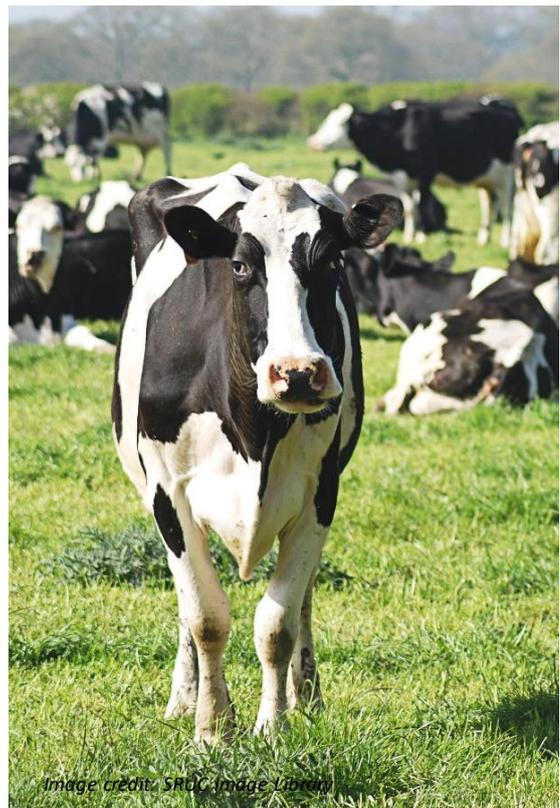


Image credit: SRUC Image Library

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Introduction – Why reduce methane emissions from cattle?

Scotland has an ambitious target of a 75% reduction of greenhouse gas (GHG) emissions by 2030¹. Although estimates vary widely, GHG emissions from agriculture are estimated at ~15%² globally and ~10% in the UK³, with around half of this being caused by enteric methane (CH₄) from ruminants.

Mitigation strategies for ruminant CH₄ include improving production efficiency (more milk or meat per CO₂e), animal breeding⁴, methane capture, feed supplements and vaccines against methanogenic bacteria⁵. Alongside improving efficiency of production and genetic selection against CH₄, another important option⁶ is the feed additive 3-nitrooxypropanol (3-NOP; trade name Bovaer 10), which has been shown to reduce CH₄ emissions in cattle by ~28%⁷.

What have studies of 3-NOP shown?

Feed supplementation with 3-NOP has little or no impact on key production metrics: feed intake (dry matter intake) reduces slightly in one meta-analysis⁸ but not another⁹. These studies both found that although milk yield falls slightly, milk fat and protein increase, so energy-corrected milk yield is unchanged.

3-NOP works by binding with and inhibiting the action of methyl-coenzyme M reductase, the final step in the pathway by which methanogenic bacteria generate energy and release methane (4H₂ + CO₂ → CH₄ + 2H₂O)¹⁰. As a result, there is less methane (CH₄), but more hydrogen (H₂) and carbon dioxide (CO₂) gas in the rumen. The balance of rumen microbiota species shifts towards bacteria which metabolise hydrogen, changing the products of fermentation. Volatile fatty acids (VFAs) are an important energy source produced by fermentation. The types of VFAs produced are altered with decreasing amounts of acetate and increased propionate and butyrate⁸.

How best to assess the welfare impact of a feed additive

Animal welfare assessment is not required for the regulatory approval of feed additives, although there is an assessment of whether they are safe for the cattle (EFSA¹¹ FSA¹² (2023)). In a tolerance study submitted for regulatory approval, the effect of 3-NOP on cattle health (including metabolic and immune markers and pathology) was assessed for 56 days with 20 cows per treatment. One group received twice the recommended dose leading to depressed water and feed intake but no other ill effects. There have been over 20 academic studies of 3-NOP for cattle including one lasting a year, none of which have resulted in major harms such as mortality or severe ill-health. Production and general health measures including condition loss, weight loss, poor fertility or milk production have shown little change across multiple studies of 3-NOP.

Studies of 3-NOP (and other feed additives) which include animal welfare assessment are needed. Protocols for use in farm level assessments such as Welfare Quality¹³ or AssureWel¹⁴ are too general. More specific approaches are needed which focus on the possibility that altered rumen fermentation results in metabolic disruption or negative experiences such as sickness/malaise, which can be detected directly or through behavioural responses:

Physiological markers of metabolic and physical health Diverse metabolic markers, gastro-intestinal tract health (from mouth ulcers or tooth problems to abnormal faeces), rumen microbiome changes outside normal healthy range. VFAs as they may be associated with mood¹⁵.

