

EFFECTIVE NUTRITIONAL STRATEGIES FOR ENTERIC METHANE MITIGATION

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California Animal Nutrition Conference; May 11-12, 2022

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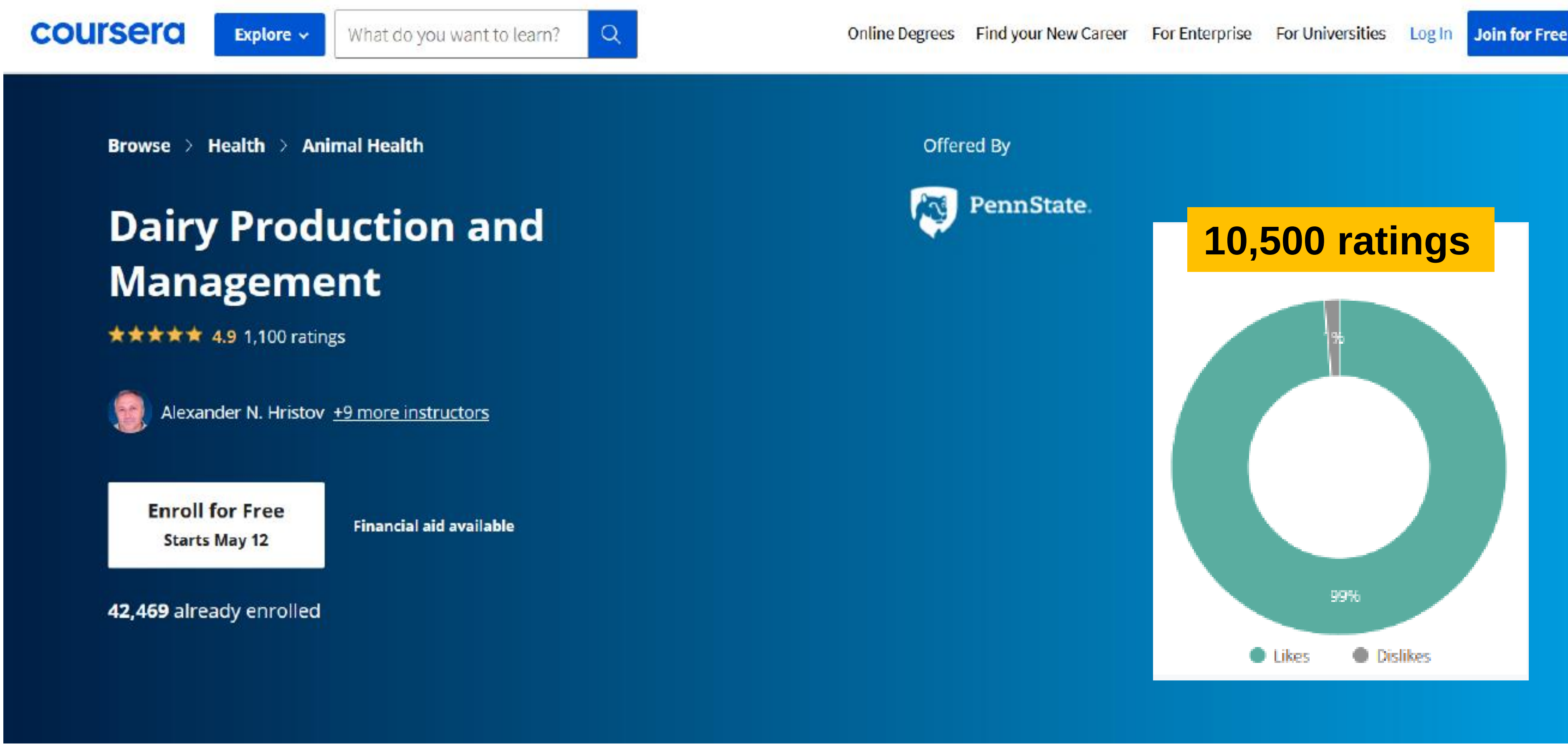
The world's first dairy MOOC current enrollment > 42,000

https://www.coursera.org/learn/dairy-production/



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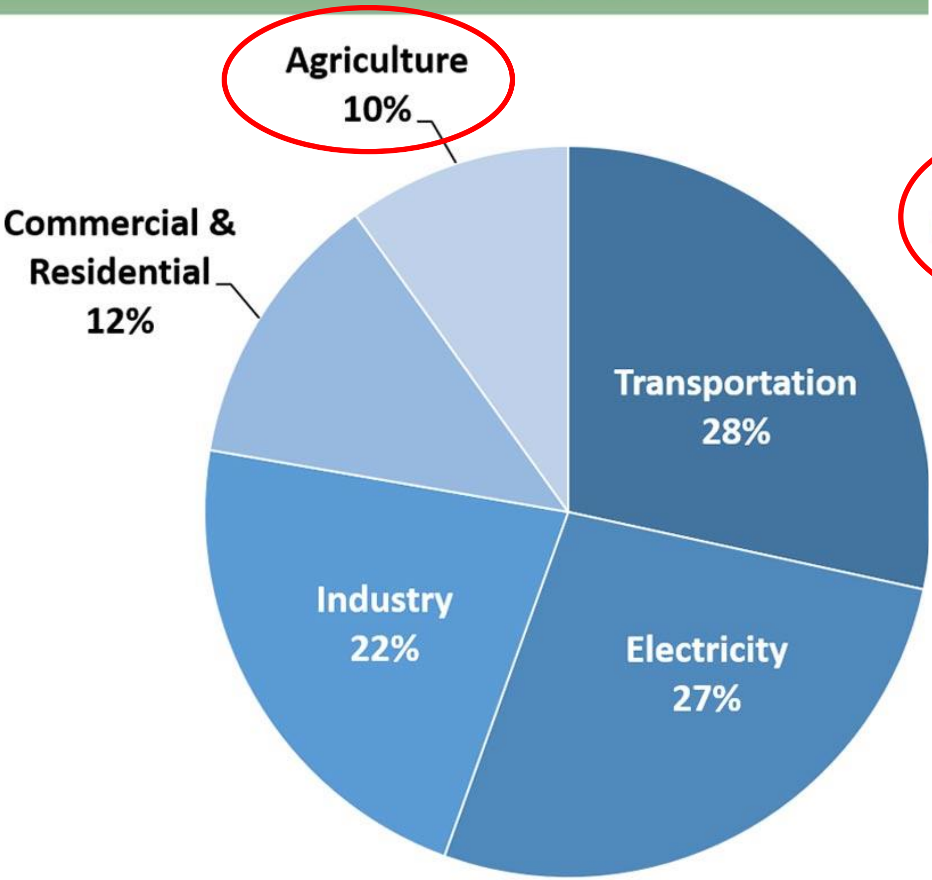
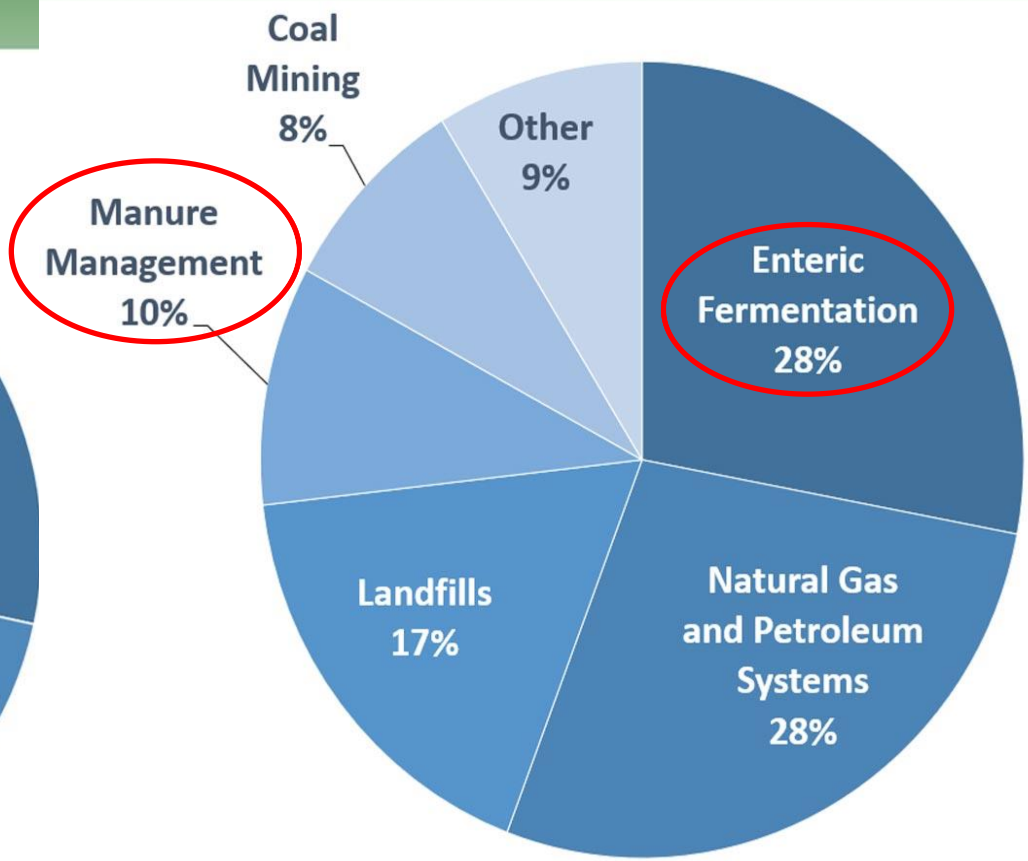
USEPA, 2020

The Big Picture: US GHG emissions by sector

Sources of Greenhouse Gas Emissions in 2018



2018 U.S. Methane Emissions, By Source

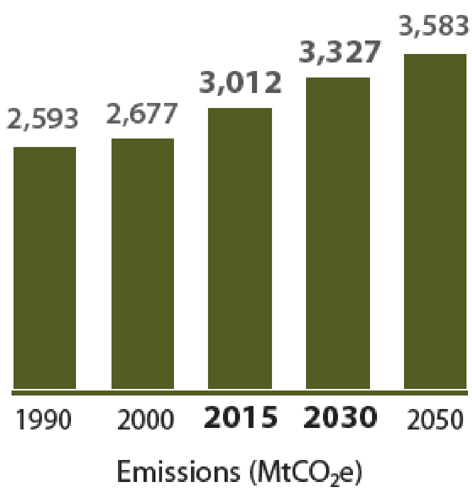


U.S. Environmental Protection Agency (2020). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018

Global projected livestock emissions by country

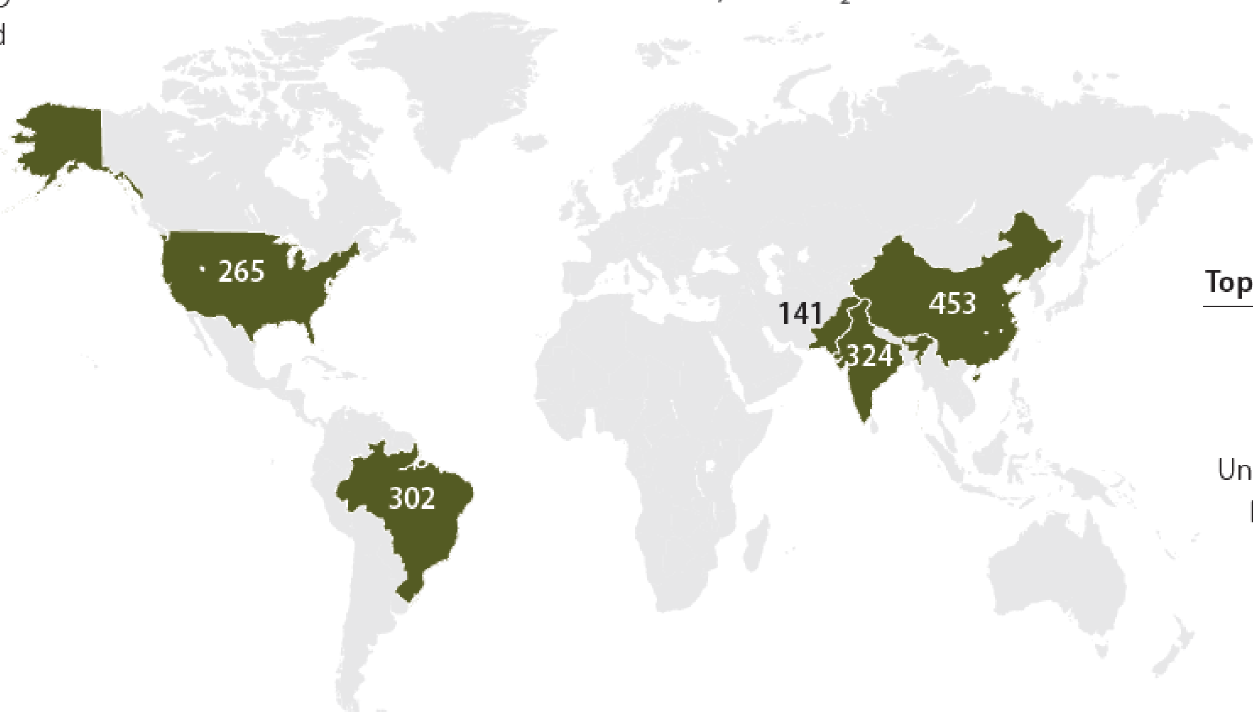
Emissions ($MtCO_2e$)

From 2015 through 2030, CH_4 and N_2O emissions from livestock are projected to increase by approximately 10%.



