QUEEN'S UNIVERSITY BELFAST
SCHOOL OF BIOLOGICAL SCIENCES
INSTITUTE FOR GLOBAL FOOD SECURITY
AgriSearch NI – Driving Excellence & Innovation
UK DAIRY Carbon Network

METHANE – THE REAL STORY

QUEEN'S UNIVERSITY BELFAST

SCHOOL OF BIOLOGICAL SCIENCES

INSTITUTE FOR GLOBAL FOOD SECURITY

AgriSearch NI
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UK DAIRY Carbon Network

Welcome and Introduction

Professor Sharon Huws

Interim Director, Institute for Global Food Security

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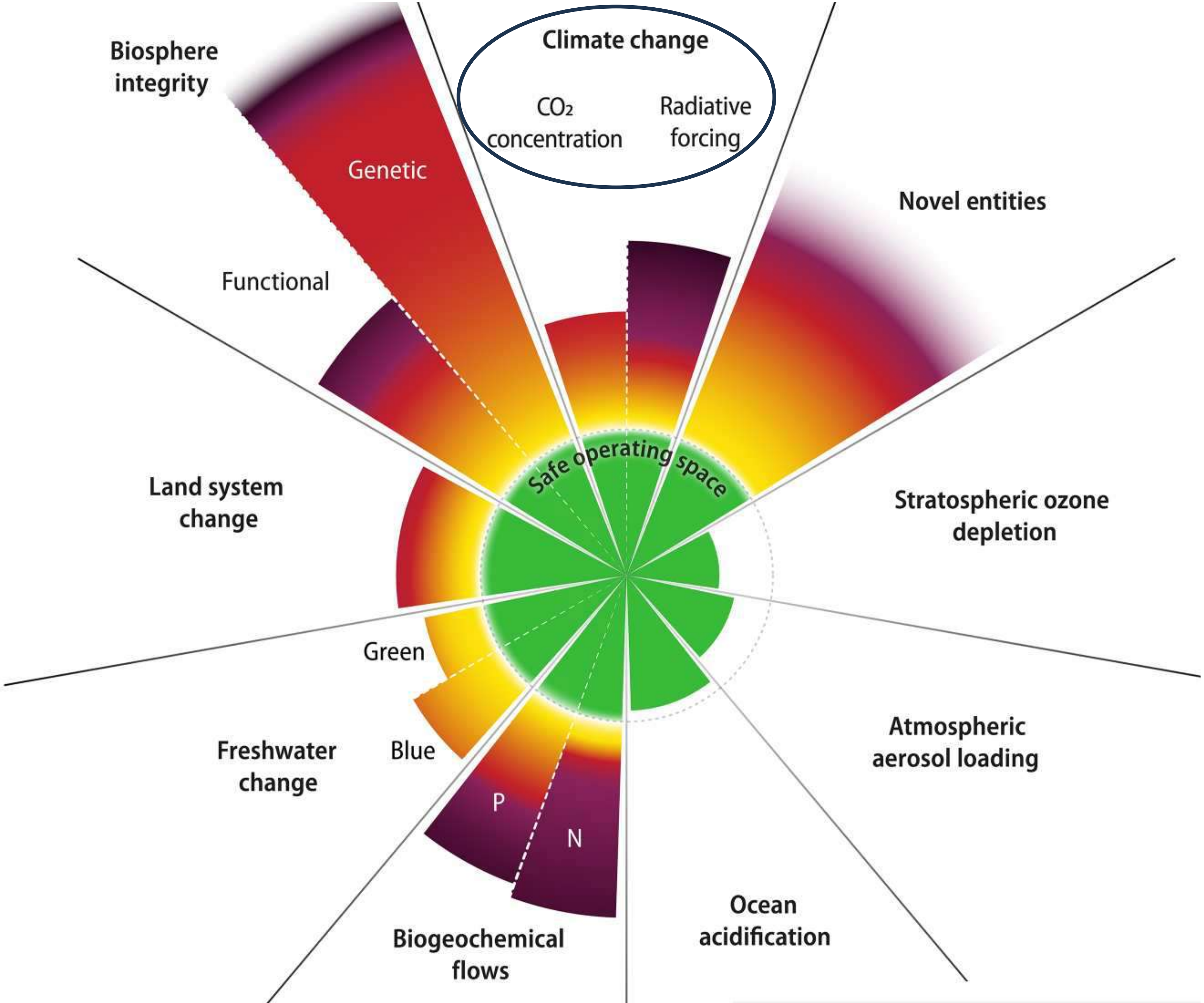
Guest Lecture