Behavioural observations Investigations should include any: Disruptions to wake, sleep, rest, rumination cycles occur; Signs of 'sickness' behaviour including reduced feed or water intake, reduced activity, social and exploratory behaviours¹⁶; Reduction in normal or positive behaviours including positive social interactions, play, enrichment use, allo-grooming, use of brushes for self-grooming etc. Qualitative Behavioural Assessment could also be used.

¹ Scottish Government 2020 <https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/pages/13/>

² FAO 2024 <https://openknowledge.fao.org/handle/20.500.14283/cd3167en>

³ ADHB 2019 <https://ahdb.org.uk/knowledge-library/greenhouse-gas-emissions-agriculture>

⁴ Climate Xchange 2024 <http://dx.doi.org/10.7488/era/5569>

⁵ FAO 2023 <https://doi.org/10.4060/cc9029en>

⁶ Duthie et al 2024 <https://sefari.scot/document/routes-to-reduce-methane-emissions-from-livestock-systems>

⁷ Martins et al 2024 <https://doi.org/10.3168/jds.2024-24783>

⁸ Martins et al 2025 <https://doi.org/10.3168/jds.2024-25653>

⁹ Kim et al 2020 <https://doi.org/10.5187/jast.2020.62.1.31>

¹⁰ Duin et al 2016 www.pnas.org/cgi/doi/10.1073/pnas.1600298113

¹¹ EFSA 2021 <https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2021.6905>

¹² FSA 2023 https://www.food.gov.uk/sites/default/files/media/document/RP1059_3NOP_SafetyAssessment_Final%20SM.pdf

¹³ Welfare Quality protocol https://www.welfarequalitynetwork.net/media/1088/cattle_protocol_without_veal_calves.pdf

¹⁴ AssureWel protocol http://www.assurewel.org/Portals/2/Documents/Dairy%20Cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol_2018.pdf

¹⁵ Bruun et al 2024 <https://doi.org/10.1080/1028415X.2023.2277970>

¹⁶ Johnson 2002 [https://doi.org/10.1016/S0165-2427\(02\)00069-7](https://doi.org/10.1016/S0165-2427(02)00069-7)



Behavioural tests Two studies suggest that cattle do not avoid 3-NOP feed (see Table). However, in both studies 3-NOP feed and control feed locations kept changing thus not allowing time for cattle to learn about any post-meal consequences. Further preference studies without location switching are needed. If any preferences are established, motivational studies of feed choice should follow. Learning/Cognition approaches such as Conditioned Place Preference would also be valuable to understand animal's experiences of feed.

Why might feed intake be reduced?

Some studies find a small reduction in feed intake, and the reason for this is unknown. Feed intake commonly varies with feed composition, so this is not in itself concerning. Several possible reasons for reduced feed intake have been proposed, and further research is needed to determine which are correct. Some of these are neutral for welfare, but others may give rise to welfare concerns. These are summarised in the table below.

Table summarising theories on why feed intake (dry matter intake) is reduced with 3-NOP and their welfare implications (based on Kjeldsen et al 2024)¹⁷

| What | Theory | Welfare if correct | Evidence supporting it |
|--|---|-----------------------|---|
| Ruminal H₂ metabolised via propionate producing pathways | Increased ruminal propionate promotes satiety, so cattle experience satiety and delay the start of their next meal. | Neutral | Yes, Kjeldsen et al (2024) ¹⁷ , Pereira et al (2022) ¹⁸ |
| Ruminal H₂ accumulation | Increased gaseous H ₂ reduces fermentation rate | Neutral | Yes, Kjeldsen et al (2024) ¹⁷ |
| Ruminal H₂ and CO₂ accumulation | Gas pressure effect - stretch receptors in rumen wall down-regulate intake | Neutral? Negative? | Unknown |
| Toxic metabolites | Unknown and possibly toxic metabolites in the rumen because of altered metabolic pathways | Negative | Unknown |
| Reduced palatability | Feed taste, odour or texture is unpleasant | Negative | Contradictory findings- Lee et al (2020) ¹⁹ cattle can discriminate 3-NOP vs control feed, despite daily location switching, and initially avoid 3-NOP feed. Lack of discrimination in Melgar et al (2020) ²⁰ . In both studies cattle show no preference after several days. |
| Post-ingestive sickness or malaise | Unpleasant effects take time to emerge, and cattle feel unpleasant sensations such as sickness, malaise or gastro-intestinal discomfort or pain | Negative | Unknown, Kjeldsen et al (2024) ¹⁷ suggest further studies (without location switching of feeds) are needed. |
| Ruminal acidosis | Problem associated with over-feeding of concentrate carbohydrate and not enough fibre. Does 3-NOP trigger this condition? | Negative | Evidence opposite to this: 3-NOP supplementation results in a less acidic rumen (increase in pH) ⁸ |

