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DI MILANO

# How to reduce emissions without reducing dairy production? Role of Nutrition

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# Milk is nature's optimized source/delivery system of nutrients

## Milk and dairy products are nutritious foods

- Milk and dairy products are foundational in Western diets providing
- ~ 12 % of total energy intake
- ~ 19% of the total protein intake
- ~ 40 % of calcium intake,
- ~ 27 % of the intake of vitamins B2 and B12
- ~ 17 % of the zinc intake
- Recommendation for the intake of milk/dairy products ranges from 250 g/d

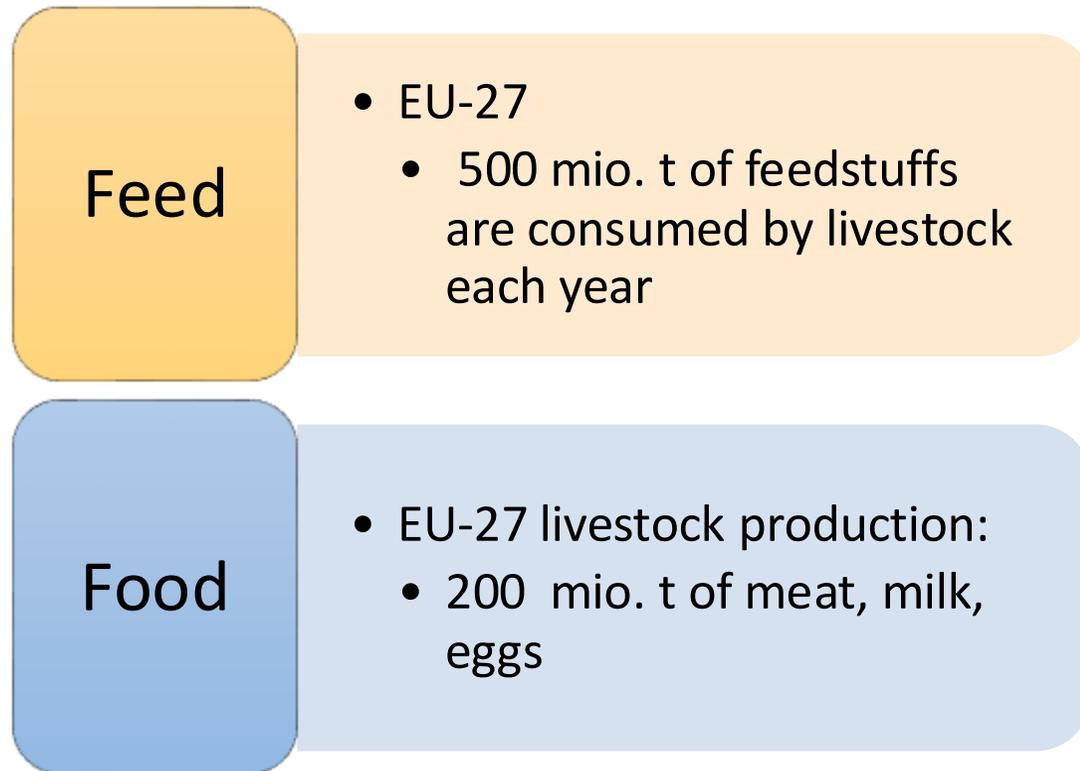
## Milk as delivery medium

- Milk is an amazing delivery system for essential nutrients, and critical biological molecules to sustain the infant and adult alike.
- Ensures high bioavailability and bioaccessibility
  - proteins and AAs~95% digestibility.
  - Calcium up to 65% in organic, 30% in conventional
  - Bioactive
- It is safe and abundant resource
- Competitive also in low economy settings.



# Livestock farming in the EU is an advance system

## EU Feed to Food



**(Gross) FCR 2.38**

## Production efficiency trend (kg feed per kg of animal product)

Product	20° cent.	Today	Efficiency improvement
Poultry	4,5	1,9	<b>57%</b>
Turkey	6,0	2,5	<b>58%</b>
Eggs	4,3	2,1	<b>51%</b>
Milk	2,2	0,7	<b>68%</b>
Pig lean	4,3	2,7	<b>37%</b>
Beef	9	7	22%
Mean	5.05	<b>2.81</b>	49%

# The major contributors to the improvement in milk yield per cow

## Genetic selection

- has accounted for approximately **60% to over 70% of the increase** in total milk, fat and protein yield in cosmopolitan breeds (e.g. Holsteins) since 1970.