Professor Ermias Kebreab

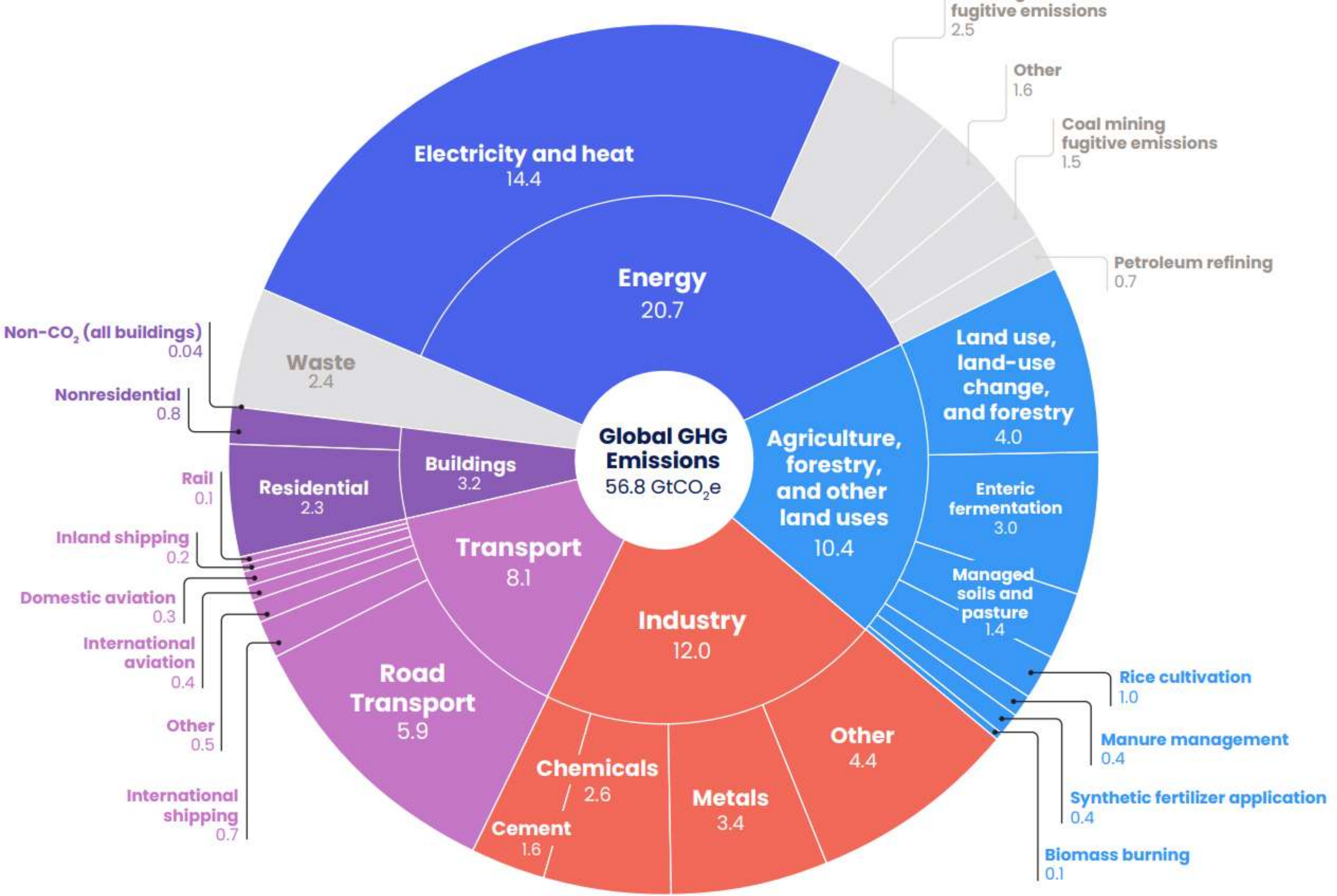
Associate Dean for Global Engagement in the College of Agricultural and Environmental Sciences, University California Davis

Methane
The Real Story

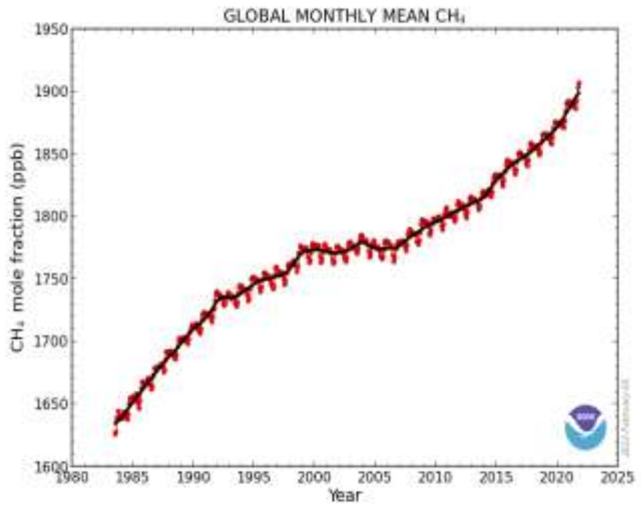
Ermias Kebreab
Associate Dean
Sesnon Endowed Chair
Professor of Sustainable Agriculture
University of California, Davis



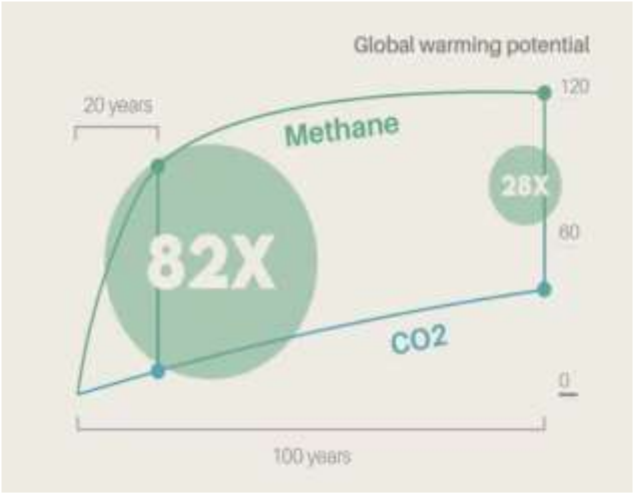
Richardson et al. 2023



Global GHG Emissions
56.8 $GtCO_2e$
Energy
20.7
Electricity and heat
14.4
fugitive emissions
2.5
Other
1.6
Coal mining fugitive emissions
1.5
Petroleum refining
0.7
Agriculture, forestry, and other land uses
10.4
Land use, land-use change, and forestry
4.0
Enteric fermentation
3.0
Managed soils and pasture
1.4
Rice cultivation
1.0
Manure management
0.4
Synthetic fertilizer application
0.4
Biomass burning
0.1
Industry
12.0
Other
4.4
Metals
3.4
Chemicals
2.6
Cement
1.6
Transport
8.1
Road Transport
5.9
International shipping
0.7
Other
0.5
International aviation
0.4
Domestic aviation
0.3
Inland shipping
0.2
Rail
0.1
Buildings
3.2
Residential
2.3
Nonresidential
0.8
Non-CO_2 (all buildings)
0.04
Waste
2.4