2030 Emissions from Top 5 Emitting Countries

Rest of World: 1,843 $MtCO_2e$



Top 5 Emitters

China
India
Brazil
United States
Pakistan

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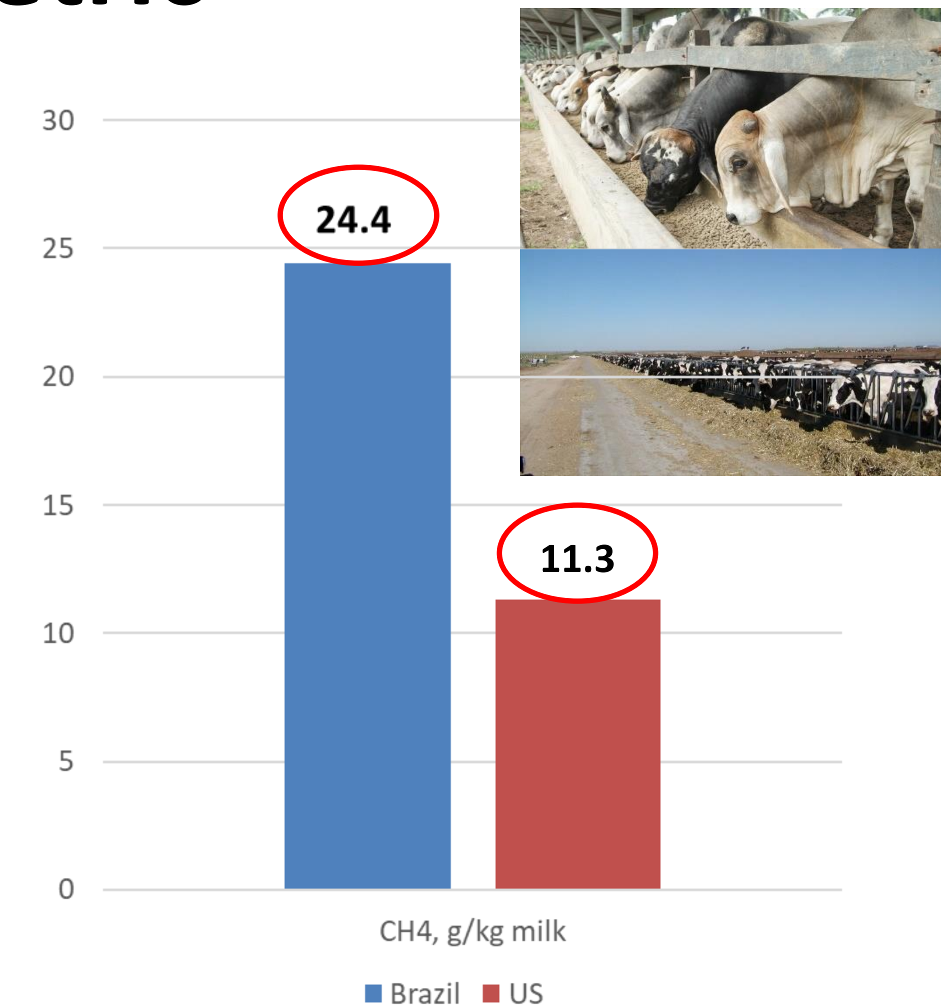
Emission intensity = an important metric

- **Brazil**: over 20 million dairy cows; 36 million tons of milk; total CH_4 = 878 million tons/yr
- **USA**: 9 million dairy cow, 99 million tons of milk (+275%); total CH_4 = 1,119 million tons/yr (+27%)



(data from the GLOBAL NETWORK project)

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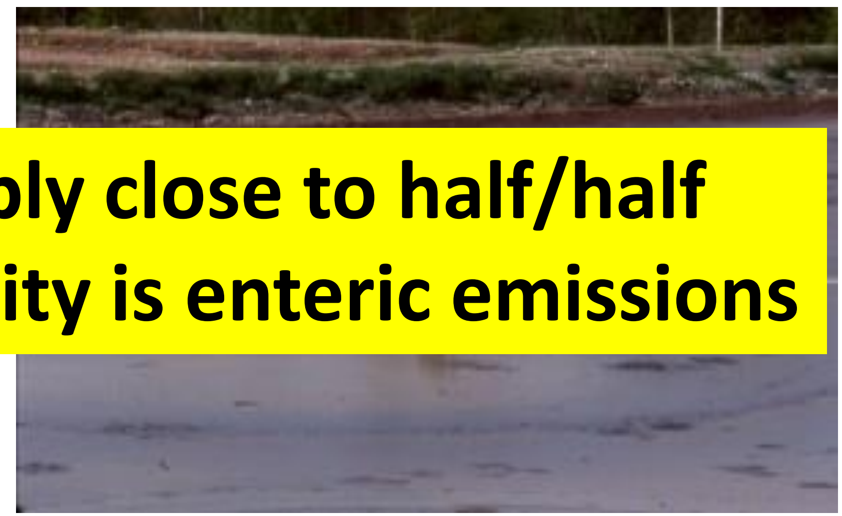
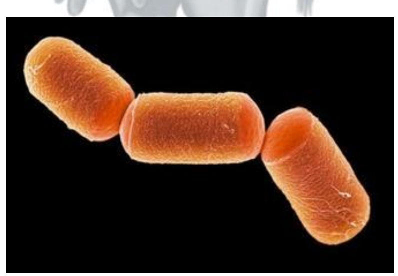
Methane emissions in ruminants



In dairy systems: probably close to half/half
In beef systems: the majority is enteric emissions