1960s

1970s

1980s



1990s

2000s

2020s

Milk yield

## Nutritional Science:

- essential to supporting the higher metabolic demands of top-producing genetics.

## Management and Cow Comfort:

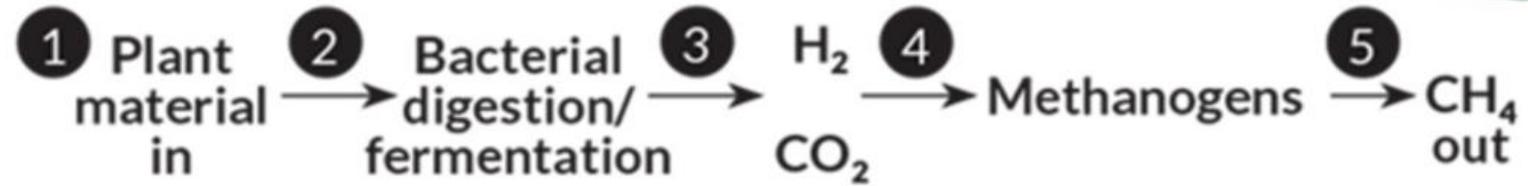
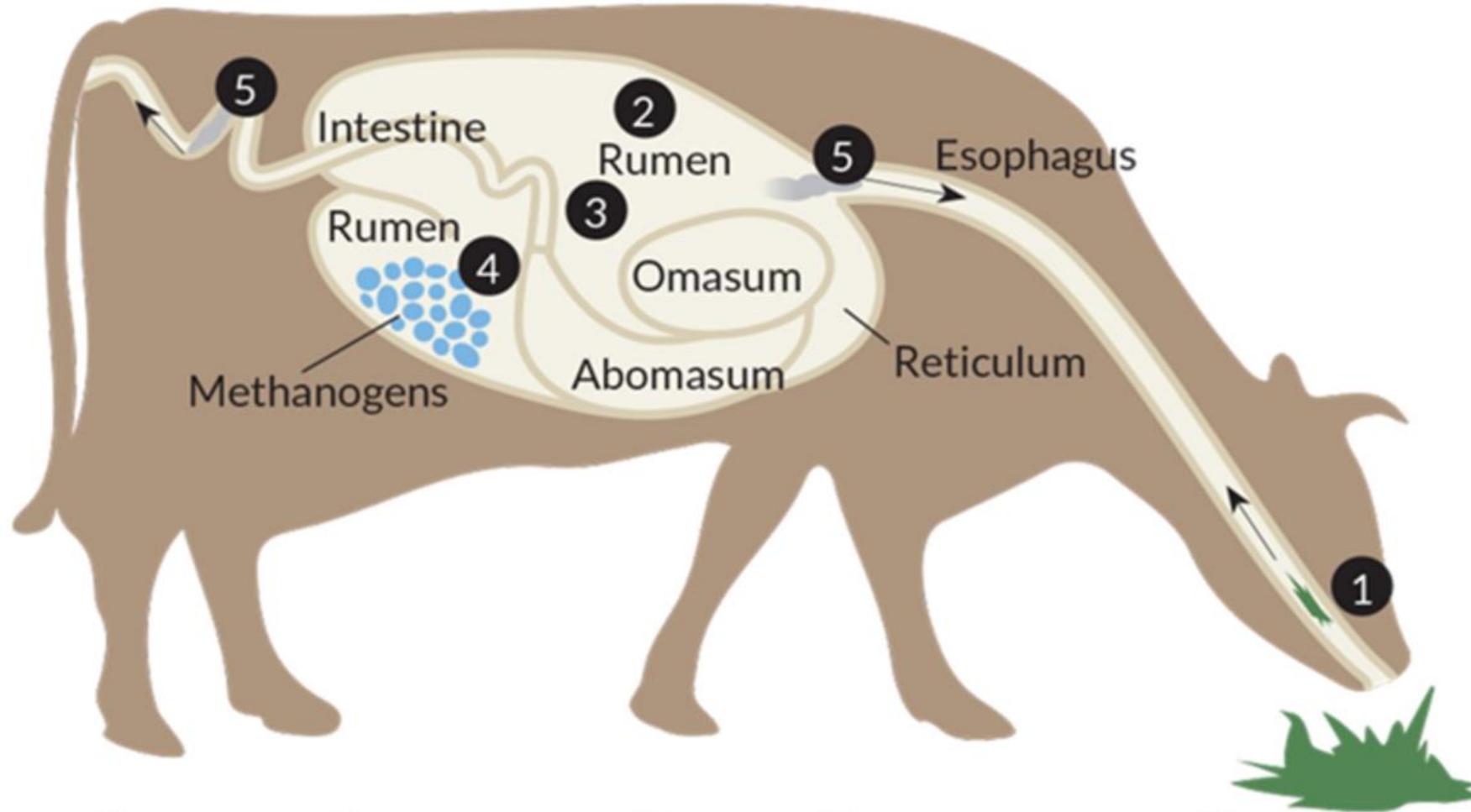
- Improvements in **housing** have allowed for maximum genetic expression.