¹⁷ Kjeldsen et al 2024 <https://pure.au.dk/portal/en/publications/potent-methane-reducing-feed-additives-in-a-danish-context-and-th/>

¹⁸ Pereira et al 2022 <https://doi.org/10.1186/s42523-021-00153-w>

¹⁹ Lee et al 2020 <https://doi.org/10.3390/ani10010064>

²⁰ Melgar et al 2020 <https://doi.org/10.3168/jds.2020-18331>

Industry experiences in the UK and Denmark

In the UK, dairy industry trials organised by Arla ran during 2025 ending in November²¹. The findings have not yet been reported. This trial was the subject of social media misinformation²².

Denmark introduced a law requiring the use of methane-reducing diet alterations (either increasing fat or adding 3-NOP) for at least 80 days a year. This applied to dairy cattle herds of 50 or more from January 2025 with latest start date of October 2025. There have been press reports of individual farmers blaming 3-NOP for diverse health problems^{23,24}. The Danish Veterinary and Food Administration now allow farms where

cattle experience feeding-related disorders to cease 3-NOP use. SEGES (Danish independent agriculture research organisation) are investigating²⁵ and surveying farmers²⁶. Common survey findings include falls in feed intake and milk yield (not unexpected given the research), with more reports among farmers who introduced 3-NOP later (October 2025) than among early adopters. The Danish experience suggests a need for improved knowledge exchange between government, scientists, industry and consumers when introducing CH₄ mitigating feed additives. "Widespread adoption ... will be dependent upon their availability, efficacy, and acceptance by farmers"²⁷.

Other feed additives could reduce ruminant methane emissions

Alternative feed additives to reduce CH₄ emissions from ruminants include increased dietary fat, red seaweed (*Asparagopsis spp*) and its active ingredient bromoform (CHBr₃), nitrate, plant secondary compounds (e.g. essential oils, tannins) and various probiotics aimed at altering the rumen microbiome⁷. Some of these are commercially available for use elsewhere (e.g. seaweed in Australia) or in the UK, although none yet with FSA approval for a claim of methane reduction. Increasing dietary fat is a feed reformulation so is already possible without any regulation. The benefits and challenges of some of these approaches have been reviewed^{7,17} and aspects of welfare discussed¹⁷. As with 3-NOP there is a dearth of studies into possible animal welfare impacts, however the principles outlined here are relevant to other approaches and additives.

3D molecular model of 3 nitro-oxypropanol
key: nitrogen, oxygen, carbon, hydrogen

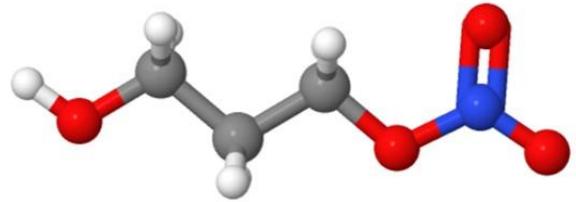


Image Credit: www.jmol.org

Policy Implications

- 3-NOP appears to be safe and effective and is authorised for use by the FSA and EFSA
- A slight reduction in feed intake is not necessarily a cause for concern, although the reason is not known. Further studies on this and on the animal welfare implications of 3-NOP and other methane-reducing feed additives would be valuable.
- Mandatory use of 3-NOP in Denmark has led to reports of animal health and welfare problems, and reduced feed intake and milk yield. Arla's UK dairy industry trial in 2025 has yet to report its findings.
- Successful adoption of 3-NOP and other additives requires scientific evidence but acceptance by farmers and consumers is crucial.

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²¹ <https://www.bbc.co.uk/news/articles/cvgvkppx4kko>

²² <https://www.euronews.com/green/2024/12/03/burping-cows-bovaer-and-boycotts-the-anti-methane-additive-thats-taking-social-media-by-st>

²³ <https://www.farmersguardian.com/news/4521568/danish-farmers-raise-concerns-about-bovaer>

²⁴ <https://www.farmersguide.co.uk/livestock/animal-health/bovaer-manufacturer-responds-to-reports-of-cattle-illnesses-and-deaths>

²⁵ <https://segesinnovation.com/about-us/news-and-media/seges-innovation-news/bovaer-seges-innovation-researchers-investigate-possible-causes-of-challenges-in-dairy-herds/>

²⁶ <https://segesinnovation.com/about-us/news-and-media/seges-innovation-news/feedback-regarding-the-use-of-bovaer-in-danish-dairy-herds/>

²⁷ Newbold et al 2022 <https://pure.sruc.ac.uk/en/publications/methane-mitigation-by-feed-supplements/>