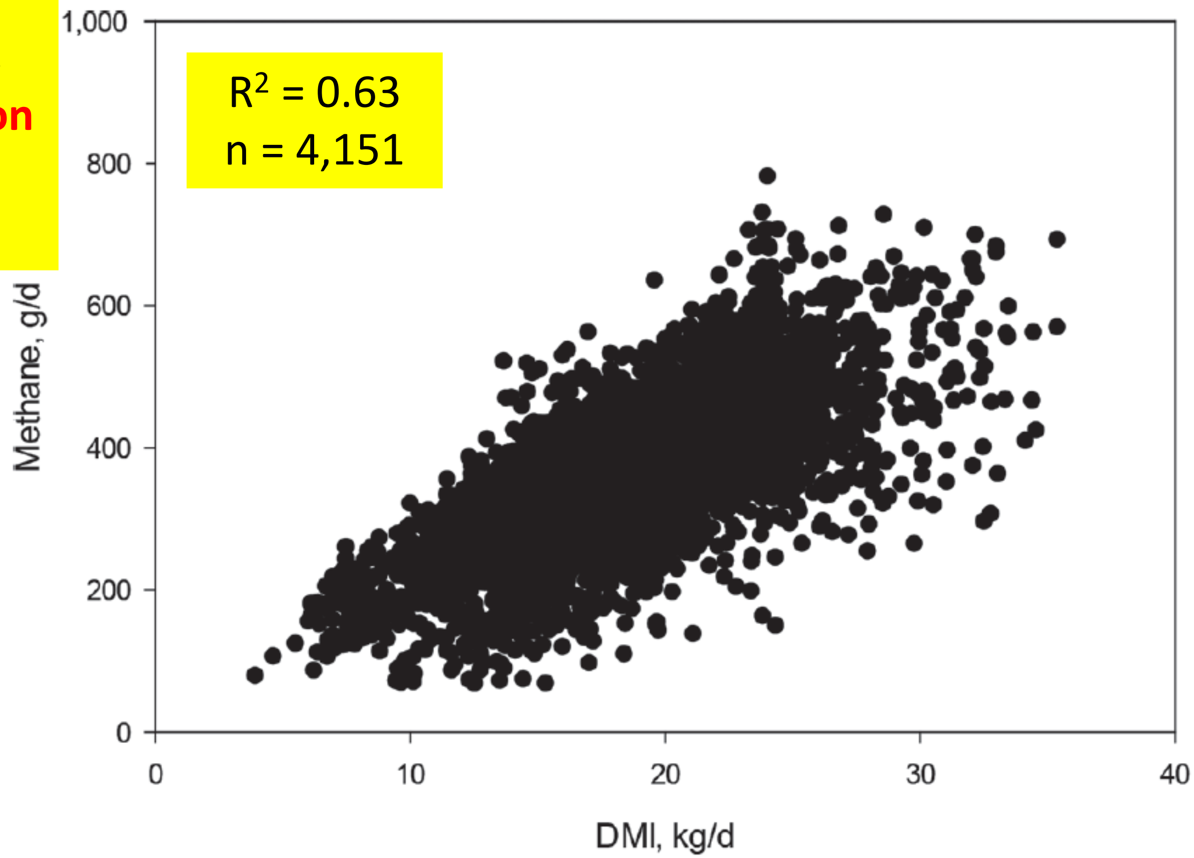
Methanobrevibacter



Hristov et al., 2018

Factors affecting enteric methane emission – DMI is most important

Other factors:
Animal genetics
Diet composition
- fiber/starch
- fat



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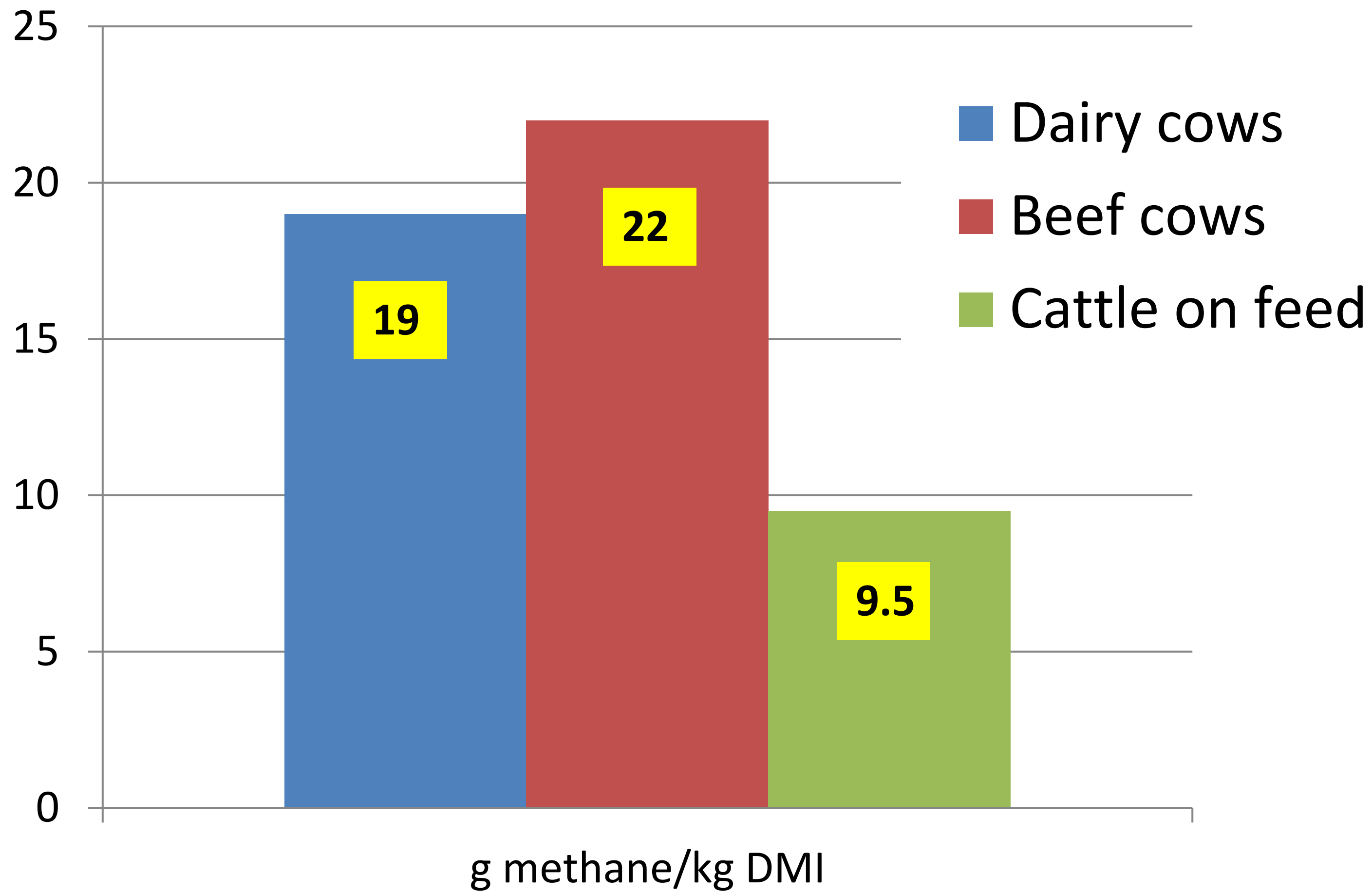
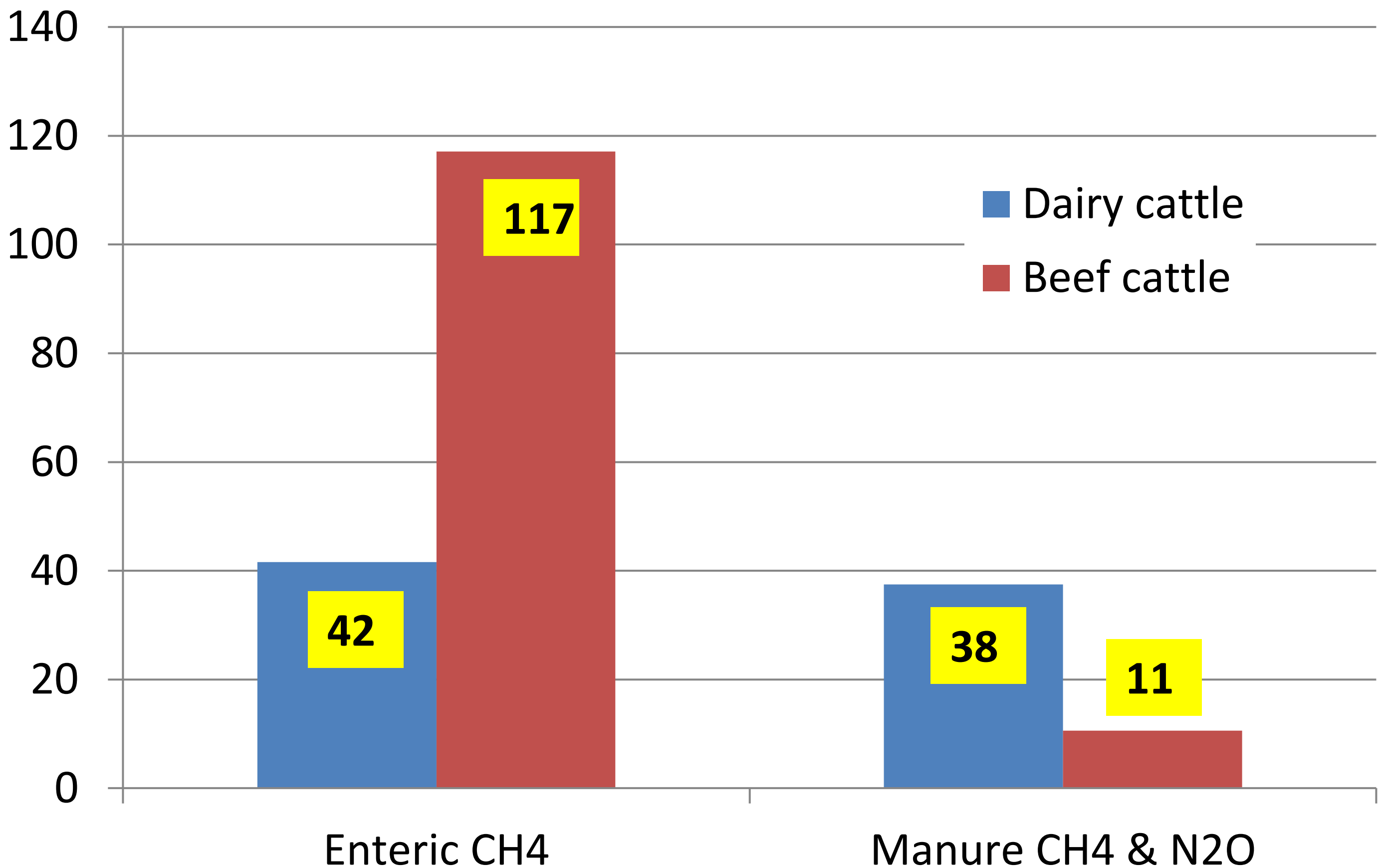
Hristov et al., 2018

More forage = more enteric methane
more grain and fat = less methane



USEPA, 2015

Total GHG emissions from dairy and beef cattle in the US (MMT CO_2 eq)



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Enteric methane mitigation strategies

- **Nutritional strategies**
  - Improving forage quality
  - Feeding concentrates
  - Lipids
  - Nitrates
  - Ionophores
  - Tannins & saponins
  - Methane inhibitors BOVAER
  - Seaweeds
  - Precision fe
- **Ma ategies**
  - n against methanogens
  - pulation of the rumen microbiome
  - Animal genetics, selecting for low-methane emission
  - Improving animal health
  - Lifetime productivity
  - IMPROVING ANIMAL PRODUCTIVITY AND FEED EFFICIENCY

With all these, well-designed and executed, independent, long-term research trials are needed to prove efficacy!

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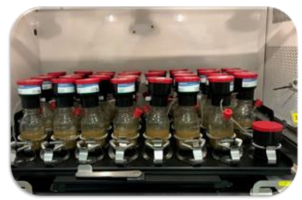
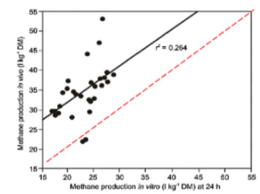
Hristov et al., 2018

Requirements for testing of feed additives for CH_4 mitigating effect

- Proven effect in **independent**, controlled, long-term animal experiments



G. Flachowsky, P. Lebzien / Animal Feed Science and Technology 176 (2012) 70–77



  - In vitro is not enough!
  - Reliable experimental design: continuous or crossover animal trials with sufficient number of animals
  - In the case of dairy – high-producing cows, relevant to the US dairy industry
  - Reliable methane measurement techniques
  - Proven long-term effect
  - **Co-benefits, no negative side effects!** (DMI, productivity, animal health, milk quality)
  - Repeatability!!

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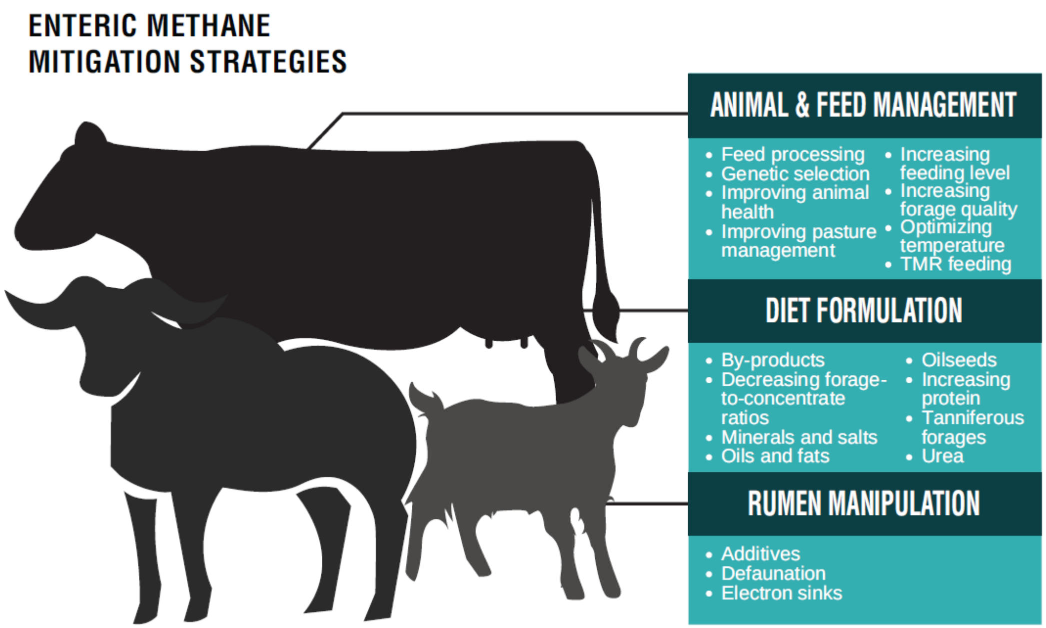
PNAS RESEARCH ARTICLE | SUSTAINABILITY SCIENCE OPEN ACCESS

Full adoption of the most effective strategies to mitigate methane emissions by ruminants can help meet the 1.5 °C target by 2030 but not 2050

Claudia Arndt[a,1], Alexander N. Hristov[b], William J. Price[c], Shelby C. McClelland[d], Amalia M. Pelaez[b,e], Sergio F. Cueva[b], Joonpyo Oh[b], Jan Dijkstra[e], André Bannink[e], Ali R. Bayat[f], Les A. Crompton[g], Maguy A. Eugène[h], Dolapo Enahoro[a], Ermias Kebreab[i], Michael Kreuzer[j], Mark McGee[k], Cécile Martin[h], Charles J. Newbold[l], Christopher K. Reynolds[g], Angela Schwarm[m], Kevin J. Shingfield[f,2], Jolien B. Veneman[n], David R. Yáñez-Ruiz[o], and Zhongtang Yu[p]

Edited by Akkihebbal Ravishankara, Colorado State University, Fort Collins, CO; received June 25, 2021; accepted February 8, 2022



Significance

Agricultural methane emissions must be decreased by 11 to 30% of the 2010 level by 2030 and by 24 to 47% by 2050 to meet the 1.5 °C target. We identified three strategies to decrease product-based methane emissions while increasing animal productivity and five strategies to decrease absolute methane emissions

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Arndt et al., 2022

Effective mitigation strategies for enteric methane: production effects

A

	Mitigation strategy	Potential emissions reduction		Relevant production system
Product-Based Reductions	1 Increasing feeding level	CH_4I_M -17% CH_4I_G No Data		Feedlot & mixed systems; Grassland systems
	2 Decreasing grass maturity	CH_4I_M -13% CH_4I_G No Data		Feedlot & mixed systems; Grassland systems
	3 Decreasing dietary forage-to-concentrate ratio	CH_4I_M -9% CH_4I_G -9%		Feedlot & mixed systems
Absolute Reductions	1 CH_4 inhibitors	CH_4I_M -32% CH_4I_G No Data	Daily CH_4 -35% CH_4Y -34%	Feedlot & mixed systems
	2 Tanniferous forages	CH_4I_M -18% CH_4I_G No Data	Daily CH_4 -12% CH_4Y -10%	Feedlot & mixed systems; Grassland systems
	3 Electron sinks	CH_4I_M -13% CH_4I_G -12%	Daily CH_4 -17% CH_4Y -15%	Feedlot & mixed systems
	4 Oils & fats	CH_4I_M -12% CH_4I_G -22%	Daily CH_4 -19% CH_4Y -15%	Feedlot & mixed systems
	5 Oilseeds (Lactating animals only)	CH_4I_M -12% CH_4I_G No Effect	Daily CH_4 -20% CH_4Y -14%	Feedlot & mixed systems