## Herd Management Tools:

- Digital record-keeping and **precision dairy** farming have enhanced efficiency, health care and management of individual cows.

Comparison between the nutritional requirements of dairy cows at peak production between NRC 2001 and NASEM 2021

DESCRIP	NRC 2001	NASEM 2021
Breed		
Body Weight (kg)		
Age (months)		
Neutral Environ		
Average Days in		
Milk Production		
Fat %		
Protein %		
Dry Matter Intak		
REQUIRE		



- NEL (Mcal/kg)
- Crude Protein (R)
- RDP %
- RUP %
- ADF min %
- NFC max %
- Starch max %
- Calcium %
- Phosphorus %

- Cobalt (mg/kg)
- Copper (mg/kg)
- Iodine (mg/kg)
- Iron (mg/kg)
- Manganese (mg/kg)
- Selenium (mg/kg)
- Zinc (mg/kg)

Vitamin A (IU/kg)	2500	5500	1000
Vitamin D (IU/kg)	680	952	+272
Vitamin E (IU/kg)	18	19	+1



ifferences in the requirements of dairy cows at peak production between NRC 2001 and NASEM 2021 (NASEM), have changed over time due to genetic selection. Modern dairy cows require more concentrate, greater digestible protein. Additionally, fiber, minerals, and vitamins have been updated to support overall health and productivity.

# Why Enteric Methane

Major climate driver  
 Methane is ~28-34×  
 heat than CO<sub>2</sub>  
 Accelerates climate  
 extreme weather, ice  
 ecosystems

## Ruminants: essential

- Convert non-edible biomass into bioavailable nutrients
- 86% of livestock feed for humans.
- Up to 12% dietary protein



## What's the beef with cows and the climate crisis?

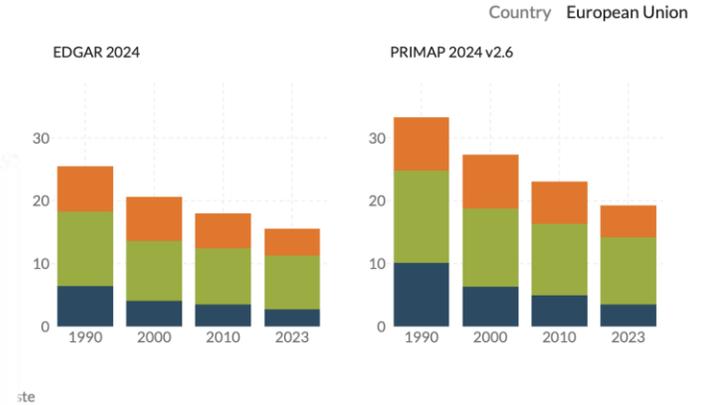
Reducing methane emissions is seen as the biggest opportunity for slowing global heating by 2040

Meat and dairy giants feed climate crisis by dragging their heels on methane



More than 40% of livestock's climate footprint is made up of methane emissions, mostly from beef and dairy cattle. Photograph: Jean-Philippe Ksiazek/AFP/Getty

