MM35: 3-Nitrooxypropanol (3NOP)

Category
Livestock management: Specific agents to supress methanogenesis

Overview
3NOP is a chemical that reduces the excretion of enteric methane by ruminants when added to their rations (or introduced via a bolus). It does so by reducing the rates at which rumen archaea convert the hydrogen in ingested feed into methane. Specifically, 3NOP inhibits methyl-coenzyme M reductase, the final step of CH_4 synthesis by archaea (Duin et al. 2016).

Mitigation summary

Effect on GHG categories*	Rating	Notes
Enteric CH_4	-	
Manure CH_4		
Manure N_2O		
Soil N_2O: applied N		
Soil N_2O: grazing		
Energy CO_2: fieldwork		
Energy CO_2: other		
CO_2 liming and urea		
CO_2 sequestration below ground		
CO_2 sequestration above ground		
Pre-farm emissions	+	Production of 3NOP
Post-farm emissions		
Substitution of higher C products		
Production increases by more than the emissions		
Confidence in mitigation effect	moderate	
Cost-effectiveness**	moderate	
Confidence in cost-effectiveness	low	

* ”-“ GHG reduction, “+”: GHG increase, “ ”: no significant effect
** low: =< £0/tCO_2e, moderate: £0/tCO_2e< >SCC, high: >SCC

Related measures and potential synergies

Measure	**Impact on other measures**
21, High sugar content grasses	AR and CE reduced
26. Breeding for rumen microflora with lower rates of methanogenesis	AR and CE reduced
27 and 29 Breeding for lower emission intensity	AR and CE reduced
31. High starch diet	AR and CE reduced
34. Plant extracts	AR and CE reduced
36. Biodiverse pasture mixtures for livestock grazing	AR and CE reduced

CE = cost-effectiveness AR = abatement rate

Inclusion in other marginal abatement cost curves

UK 2008	UK 2010	UK 2015	Ireland 2012	France 2013	France 2019
No	No	No	No	No	?

What does the measure entail?
The ingestion of a small amount of 3NOP each day, typically in the range of.0.05 to 0.2g NOP per kg of DMI (Javanegara et al. (2017), i.e. for cattle the effective dose required is likely to be in the order of 2-3g of 3NOP/animal/day (Haisan et al. 2014, Martinez-Fernandez et al. 2018). For housed animals the 3NOP could be mixed in with the ration. For grazing animals, it may be possible to deliver the 3NOP via a bolus.

Abatement rate
While 3NOP is a new mitigation measure (it was patented in 2012, Duval and Kindermann 2012) a range of experimental studies and meta-analyses have been undertaken (Table 1).

Table 1 Summary of studies of the mitigation effect of 3NOP

System	Parameter	Effect	Country	Year	Reference
Sheep	Enteric CH_4	25% reduction in CH_4 yield*	Australia	2013	Martinez-Fernandez et al (2013)
Dairy cattle	Enteric CH_4	4 to 7% reduction in CH_4 yield	UK	2014	Reynolds et al. (2014)
Dairy cattle	Milk yield and fat Milk protein	No effect Increase	UK	2014	
Beef cattle	Enteric CH_4	33% reduction in CH_4 yield	Canada	2014	Romero-Perez et al., (2014)
Beef cattle	Daily weight gain DMI	No effect Small decrease	Canada	2014	
Dairy cattle	Enteric CH_4	60% reduction in CH_4 yield	Canada	2014	Haisan et al., (2014)
	DMI, milk yield Daily weight gain	No effect Increased	Canada	2014	
Dairy cattle	Enteric CH_4	30% reduction in CH_4 yield	USA	2015	Hristov et al., (2015)
Dairy cattle	DMI, milk yield Daily weight gain	No effect Increased	USA	2015	
Dairy cattle	Enteric CH_4	23-37% reduction in CH_4 yield	Canada	2016	Haisan et al., (2016)
Dairy cattle	DMI, milk yield Daily weight gain	No effect No effect	Canada	2016	
Beef cattle	Enteric CH_4	7 to 81% reduction in CH_4 yield, varies with diet and dose	Canada	2016	Vyas et al., (2016a)

Beef cattle	Daily weight gain DMI	No effect High dose: reduced	Canada	2016	
Beef and dairy cattle	Enteric CH_4	30% reduction in CH_4 yield	Canada	2016	Duin et al. (2016)
Ruminants	Enteric CH_4	19-33% reduction in CH_4 yield	Various	Various	Jayanegara et al., (2017)
Beef cattle	Enteric CH_4	38% reduction in CH_4 yield	Australia	2018	Martinez-Fernandez et al (2018)
Beef cattle	Daily weight gain	Increase	Australia	2018	
Beef cattle	Enteric CH_4	37-42% reduction in CH_4 yield	Canada	2018	Vyas et al. (2018)
Beef cattle	FCR	5% decrease	Canada	2018	
Beef cattle Dairy cattle	Enteric CH_4 Enteric CH_4	Effect on CH_4 yield: 17.1%+/-4.2% 38.8%+/-5.5%	Various	Various	Dijkstra et al. (2018)