Production system: Feedlot & mixed systems; Grassland systems

Arndt et al., 2022

Effective mitigation strategies for enteric methane: production effects

B

	Mitigation Strategy	Intake	Digestibility	Milk	Gain
		Relative Treatment Effect on Animal Performance			
Product-Based Reductions	1 Increasing feeding level	+58%	-7%	+17%	+162%
Product-Based Reductions	2 Decreasing grass maturity	No Effect	+15%	+9%	No Data
Product-Based Reductions	3 Decreasing dietary forage-to-concentrate ratio	+9%	No Effect	+17%	+21%
Absolute Reductions	1 CH_4 inhibitors	No Effect	No Effect	No Effect	No Effect
Absolute Reductions	2 Tanniferous forages	No Effect	-7%	No Effect	No Effect
Absolute Reductions	3 Electron sinks	-2%	No Effect	+3%	No Effect
Absolute Reductions	4 Oils & fats	-6%	-4%	No Effect	No Effect
Absolute Reductions	5 Oilseeds (Lactating animals only)	No Effect	-8%	No Effect	-13%

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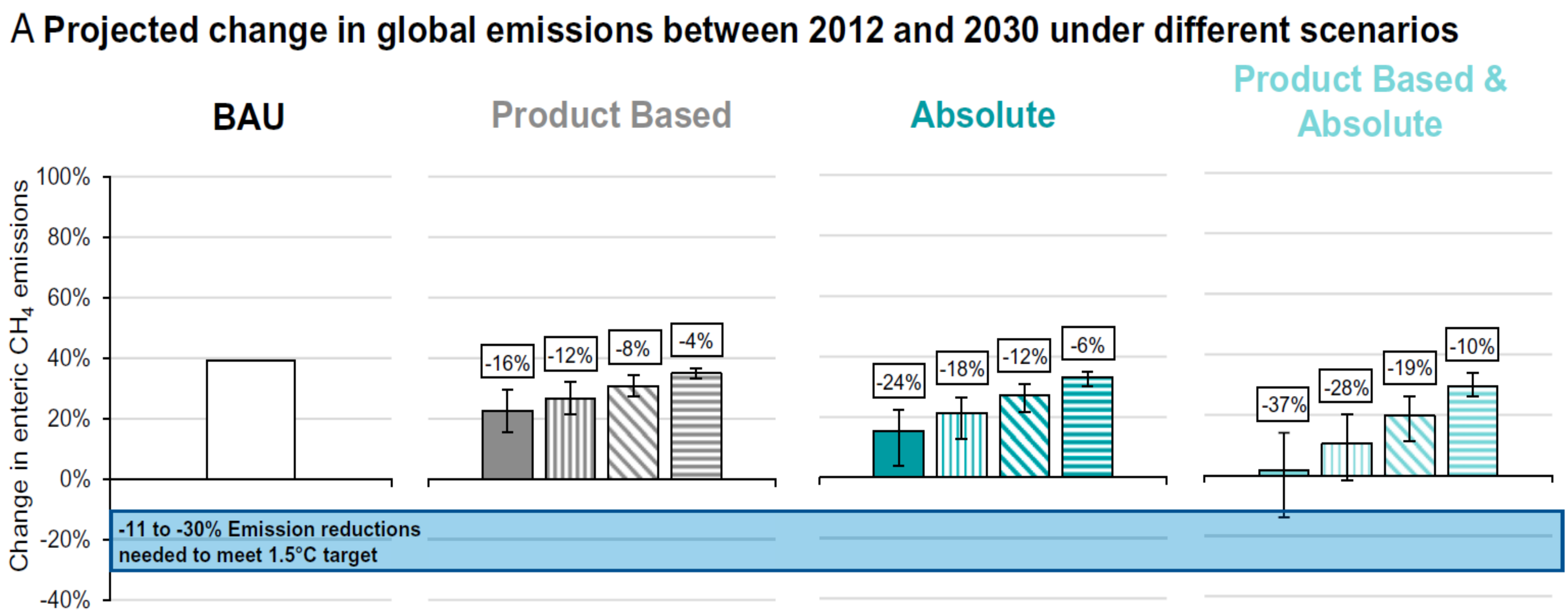
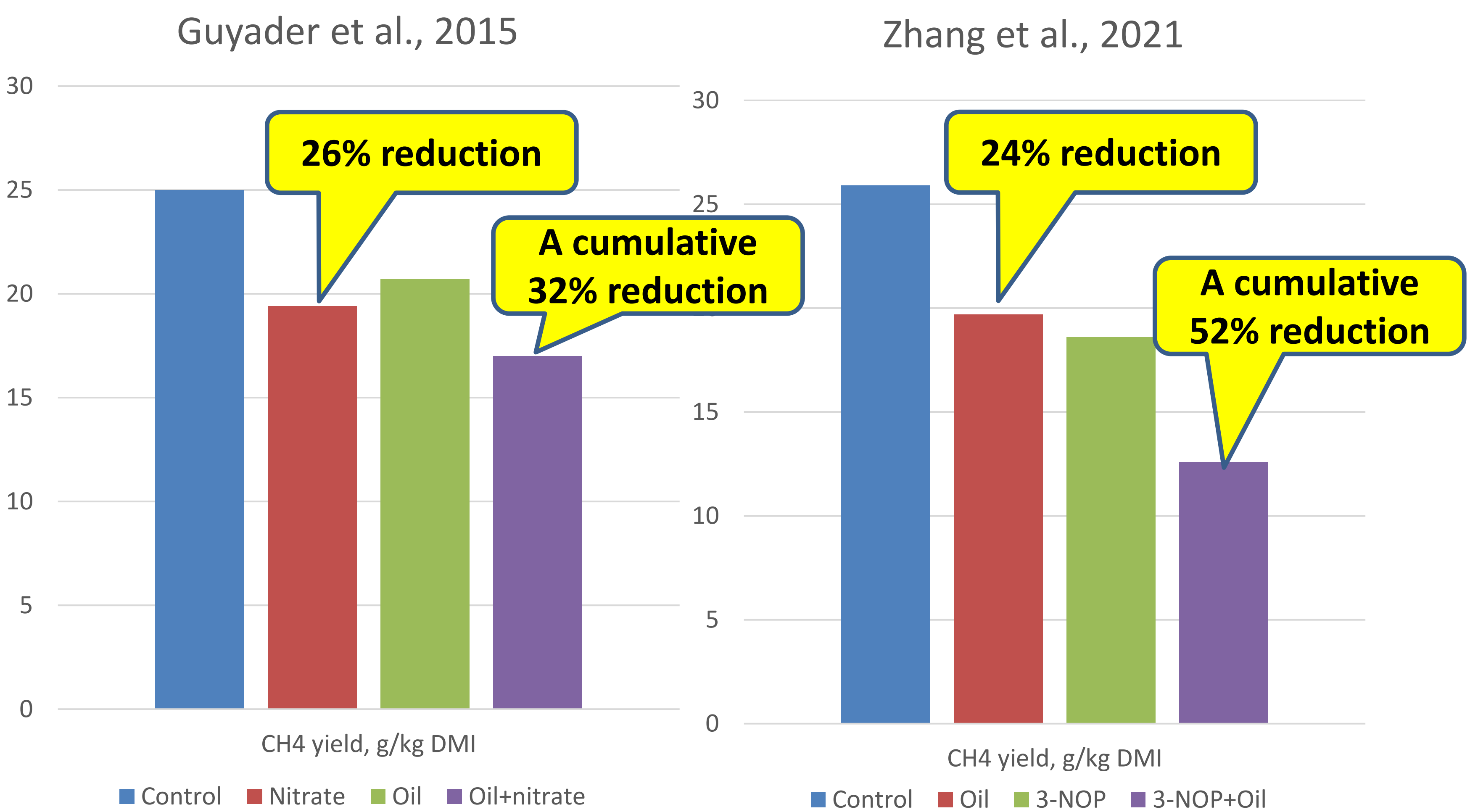
Arndt et al., 2022

Globally, only 100% adoption of the most effective PB and ABS strategies (increasing production and CH_4 inhibitor, respectively) decreased enteric CH_4 emissions sufficiently (14%) to meet the 1.5 °C target by 2030



Additive effects of mitigation practices?



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3-nitrooxypropanol

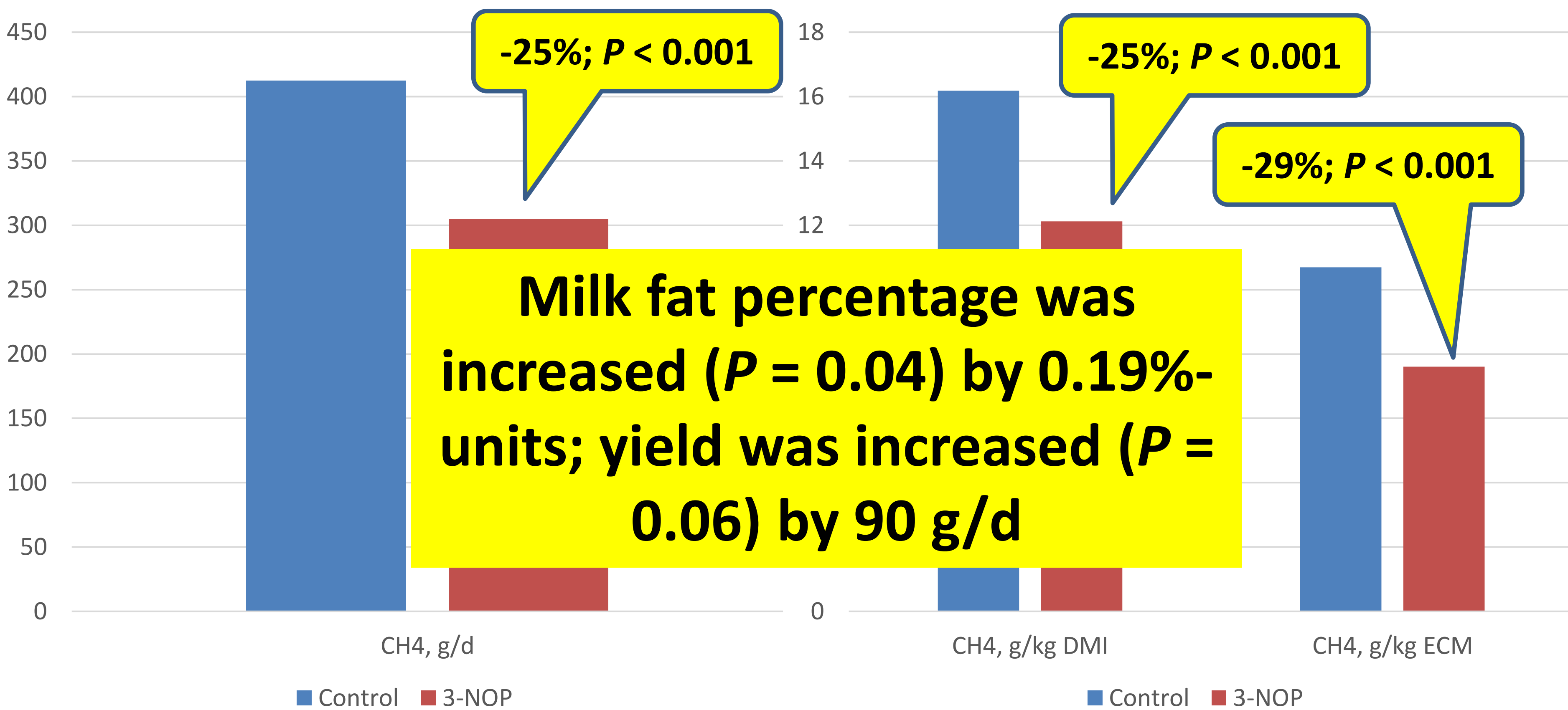
Elanco

27 April 2022

Elanco and Royal DSM Announce Strategic Alliance in U.S. for Bovaer® – A Revolutionary, Methane-Reducing Feed Additive for Cattle