Union's historic methane emissions



**25%** of global dairy GHG emissions are from dairy farms in **developed countries**.

**75%** of global dairy GHG emissions are from dairy farms in **emerging countries**.

Emissions in dairy regions vary from 1.3-1.4 kg-CO<sub>2</sub> eq/kg milk in developed regions to 4.1-6.7 kg-CO<sub>2</sub> eq/kg milk in emerging regions

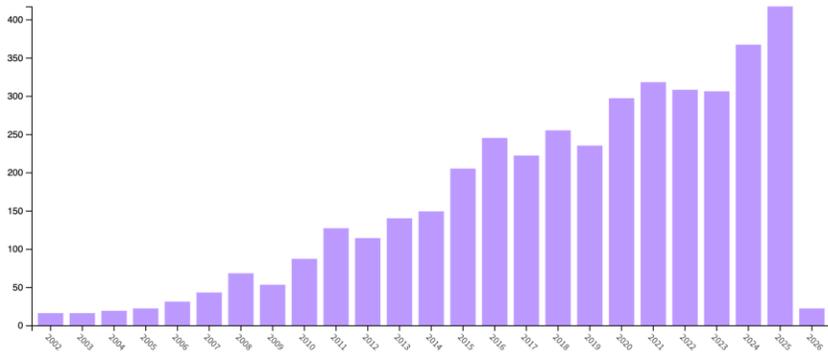
**2.7%** Global dairy sector emissions, share on global GHG emissions (FAO 2010)

**2.2%** Milk production emissions, share on global GHG emissions (FAO 2010 & IFCN estimations)

# Scientific effort

4,140 results from Web of Science Core Collection for:

methane (Topic) and emission (All Fields) and dairy (All Fields)



**Book of Abstracts**  
of the 75<sup>th</sup> Annual Meeting  
of the European Federation of Animal Science



Book of Abstracts No. 34 (2024)  
Florence, Italy  
1-5 September, 2024

**Book of Abstracts**  
of the 76<sup>th</sup> Annual Meeting  
of the European Federation of Animal Science



Book of Abstracts No. 39 (2025)  
Innsbruck, Austria  
25 - 29 August, 2025

Methane: 453 and 588



# Rumen manipulation: feed additives & nutritional strategies

Research on CH<sub>4</sub>-reducing additives is accelerating offering a practical, science-based strategy to improve sustainability of ruminant production, while maintaining food security.

## MAIN POSSIBLE INTERVENTIOS

- **Inhibiting methanogens**
  - Directly reduce the population or activity of methane-producing archaea
- **Redirecting hydrogen**
  - Divert H<sub>2</sub> away from methane formation toward alternative pathways
- **Modifying fermentation**
  - Shift rumen fermentation patterns to produce less hydrogen
  - Promote propionate formation over acetate and butyrate
- **Integration of Circularity in Livestock Production**

Vary in **mode of action, efficacy, and readiness for adoption**

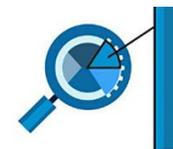
# FEED ADDITIVE :

## Methanogenesis Inhibitors

### 3-Nitroxypropanol (3-NOP)

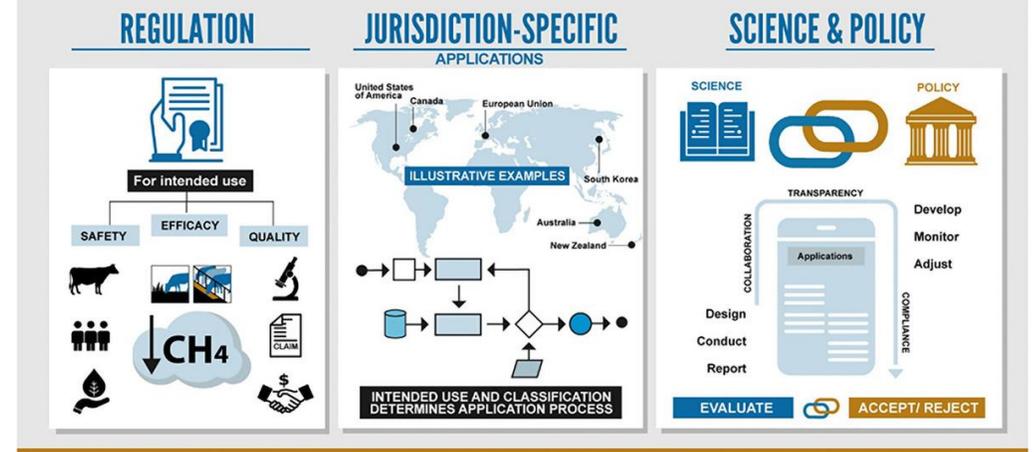
Directly inhibits methanogen enzyme (*methyl-coenzyme M reductase, MCR*)