Methane emissions are rising



Warming potential of methane compared to CO_2

+ 0.5 °C

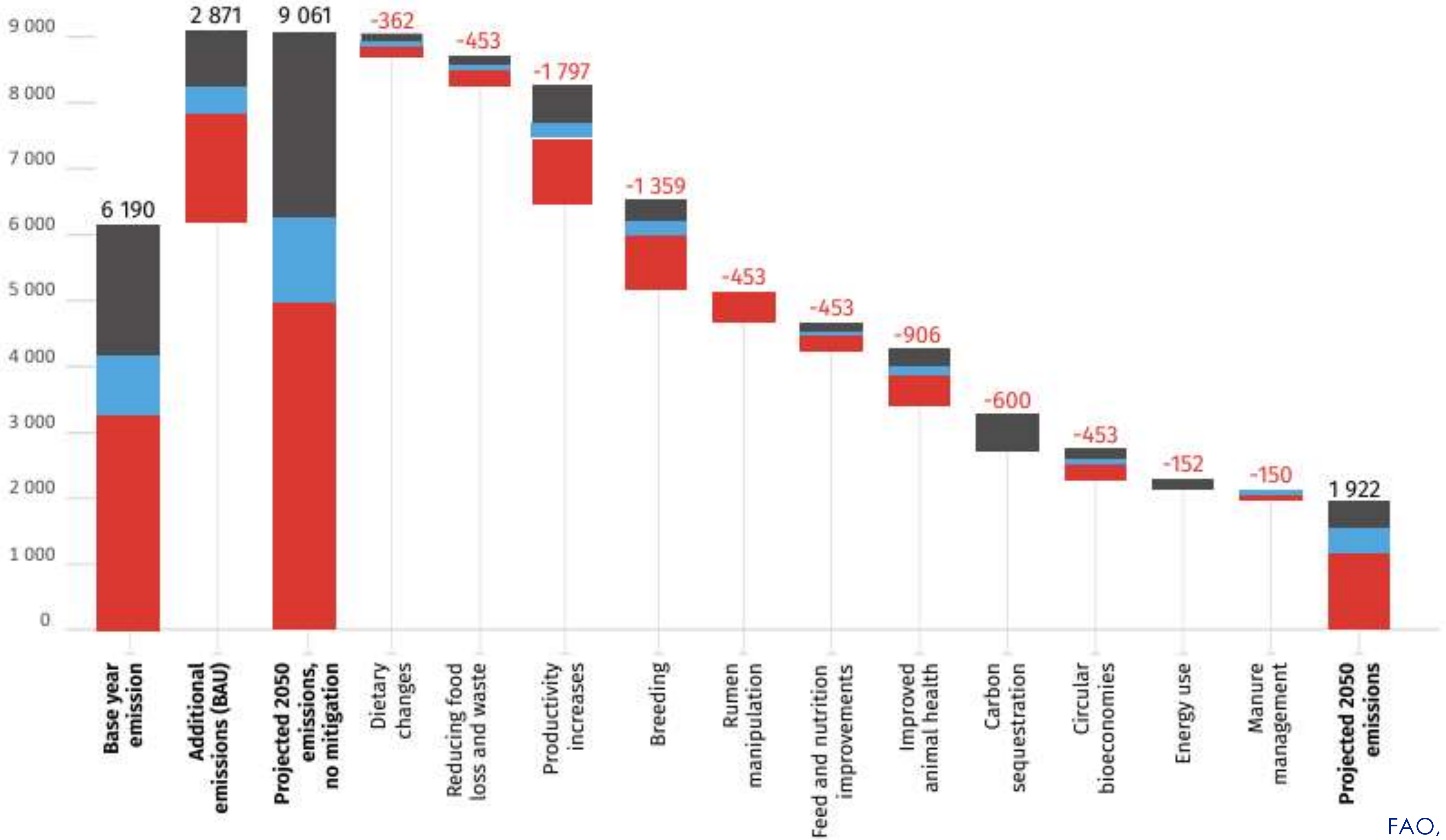
Current temperature increase due to anthropogenic methane emissions