Melgar et al., 2019

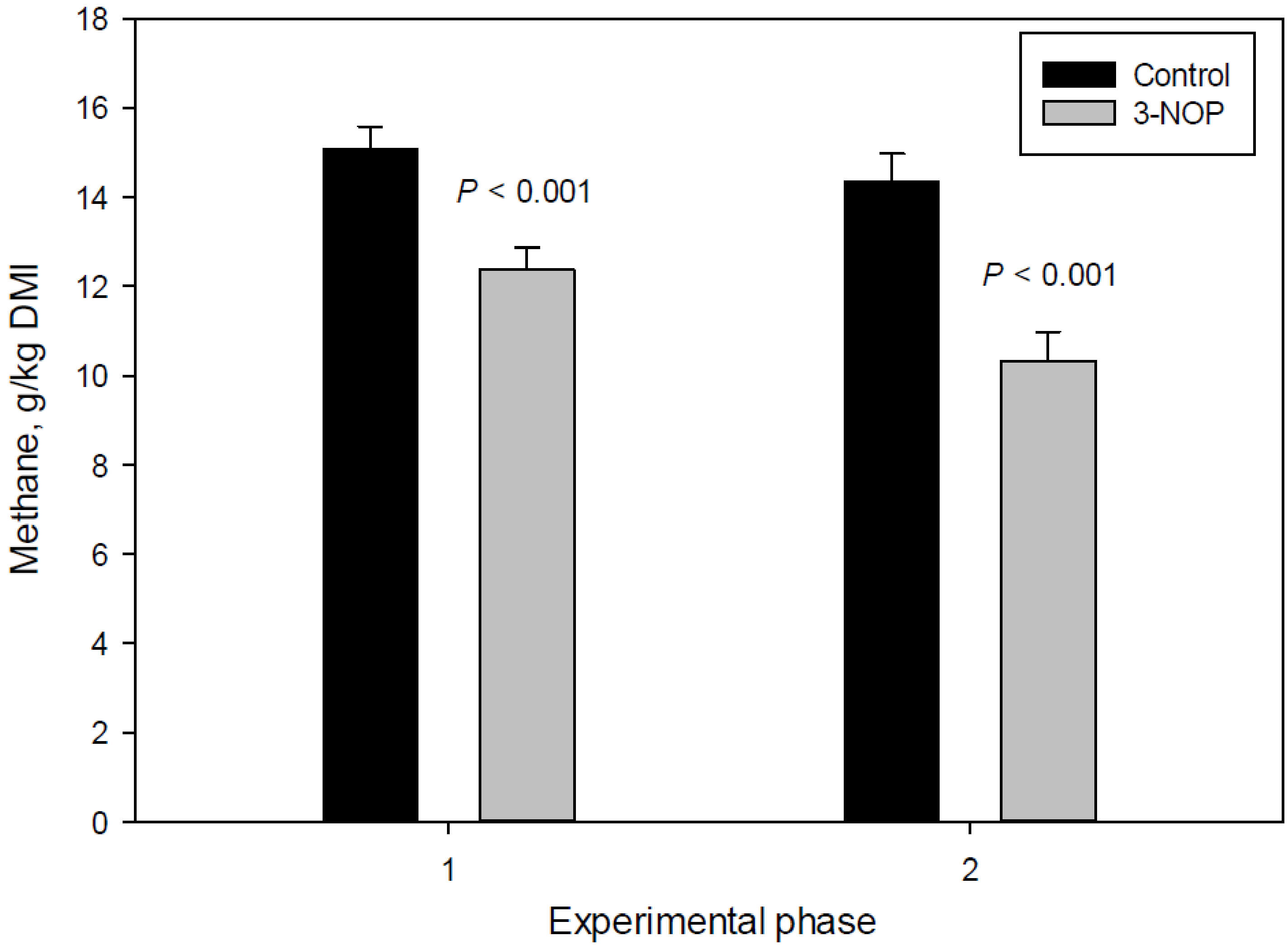
Meta-analysis of Penn State's 3-NOP data with dairy cows



Milk fat percentage was increased (*P* = 0.04) by 0.19%-units; yield was increased (*P* = 0.06) by 90 g/d

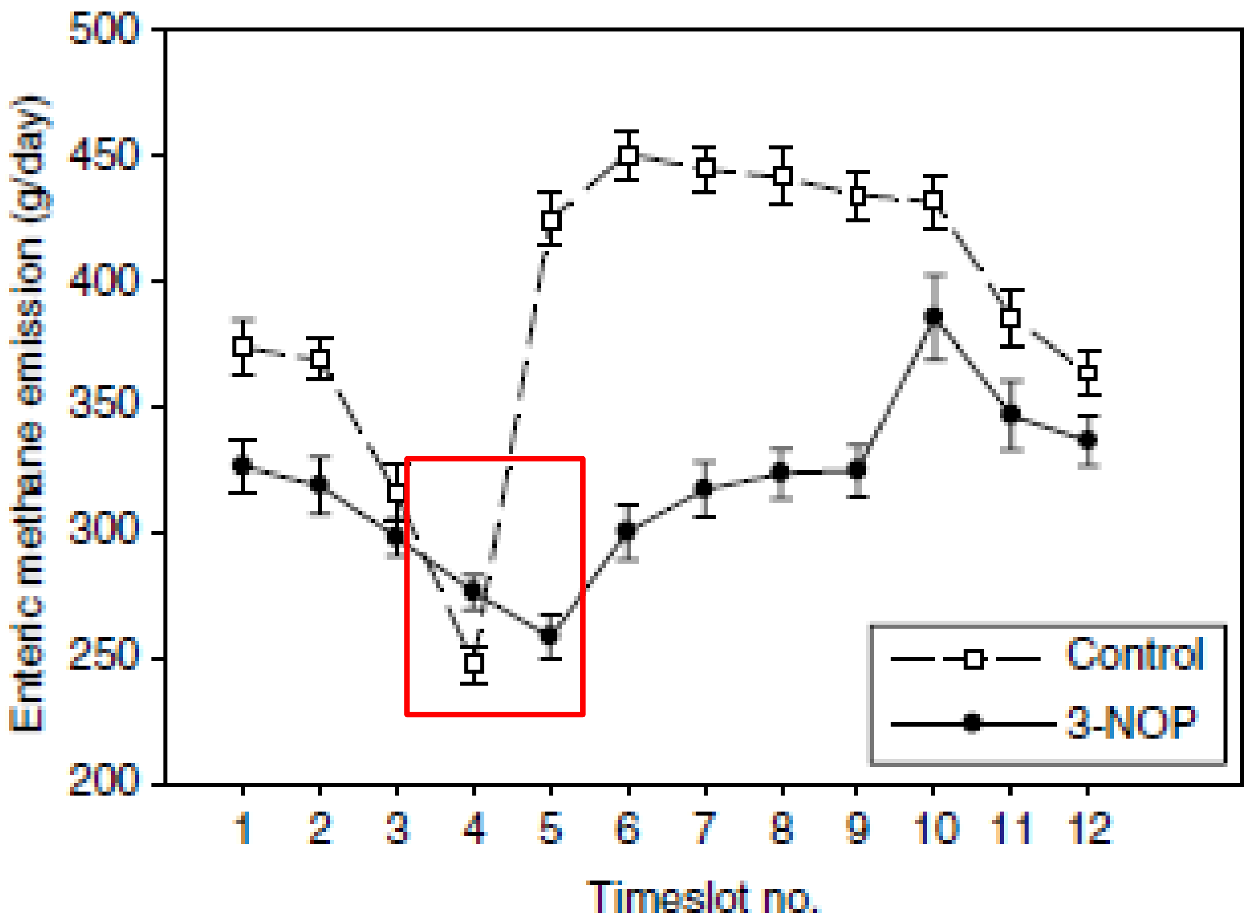
Melgar et al. (2019)

The effect of 3-NOP is immediate and reversable



Hristov & Melgar, 2019

Diurnal pattern in the mitigation effect of 3-NOP



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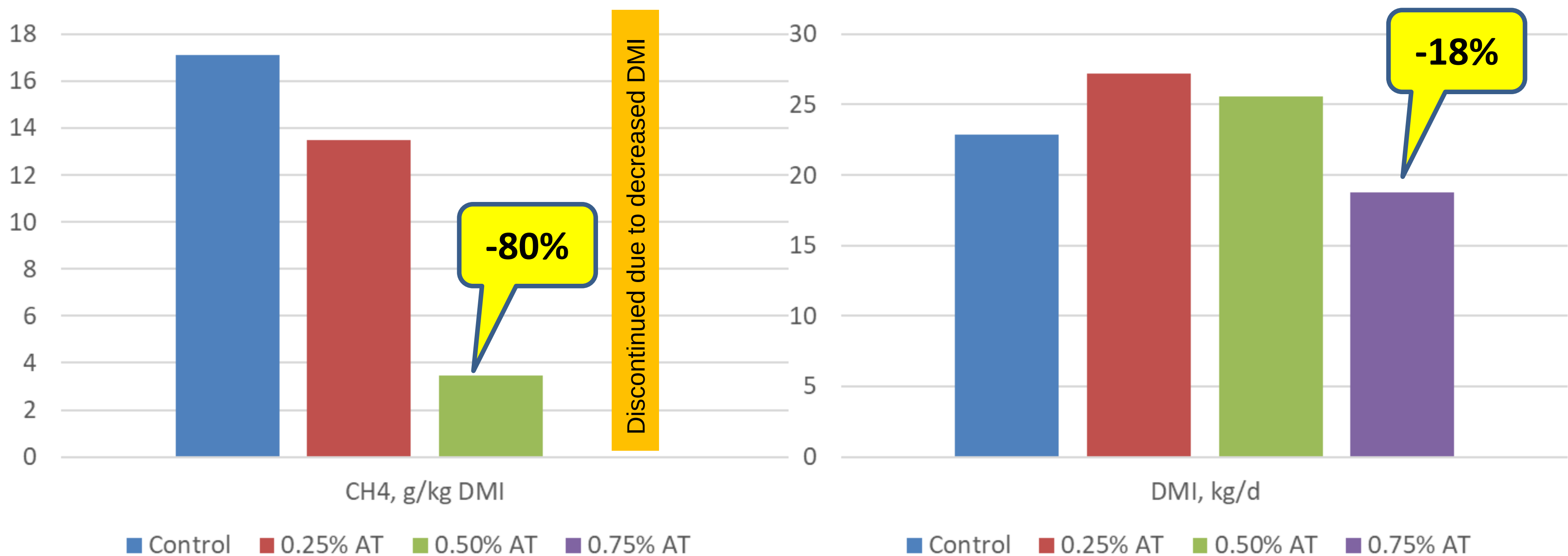
Large reduction in methane emission with *Asparagopsis taxiformis* in dairy cows