- CH<sub>4</sub> reduction: 20–40%
- Dose-dependent: 60–180 mg/kg DMI
- No negative effect on intake, milk, or growth
- Commercially available (e.g., Bovaer®)



### REGULATORY FRAMEWORK AND EVIDENCE REQUIREMENTS FOR THE USE OF ANTIMETHANOGENIC FEED ADDITIVES (AMFA)

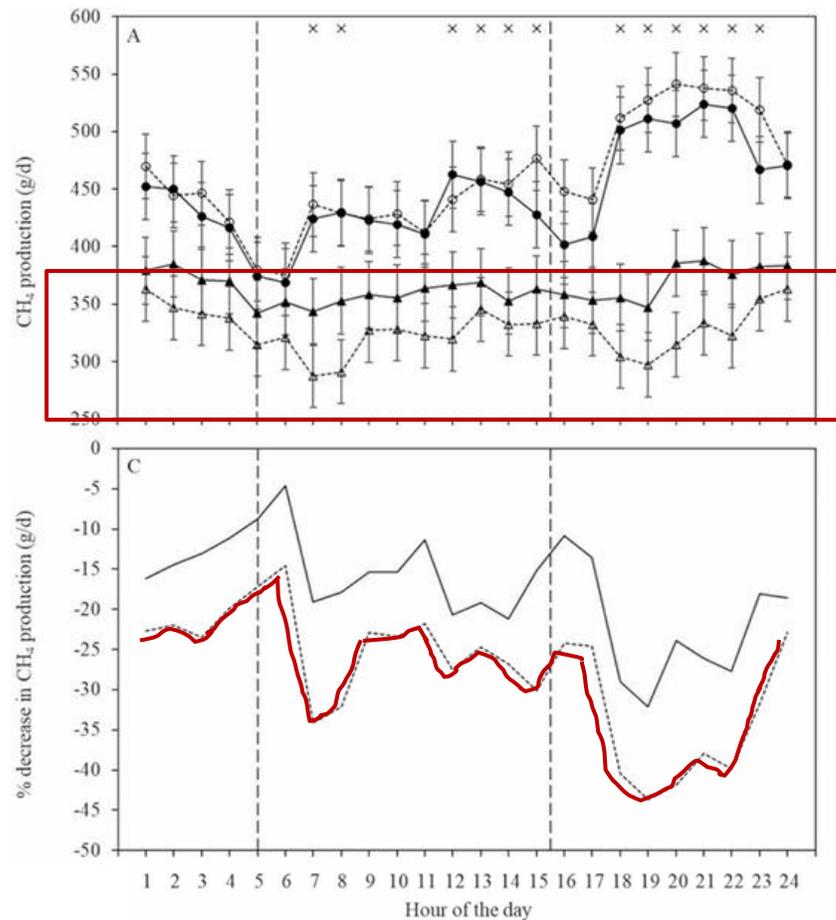
The use of AMFA on ruminant production system requires authorization from jurisdiction-specific legal authorities



Created by Florencia Garcia and Yelena Grigorenko. Used with permission.



# Direct inhibitors (3-NOP) offer the fastest, most effective methane reduction while maintaining productivity



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<https://doi.org/10.3168/jds.2025-26957>

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Investigating interactions between grass silage– or corn silage– based diets and 3-nitrooxypropanol on fermentation and methane emission dynamics and rumen microbiome in dairy cattle

Sanne van Gastelen,<sup>1\*</sup> Jan Dijkstra,<sup>2</sup> Sven J. J. Alferink,<sup>2</sup> Gisabeth Binnendijk,<sup>1</sup> Arie Klop,<sup>1</sup>

Emiel Ver Loren van Themaat,<sup>3</sup> Nicola Walker,<sup>4</sup> and André Bannink<sup>1</sup>