~ 0.3 °C

The temperature increase we can avoid by 2040s with a methane reduction of 30%

SUSTAINABLE AGRICULTURE at UC DAVIS

NOAA, Earth.org, IPCC



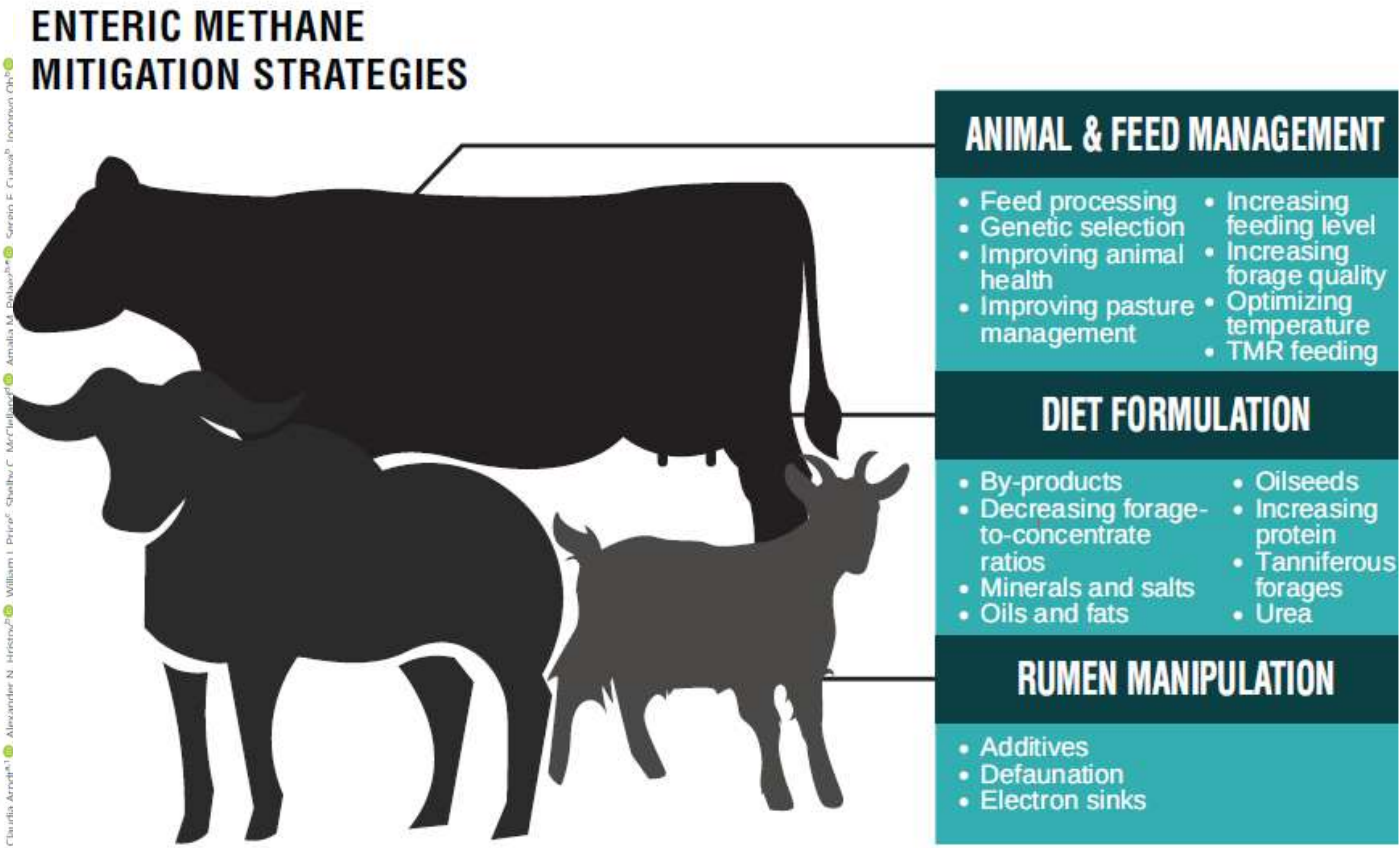
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
6 190
2 871
9 061
-362
-453
-1 797
-1 359
-453
-453
-906
-600
-453
-152
-150
1 922
Base year emission
Additional emissions (BAU)
Projected 2050 emissions, no mitigation
Dietary changes
Reducing food loss and waste
Productivity increases
Breeding
Rumen manipulation
Feed and nutrition improvements
Improved animal health
Carbon sequestration
Circular bioeconomies
Energy use
Manure management
Projected 2050 emissions