Asparagopsis taxiformis **(source: Penn State)**

Stefenoni et al., 2021



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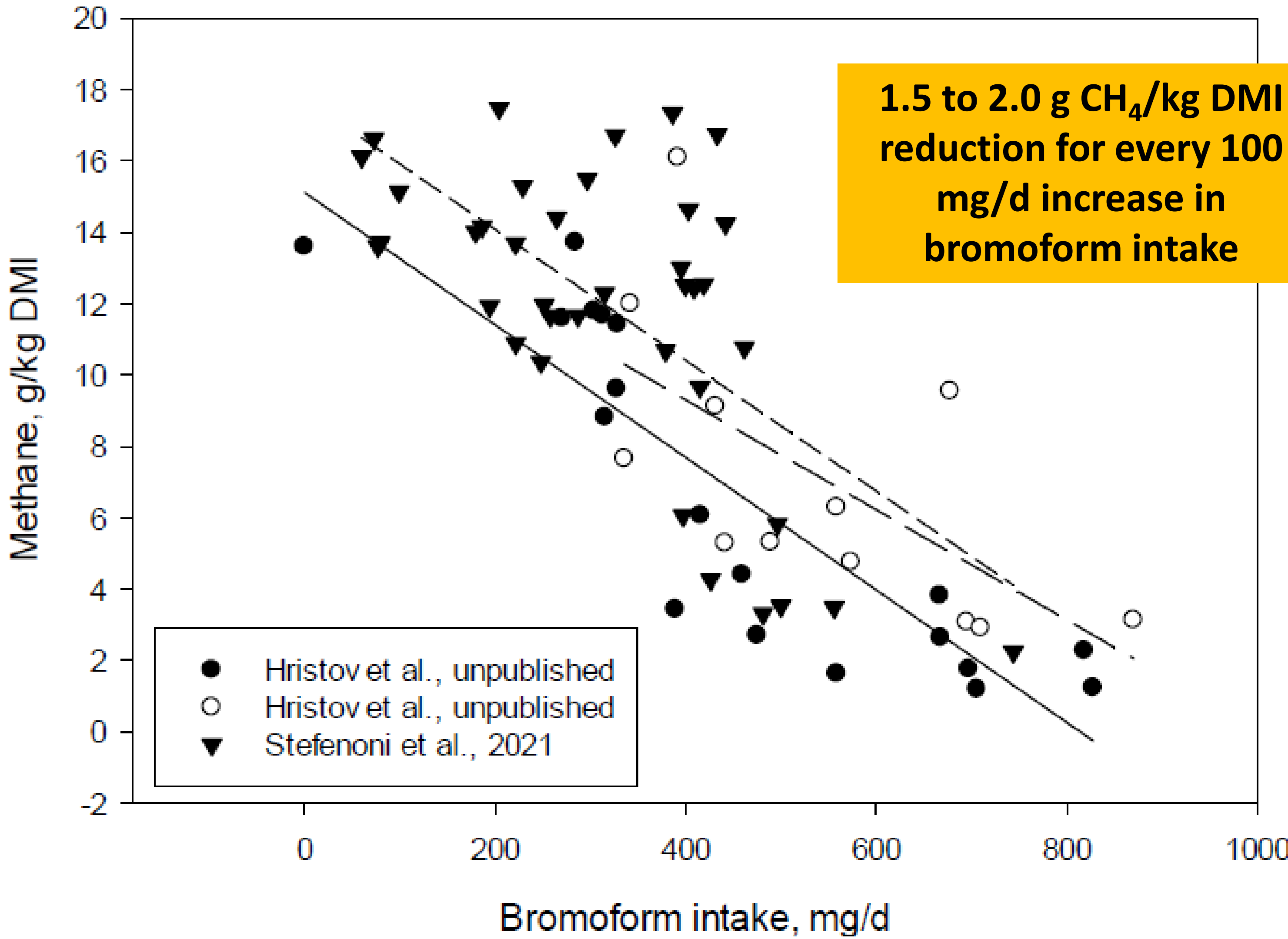
Penn State data

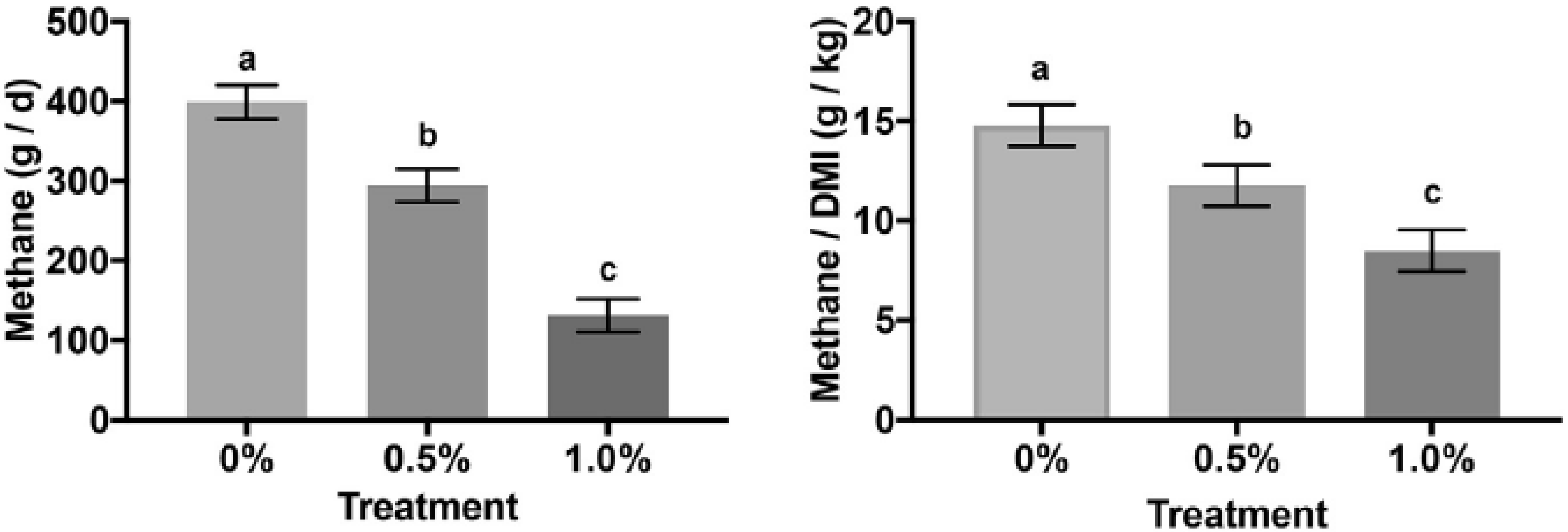
Bromoform intake and methane yield

1.5 to 2.0 g CH_4/kg DMI reduction for every 100 mg/d increase in bromoform intake



Roque et al., 2019

Similar results at UC Davis with *A. armata*



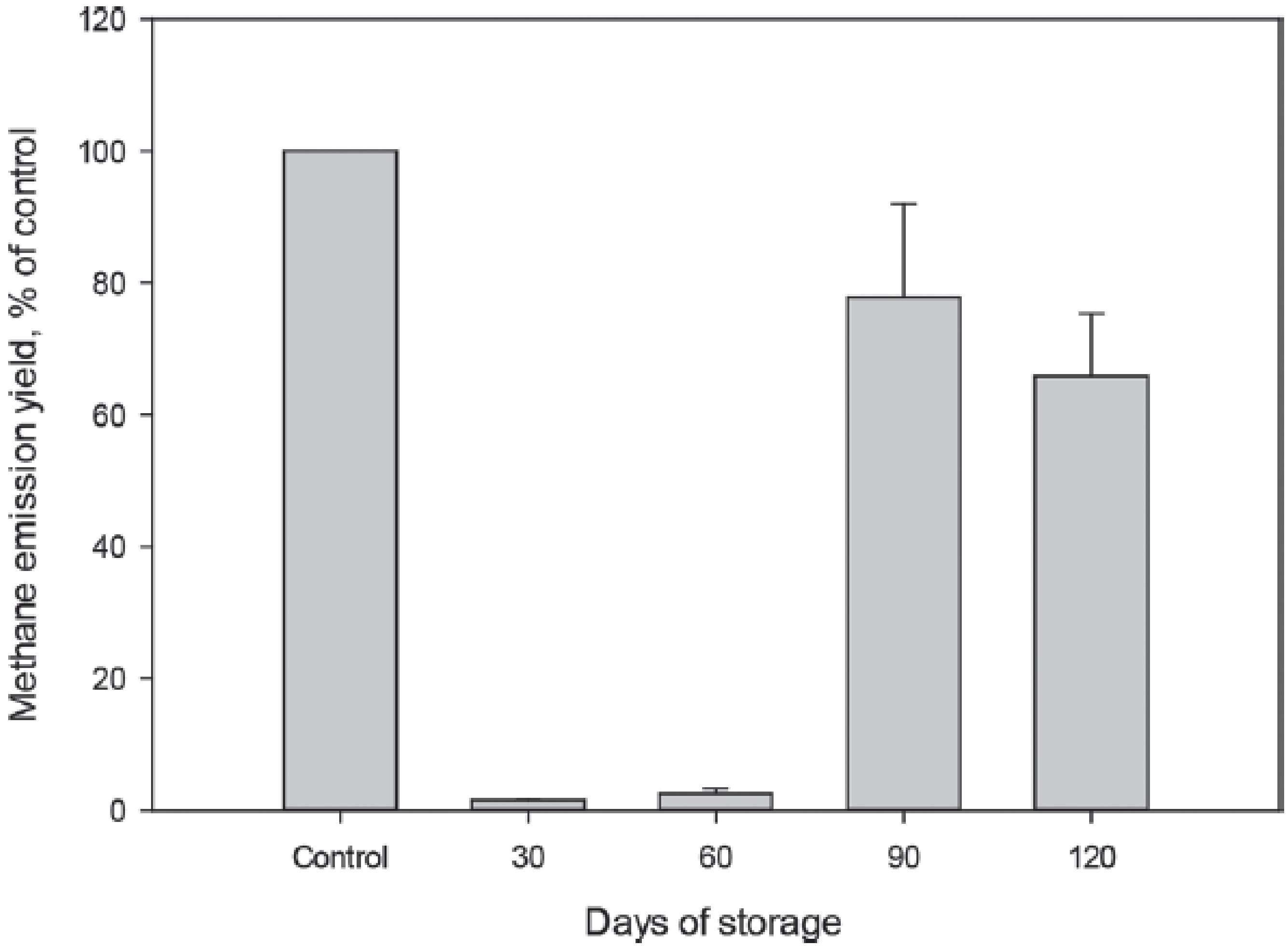
Many unanswered questions…

- How are bromoforms affected by:
  - Harvest, sunlight, transportation, processing & storage
- Aquaculture production
- Rumen adaptation
- Long-term production effects
- Doses/practicality
- Feasibility
- Milk quality – I, Br
- Consumer acceptance

Asparagopsis taxiformis **(source: Wikipedia)**

Stefenoni et al., 2021

Diminishing activity of AT over time?



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Aquaculture production?

Blue Ocean Barns Brominata Approved for Sale in California

By Blue Ocean Barns   May 6, 2022 Updated May 6, 2022

BLUE OCEAN
BARNS

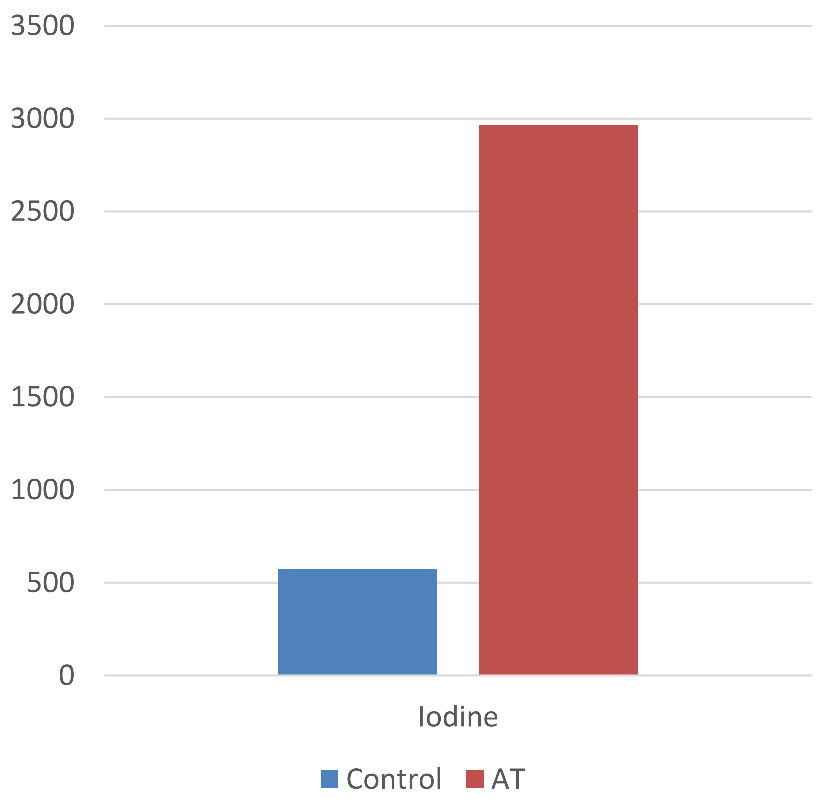
Blue Ocean Barns (PRNewsfoto/Blue Ocean Barns)
By Blue Ocean Barns