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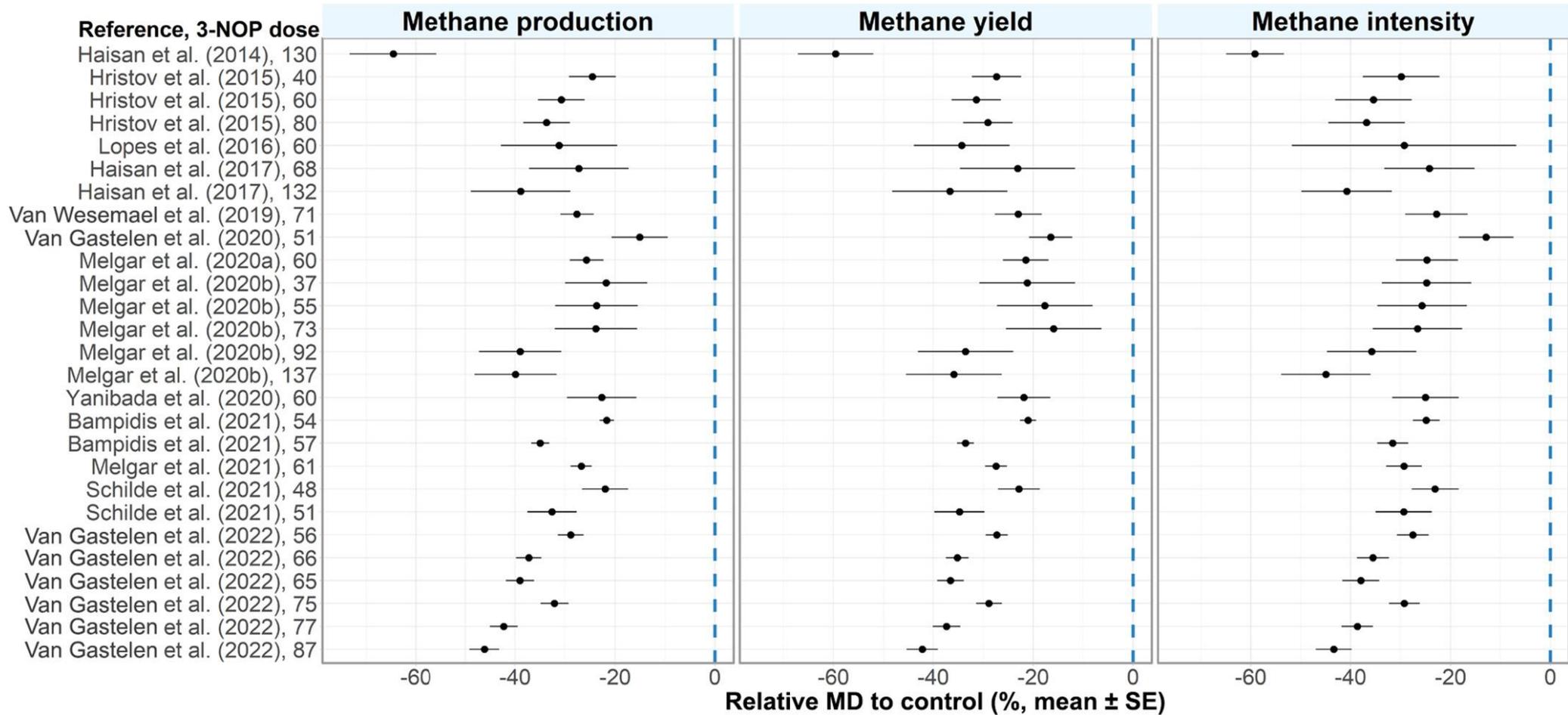
<sup>3</sup>dsm-firmenich, Science & Research, 2600 MA, Delft, the Netherlands