FAO, 2023

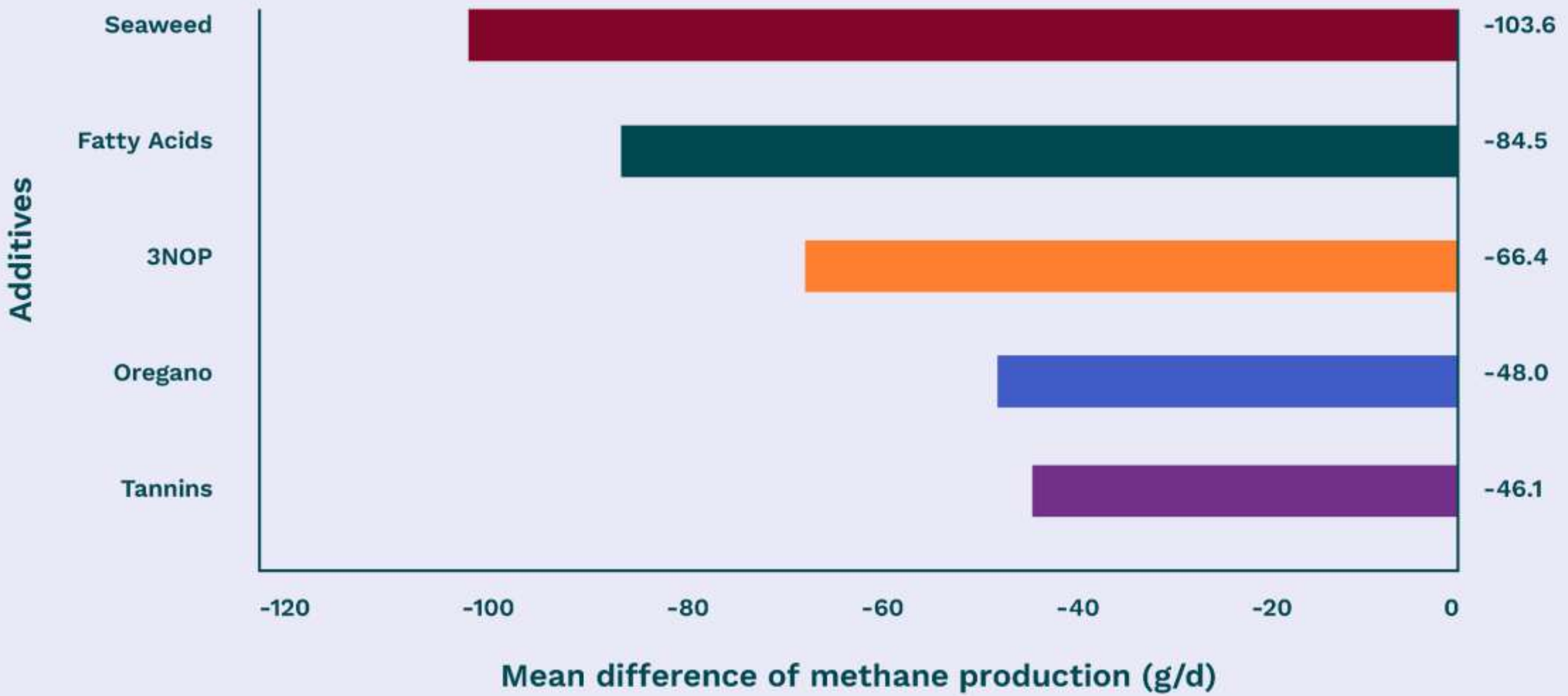
PNAS
RESEARCH ARTICLE | SUSTAINABILITY SCIENCE
OPEN ACCESS

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

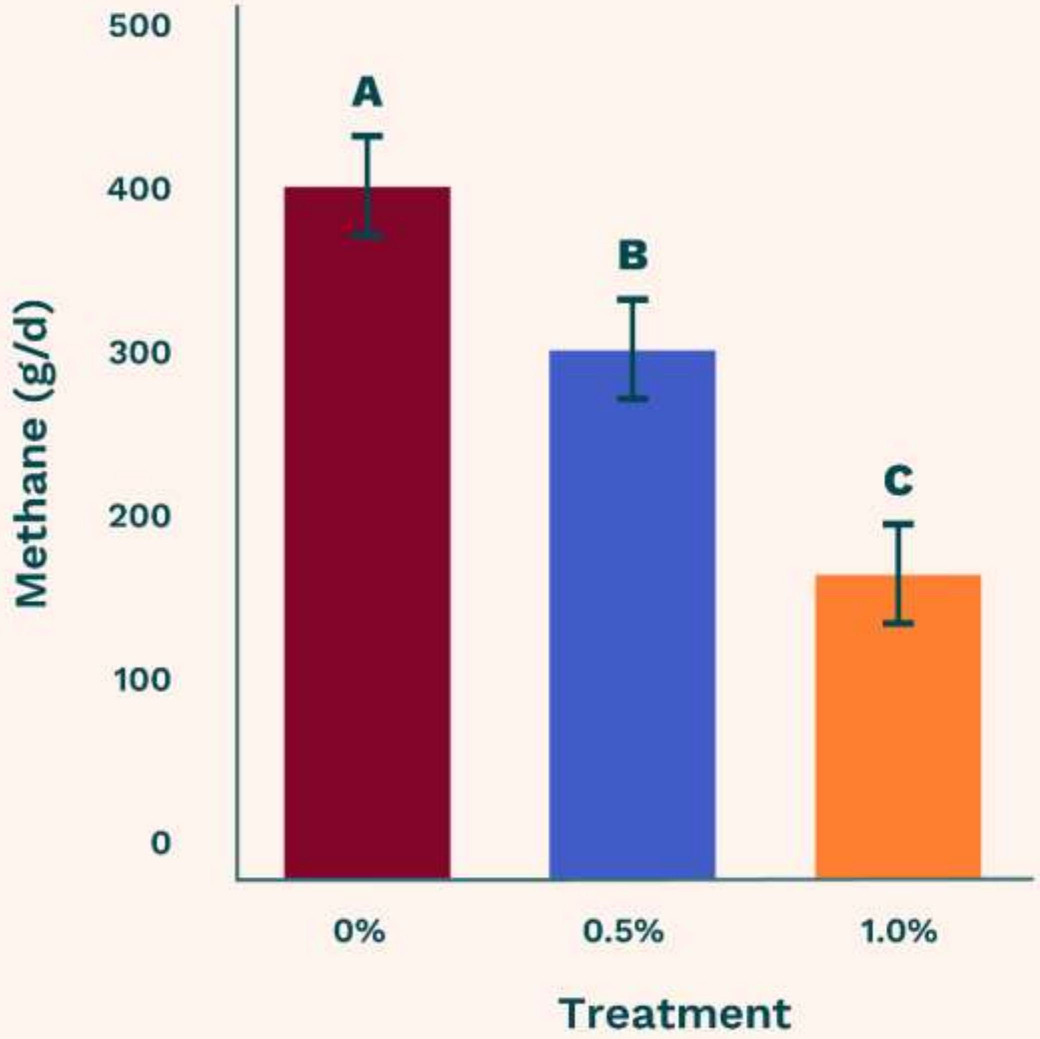
Claudia Arndt[a,1], Alexander N. Hristov[b], William J. Price[c], Shelby C. McClelland[d], Amalia M. Pelaez[b], Sergio F. Cueva[b], Joonpyo Oh[b]