Natural digestive aid for cattle is made from a red seaweed proven in trials to reduce enteric methane emissions by more than 80%

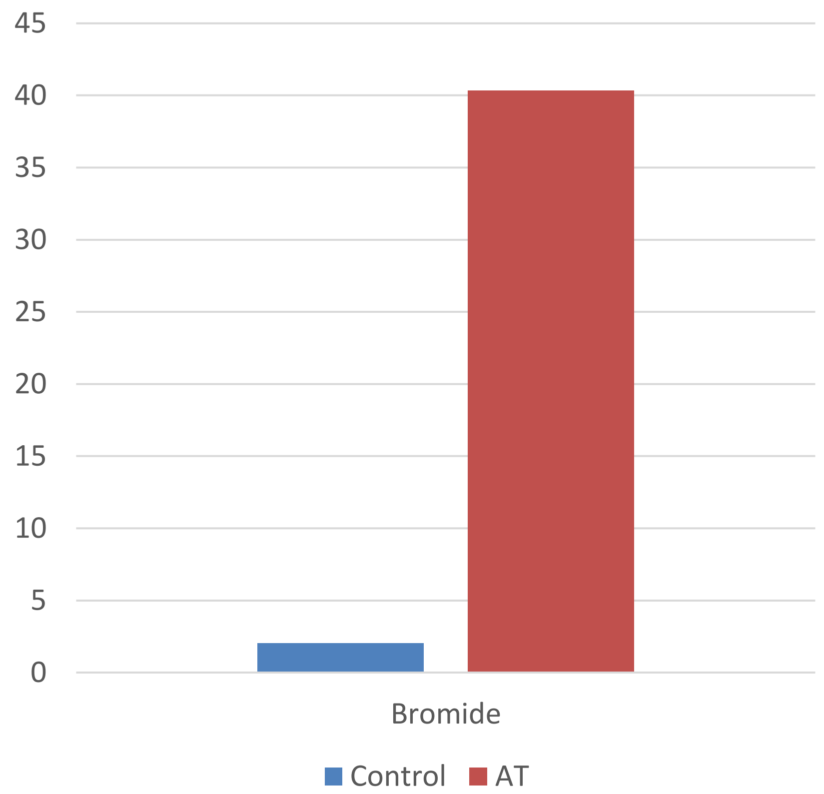
Stefenoni et al., 2021

Milk quality?

Milk iodine, ng/mL



Milk bromide, mg/L



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Plant extracts & microbials

- Numerous experiments
- Ma[illegible]n vitro, not followed up by animal trial[illegible]
- Several c[illegible]mercial products:
  - **Mootral** (gar[illegible]itrus extract) – on[illegible]dy with beef cattle showed [illegible] of the experim[illegible]
  - **Agolin** [illegible]ysis showed an overall 2% d[illegible]se in CH_4 yi[illegible]nd 13% beyond 28 d of treatme[illegible]
  - **AVT** ([illegible]cum & botanicals) – 5% decrease[illegible]H_4 yield
  - [illegible] – up to 25% reduction in CH_4 yield in vitro
  - For some of these, adaptation may be needed to show effects

Cannot be recommended until independent research is available to verify claims. The effect, if proven, may not exceed 10-15%.

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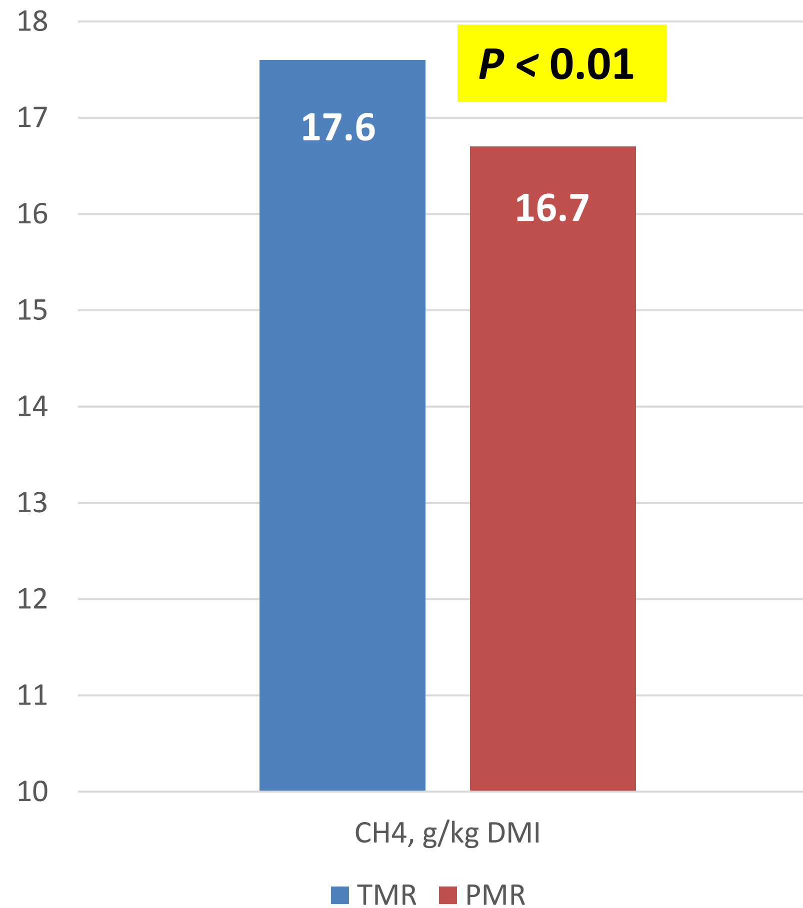
Martins et al., 2022

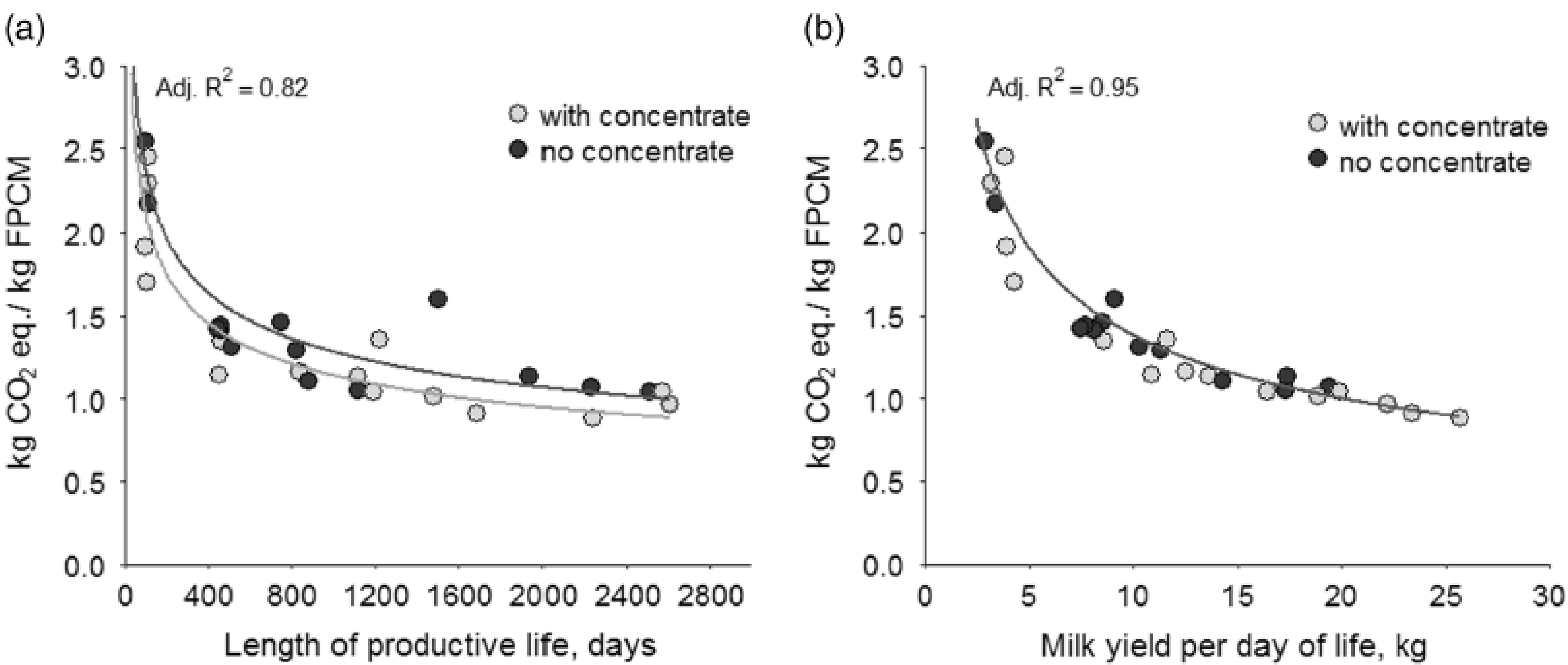
Management practices - precision feeding



Management practices - lifetime productivity

>106,000 kg of milk in 10 lact.
Freyer et al. (2008)

Same milk production,
but from 5 cows/2 lact. each



Grandl et al., 2019

Hristov et al., 2013

Management practices – increased productivity

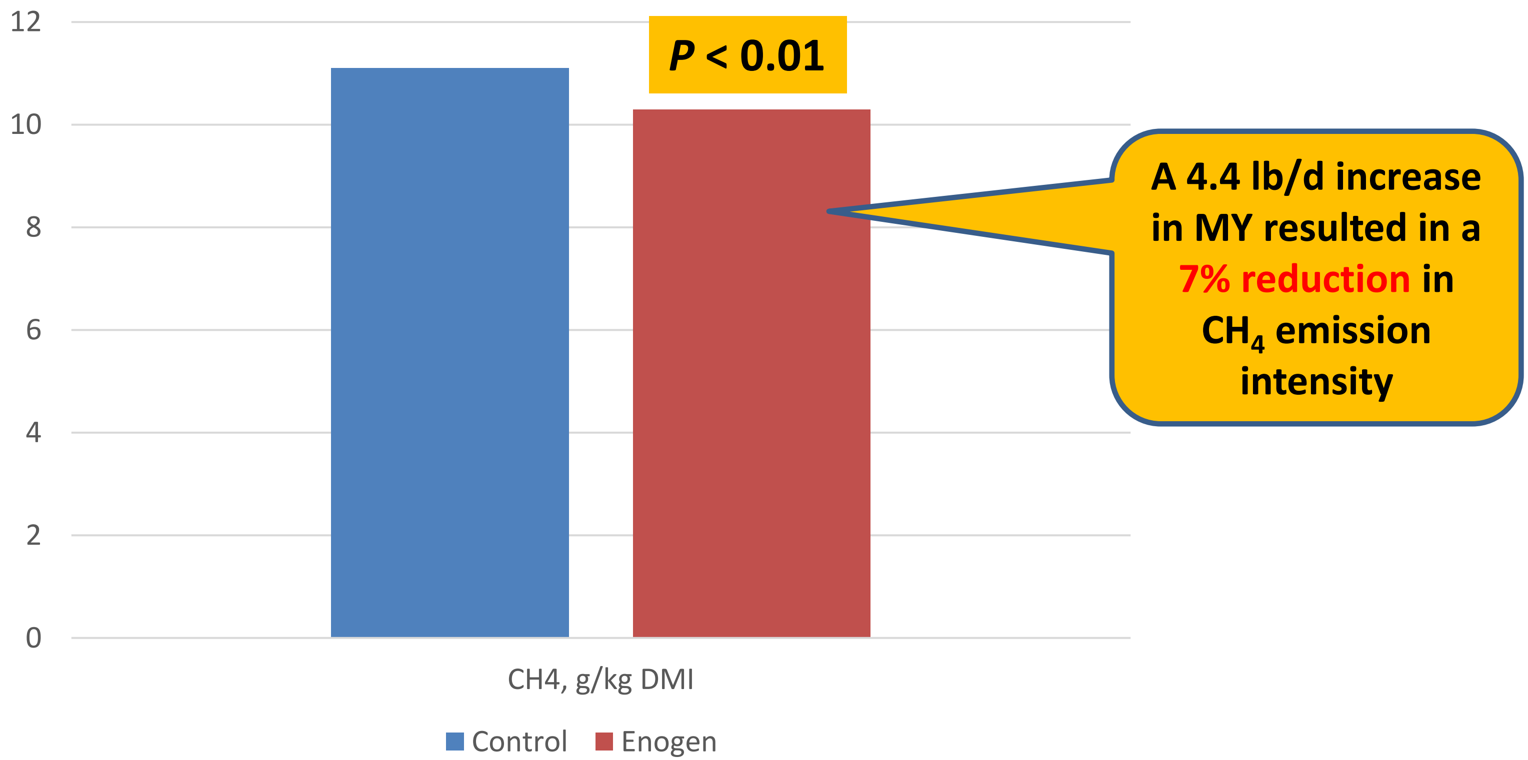
SPECIAL TOPICS—Mitigation of methane and nitrous oxide emissions from animal operations: III. A review of animal management mitigation options[1]