<sup>4</sup>dsm-firmenich, Animal Nutrition & Health, 4002 Basel, Switzerland

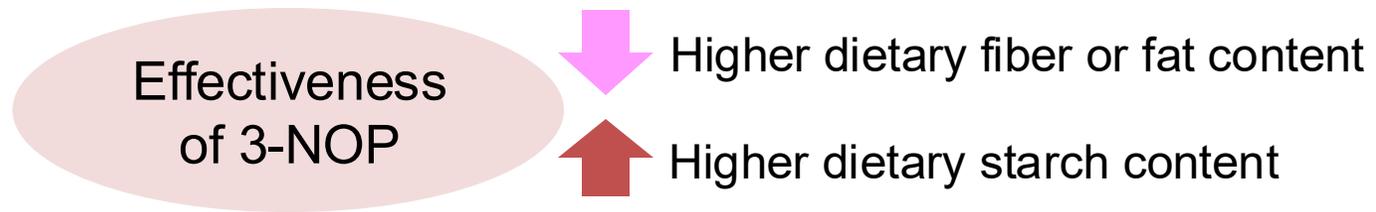
- No effect of basal diets on CH<sub>4</sub> emission, ruminal pH, or acetate:propionate ratio
- 3-NOP lower the CH<sub>4</sub> production

-20.1% CH<sub>4</sub> yield (g/kg DMI)  
-21.1% CH<sub>4</sub> intensity (g/kg ECM)





The current meta-analysis indicates that the overall effectiveness of 3-NOP at mitigating CH<sub>4</sub> emissions was 32.7%, 30.9%, and 32.6% for CH<sub>4</sub> production, yield, and intensity, respectively, at an average 3-NOP dose of 70.5 mg/kg DM



<https://doi.org/10.3168/jds.2022-22211>

Others “FEED ADDITIVE”:

## Methanogenesis Inhibitors & Redirecting Hydrogen

### Macroalgae (*Asparagopsis taxiformis* and *A. armata*)

Halogenated compounds (bromoform) inhibit methanogen enzyme (*B12-dependent methyltransferase*) by reacting with  $B_{12}$

- **CH<sub>4</sub> reduction: 10–90%**
- Inclusion rate: ~ 0.2–1% DM
- Influencing factors: chemical composition, time of collection and growth environment
- Limitations: highly volatile, residue in milk (bromoform, iodine), ozone depletion potential and supply chain challenges

### Nitrates

Directly compete with methanogens for  $H_2$  (alternative hydrogen sink)

$NO_3^-$  is reduced to  $NH_4^+$  by rumen microbes (hydrogen redirection)

- **CH<sub>4</sub> reduction: 10–18 %**
- Inclusion rate: 15-20 g/kg DM
- Requires careful adaptation and management to avoid toxicity (methaemoglobinemia)
- Emerging solution: encapsulated nitrate

# Rumen modifiers

## Dietary lipids

Mixed mechanisms of action: alternative hydrogen sink (bio-hydrogenation) + microbial inhibition (toxic effect on methanogens and protozoa); Shift VFA profile towards propionate formation

- CH<sub>4</sub> reduction: **10–20%**
- Inclusion rate: 2-6 % of dietary DM
- High inclusions (> 5 %) depress fiber digestion, reduce DMI, negative effect in fat milk content and yield
- Limitations: fat source and diet composition strongly influence the effect; impact on manure emission needs to be investigated

## Plant secondary compounds (flavonoids, tannins, saponins)

Broad antimicrobial effects and reduction in hydrogen availability

- CH<sub>4</sub> reduction: highly variable (**0-40%**), often short-lived
- Inclusion rate variable (whole plant vs. extract): e.g. Tannins > 20 g/kg DM; saponins 2-10 g/kg DM; flavonoids 1-2 g/kg DM
- Influencing factors: botanical source and dose
- Major issue: inconsistent response across diets and systems, reduction in fiber digestibility and DMI

## Essential oils (oregano, cinnamon, garlic)

Bioactive compounds with broad antimicrobial activity: indirect suppression of methanogens

- Limitation: non specific → may also limit beneficial microbes
- CH<sub>4</sub> reduction: **0-40%** (single EO inconsistent, often transient)
- Major issue: high in vitro potential, but negligible and inconsistent in vivo methane reduction
- EO blends (e.g. Agolin, Mootral) show some promising results (up to ~30% CH<sub>4</sub> reduction in specific trials)