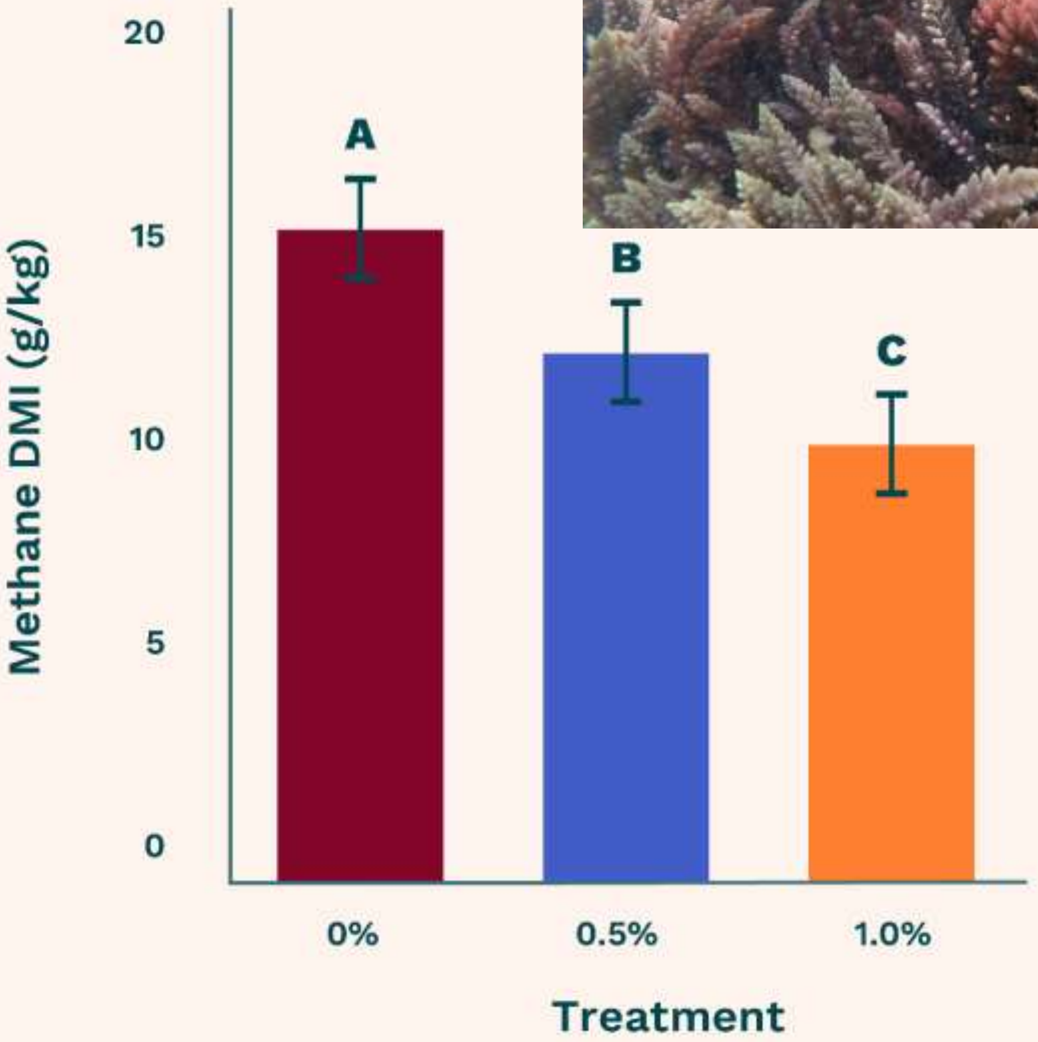


Methane reductions from feed additives



Honan et al., 2021





Roque et al., 2019

PNAS
RESEARCH ARTICLE | AGRICULTURAL SCIENCES
OPEN ACCESS

Mitigating methane emissions in grazing beef cattle with a seaweed-based feed additive: Implications for climate-smart agriculture

Paulo Meo-Filho[a], John F. Ramirez-Agudelo[a], and Ermias Kebreab[a]