A. N. Hristov,*[2] T. Ott,* J. Tricarico,† A. Rotz,‡
G. Waghorn,§ A. Adesogan,# J. Dijkstra,‖ F. Montes,¶ J. Oh,* E. Kebreab,**
S. J. Oosting,‖ P. J. Gerber,†† B. Henderson,†† H. P. S. Makkar,†† and J. L. Firkins‡‡

- Applicable to all species
- High enteric methane mitigation potential
- High nitrous oxide mitigation potential
- Effective and recommended

Welchez et al., 2020

Increased milk production = decreased emission intensity: corn silage example



A free-stall, Calan gates study with 48 cows

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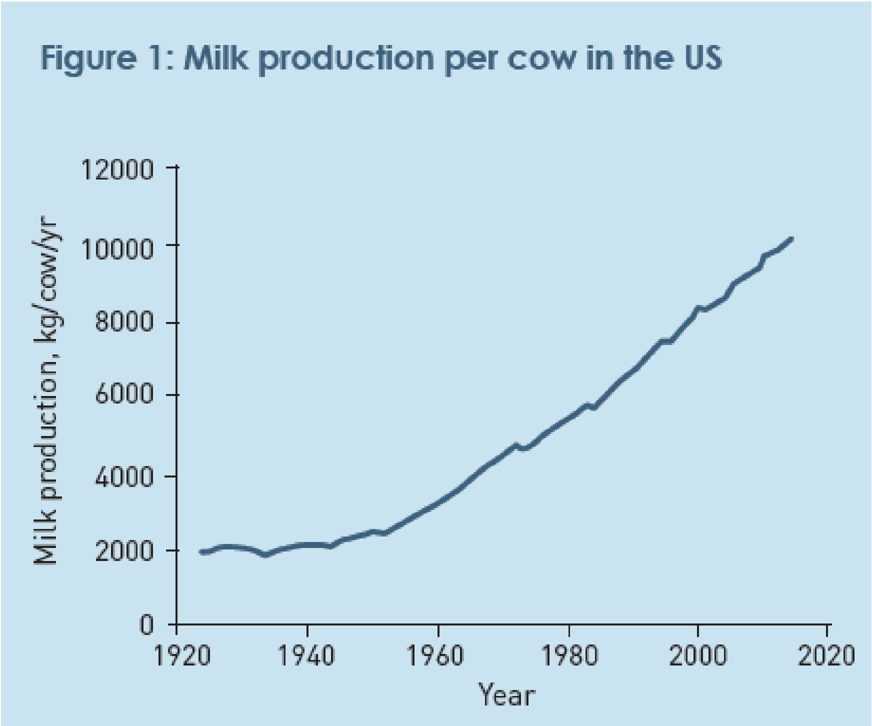
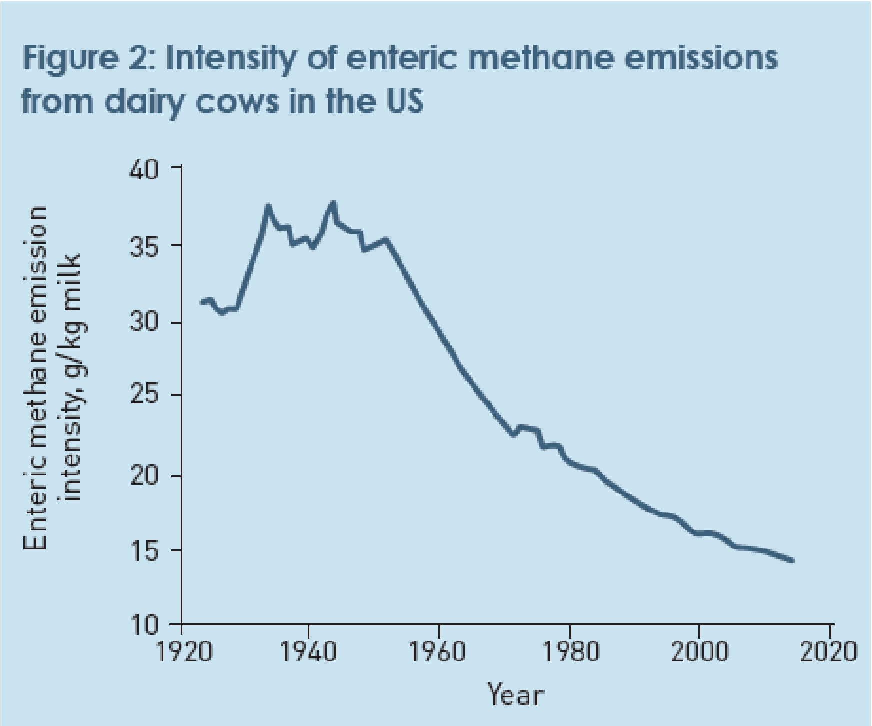
The US dairy industry is a good example of emission intensity reductions





Hristov, 2015

Hristov et al., 2013

Reproductive management practices to decrease GHG emission intensity

- Following practices were found to have "High effectiveness" in decreasing iGHG
  - Crossbreeding
  - Reduction in stressors
    - Heat, diseases, nutrition
  - Assisted reproductive technologies
    - AI, embryo transfer
  - Pregnancy diagnosis

736 days average lactation on a KZ dairy farm

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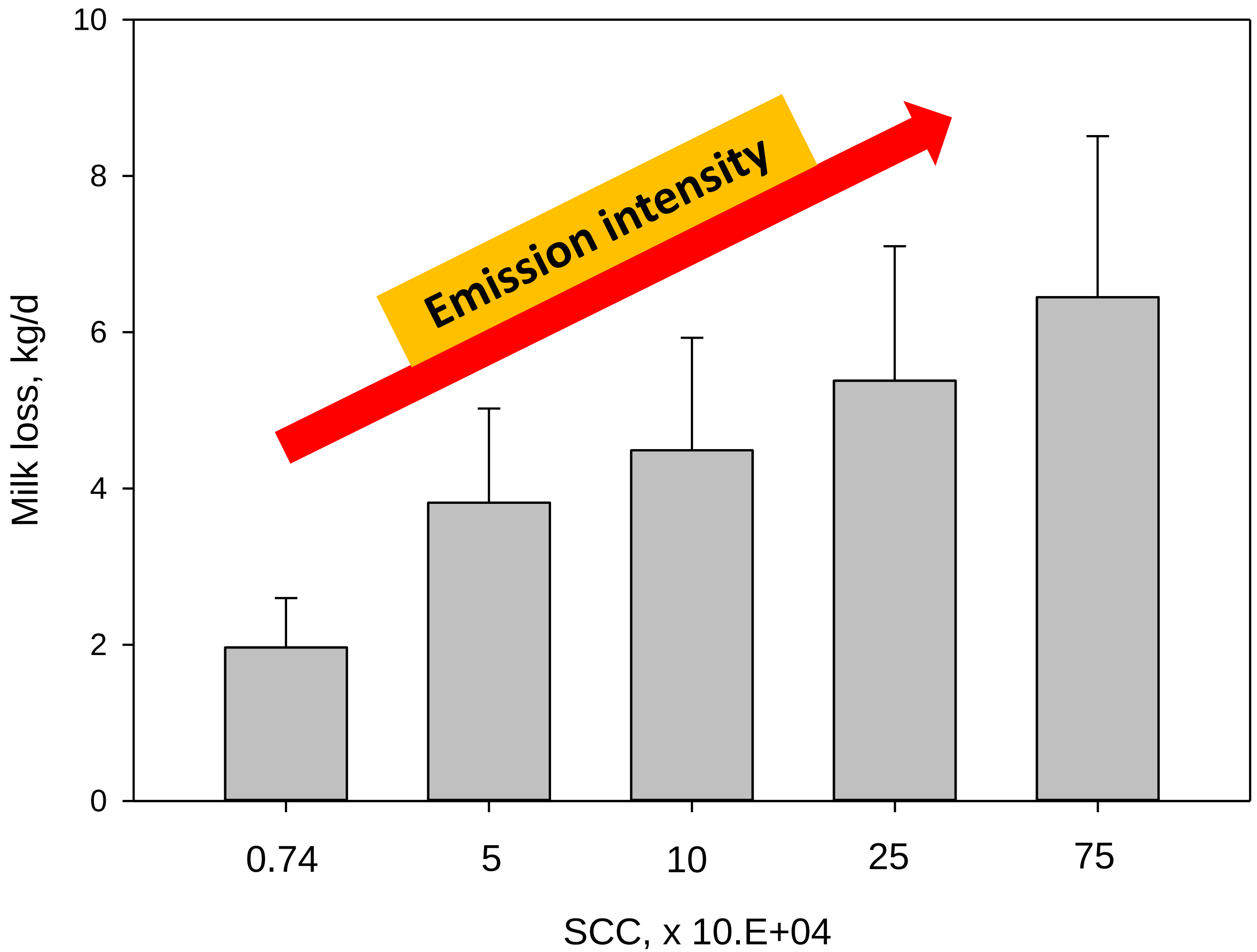
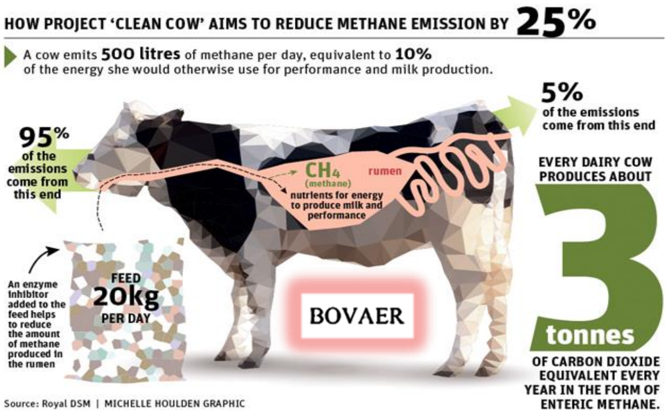
Potter et al., 2017

Potential animal health effects on methane emission intensity



Take-home message

- Only 2 strategies have a pronounced mitigation effect on enteric methane – **need long-term, full lactation studies**
  - 3-Nitrooxypropanol (Bovaer), *Asparagopsis* spp.
- Oils can decrease methane by up to 20%
- Nitrates are also effective (15-19% decrease)
- Tannins may be effective, but more research is needed



- Combining practices may deliver an estimated 40-50% reduction
- So far, no evidence of other feed additives with a consistent mitigation effect of over 10%
- Several animal management practices can also be effective/recommended
- Major constraints going forward:
  - Production responses to effective methane mitigants (co-benefits)
  - Long-term effects and consistent responses with various diets are largely unknown
  - Delivery in grazing systems is challenging


QUESTIONS?
2134
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1940
Control