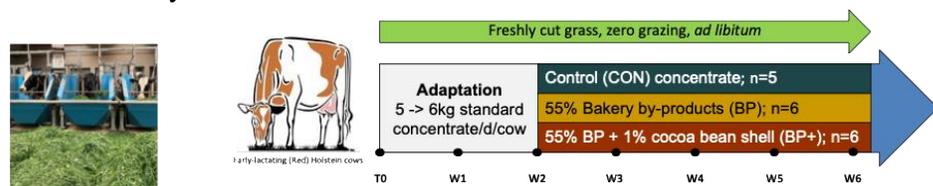
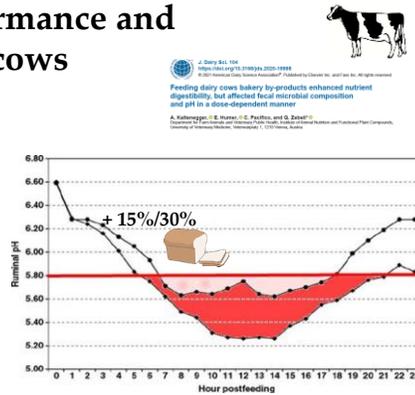
# Designing circular diets

## BBP improve production performance and ruminal health in dairy cows

- Inclusion of 15-30% BBP:
  - ++ energy density
  - ↑ dry matter intake (+1,9kg)
  - ↑ milk yield (+4kg/d)
  - ↓ time of rumen pH <5.8 (acidosis risk)

30% BP in the diets in mid-lactation dairy cows shifted the nutrient profile from a glucogenic diet to a lipogenic diet,

i.e. potential to enhance performance and lower the risk of SARA in dairy cows



g/kg DM	Herbage	CON	BP	BP+
Crude protein	183.9	105	113	114
ADF/NDF	240/388	43/142	72/149	75/136
Ether extracts	-	64	114	119
Starch	-	653.1	114.4	118.6
WSC	143.6	38.8	141.1	142.3
NE (MJ/kg DM)	6.6	7.44	7.57	7.42

75:25 Herbage:Concentrate  
 Statistics: Linear mixed models (R:lme4).  
 Week, concentrate, their interaction and baseline covariable as fixed effects

Animal 19 (2025) 101512

Contents lists available at ScienceDirect

**Animal**

The international journal of animal biosciences

Review: Nutritional, safety, and environmental aspects of former foodstuff products in ruminant feeding<sup>☆</sup>

M. Tretola<sup>a,1,\*</sup>, P. Lin<sup>a,b,1</sup>, J. Eichinger<sup>c,1</sup>, M. Manoni<sup>b,1</sup>, L. Pinotti<sup>b,d</sup>

Resources, Conservation & Recycling 223 (2025) 108536

Contents lists available at ScienceDirect

**Resources, Conservation & Recycling**

journal homepage: [www.sciencedirect.com/journal/resources-conservation-and-recycling](http://www.sciencedirect.com/journal/resources-conservation-and-recycling)

Upcycling former food products in livestock diets: a one health approach to prevent resource-depleting farming systems

Camilla Govoni<sup>a,\*</sup>, Matteo Ottoboni<sup>b</sup>, Michele Manoni<sup>b</sup>, Luciano Pinotti<sup>b</sup>, Maria Cristina Rulli<sup>a</sup>

Animal 19 (2025) 101477

Contents lists available at ScienceDirect

**Animal**

The international journal of animal biosciences

Former food and cocoa bean shells in early-lactating cows on a herbage-based diet: effects on ruminal fermentation and blood metabolites

A.-M. Reiche<sup>a,\*</sup>, M. Tretola<sup>b</sup>, L. Eggerswiler<sup>c</sup>, L. Pinotti<sup>d</sup>, F. Dohme-Meier<sup>a</sup>

# Food production and consumption over the years

<b>Society</b>	Hungry and needs <b>something to eat</b>	Would like <b>something good to eat</b>	Needs <b>safe food</b>	<b>Nutritious, safe, sustainable &amp; affordable food</b>
<b>Policy</b>	<b>Food security:</b> Produce and supply enough food	<b>Food quality:</b> Reduce surpluses in the EU	<b>Food safety:</b> risk assessment	<b>Sustainability:</b> <ul style="list-style-type: none"> <li>• lower environmental impact</li> <li>• Food supply chain resilient to geopolitical/environmental shocks</li> </ul>
<b>Research</b>	<b>Increase food production</b> using all resources	Food quality Process <b>quality</b>	<b>Safety</b> <b>Traceability</b>	<b>Sustainable and circular</b> food production systems
	<b>1945-60</b>	<b>1980-90</b>	<b>2000-10</b>	<b>2020....</b>

# Thank you!

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