Seaweed Alternatives

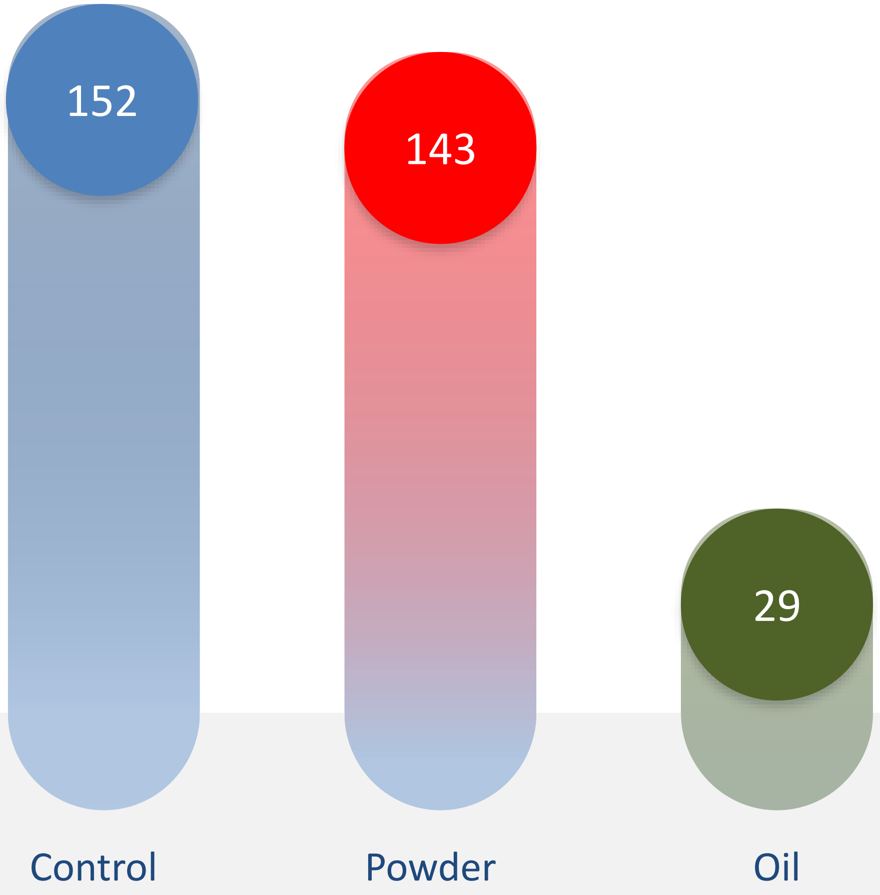
Kelly et al. 2025

Control

Powder

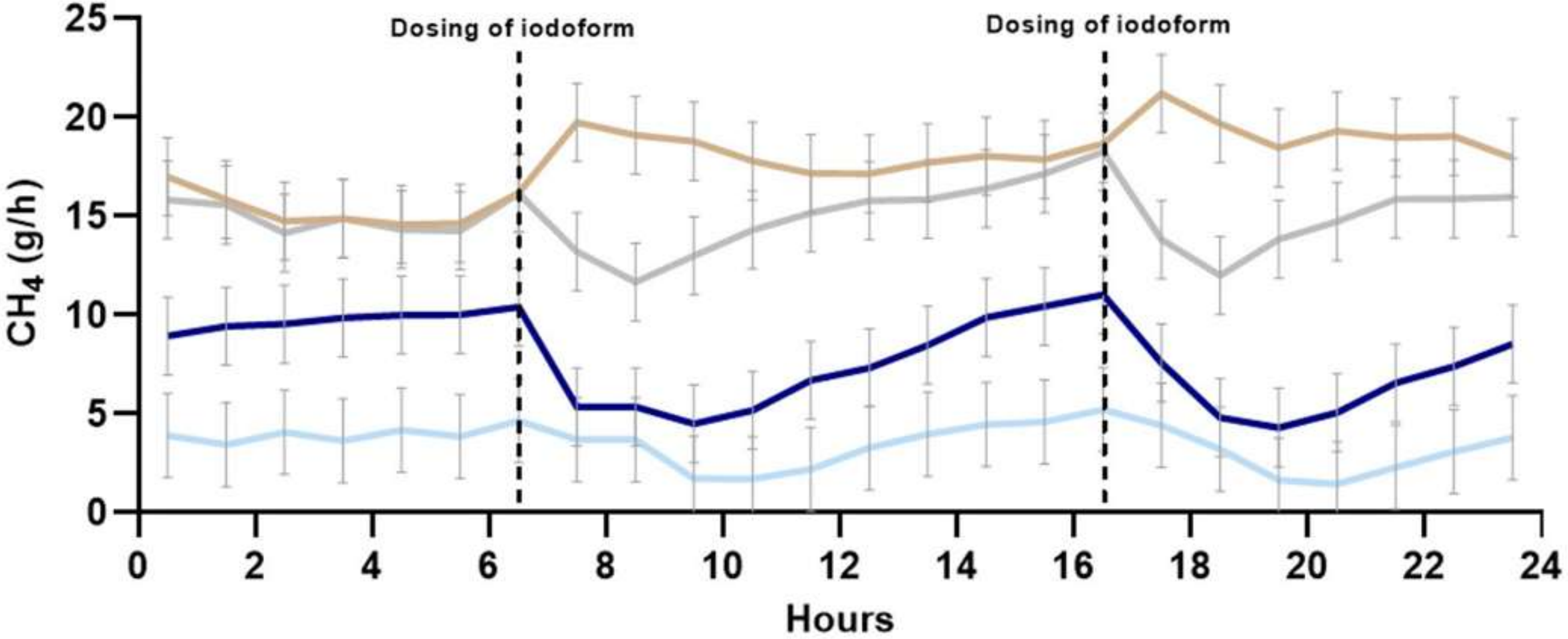
Oil

Enteric methane emissions (g/d)