*CH_4 yield: the kg of CH_4 per kg of dry matter intake (DMI)

Javanegara et al. (2017) undertook a meta-analysis of 3NOP based on 12 *in vivo* studies from 10 articles. Their results showed that increasing level of 3-NOP addition in diets of ruminants decreased enteric CH_4 emissions per unit of DMI, while having no effect on DMI and limited effects on the production performance of dairy cows and beef cattle. They concluded that "3-NOP is an effective feed additive to mitigate enteric CH_4 emissions without compromising productive performance of ruminants." Papers published since 2017 reinforce this conclusion.

Cost-effectiveness

No significant one-off costs arising from the measure are predicted. The main recurring costs are likely to arise from the purchase and administering of 3NOP (see Table 2).

Table 2. Costs/savings of the operation (figures in brackets are savings)

Costs/savings	**Total cost**	**Source**
Purchase of 3NOP	Not known	
Administering 3NOP	Not known	
Change in animal performance	Likely to be minor, potentially a net benefit	Literature, see Table 1

No estimates of the cost effectiveness of 3NOP have been undertaken. The cost of 3NOP is unknown as the product is not yet commercially available. However given the low amounts required, the large reduction in enteric methane and the limited effects on animal performance, the CE is likely to be low positive. It has been estimated that the cost of Mootral (an alternative to 3NOP) would be $50 per cow per year (Zwick 2017). Assuming a similar cost for 3NOP (and a reduction in enteric methane of 30%) would imply a cost-effectiveness of <£50/tCO_2e. It is possible that improved animal performance (e.g. Vyas et al. 2018 noted a 5% improvement in feed conversion efficiency) could be greater than the costs, leading to a net financial benefit.

The cost-effectiveness is categorised as being in category 2, moderate cost.

Applicability, current uptake and potential additional maximum uptake

In theory 3NOP could be used with beef cattle, dairy cattle and sheep. Most of the studies with 3-NOP have focused on high quality concentrate-based diets, however Martinez-Fernandez et al (2018) found a reduction in enteric CH_4 from beef cattle fed a roughage diet.

Rooke et al. (2016, p13) noted that “The patent states that (a) the product could be supplied as a premix for incorporation into diets on farm or (b) a bolus delivered into the rumen to release 3NOP over an extended time period and therefore compatible with the grazing situation”.

Assumptions used in the MACC

1. Reduction in methane yield (i.e. Ym):
    a. 20% for beef cattle
    b. 30% for dairy cattle.
2. No effect on animal performance
3. Emissions associated with 3NOP production are given in Table 3.
4. Cost-effectiveness: \$1/tCO_2e
5. Applicable to beef and dairy cattle while not grazing.

Table 3 Emissions arising from 3NOP production

	3NOP dosage (kg/year)			**GHG from 3NOP production, kgCO_2e per:**	
	g/kgDMI*	kgDMI/year **	kgNOP/year	kg3NOP***	year
Dairy cow	0.125	16.6	0.76	47.9	36
Suckler cow	0.125	9.3	0.42	47.9	20
Beef steer	0.125	7.0	0.32	47.9	15

*Assumption based on Jayanegara et al. (2018)
**Calculated using SAEM (MacLeod et al. 2017)
*** Alvarez-Hess et al. (2018)

Ancillary effects

Ancillary effects are summarised in Table 4. LLonch et al. (2016) concluded that: “The 3NP compound is anticipated to be an effective and harmless dietary strategy to mitigate CH_4, however, more toxicity focused studies are warranted to confirm this before it is used on a commercial scale.”

“Despite the promising effects of 3-NOP, further studies are required to assess carry-over of the compound into animal products and food safety concern when the products are consumed by human.” Javanegara et al. (2017)

Table 4. Ancillary effects of the operation

Positive effects		**Source**
Off-farm GHG	Possible improvement in FCR leading to reduced feed demand	Various, see Table 1

Production	Possible improvements in animal performance (e.g. FCR and growth rates).	“”
Adaptation	None	
Environment	Improvements in animal performance could lead to reduction of non-GHG impacts, e.g. water and air quality	
Negative effects		
Off-farm GHG	GHGs associated with 3NOP production	
Production	No known effects	
Adaptation	None	
Environment	No know effects	

FCR: feed conversion ratio

Identified implementation challenges and barriers

Table 5. Potential barriers to uptake and key risks/uncertainties

Barrier to uptake	**Source**
Not yet approved for use as a feed additive. Approval currently being sought in North America. Likely to take at least 2 more years.	Gibson 2018
Other key risks/uncertainties	

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Prepared by:	Michael MacLeod, SRUC
Contact:	Michael.Macleod@sruc.ac.uk