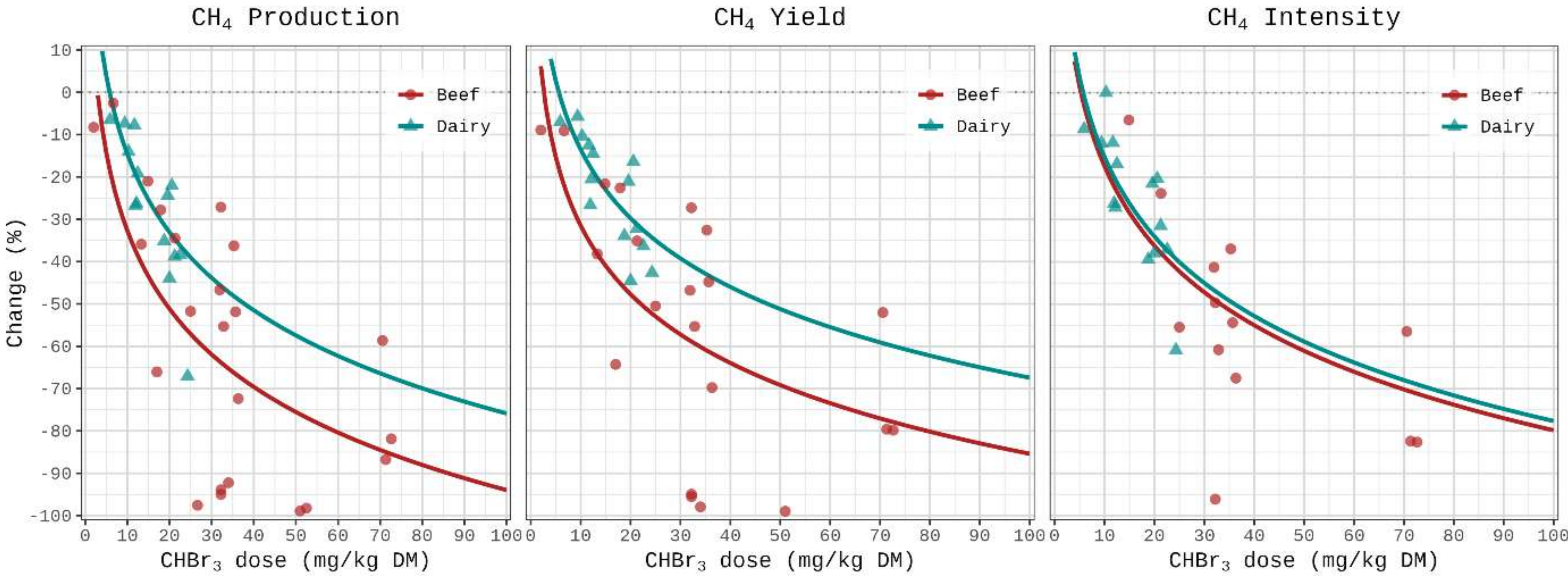
Kelly et al. 2025

Thorsteinsson et al. 2023

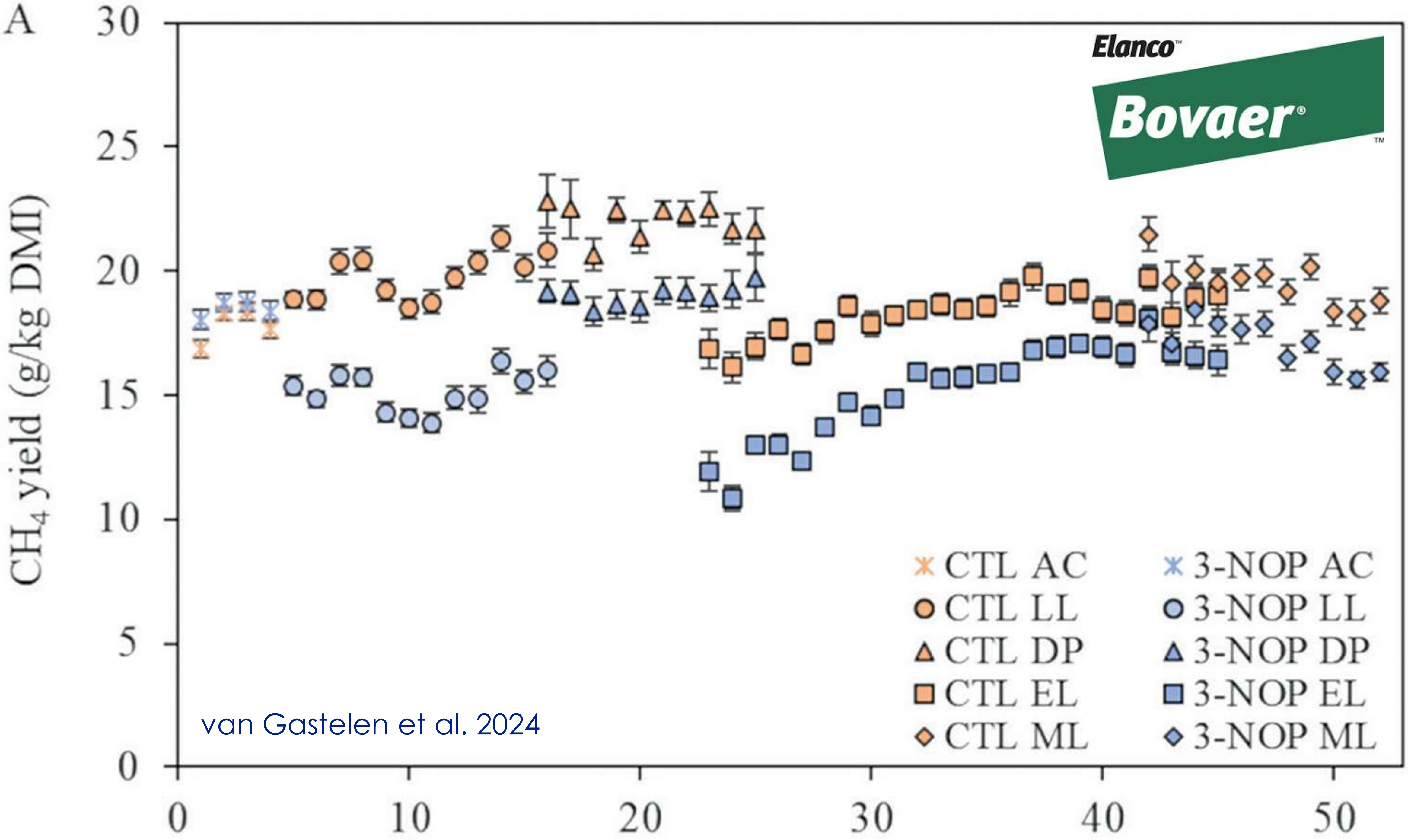


0 mg/d	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
320 mg/d	a	ab	a	a	a	b	b	b	b	a	a	a	a	a	a	a	b	b	a	a	a	a	a	a
640 mg/d	b	b	b	a	a	b	c	c	c	b	b	b	b	b	b	b	c	c	b	b	b	b	b	b
800 mg/d	c	c	c	b	b	c	c	c	c	b	b	b	b	c	c	c	c	c	b	b	b	b	b	b

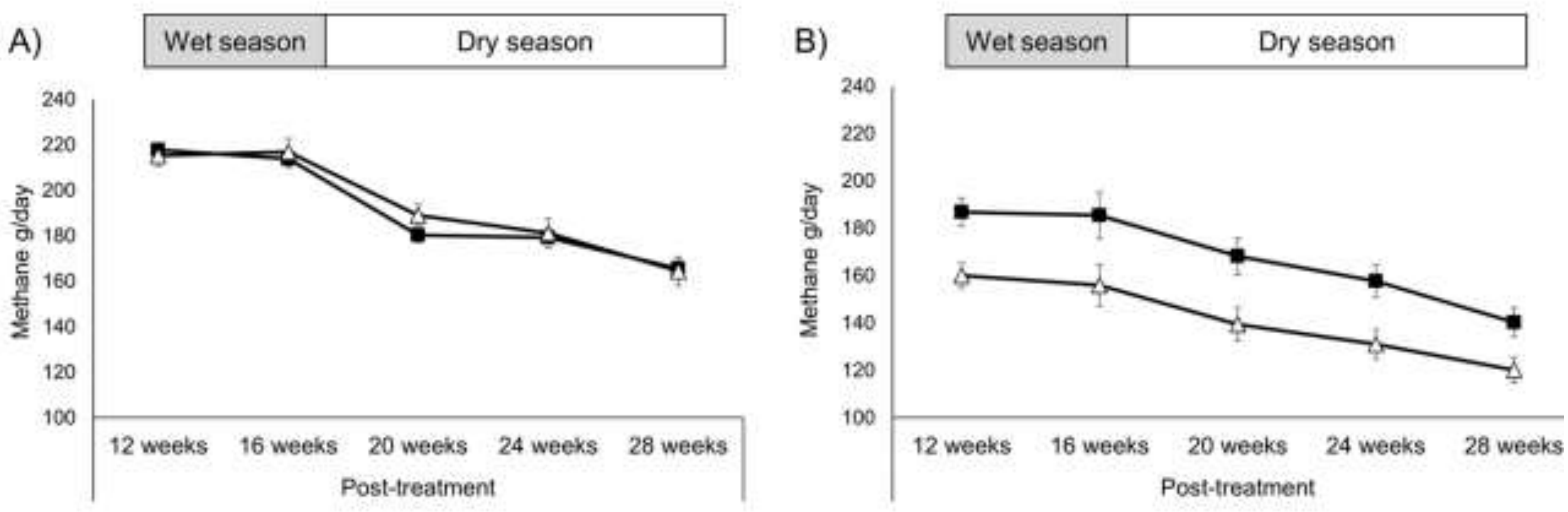
Meta-analysis - Bromoform



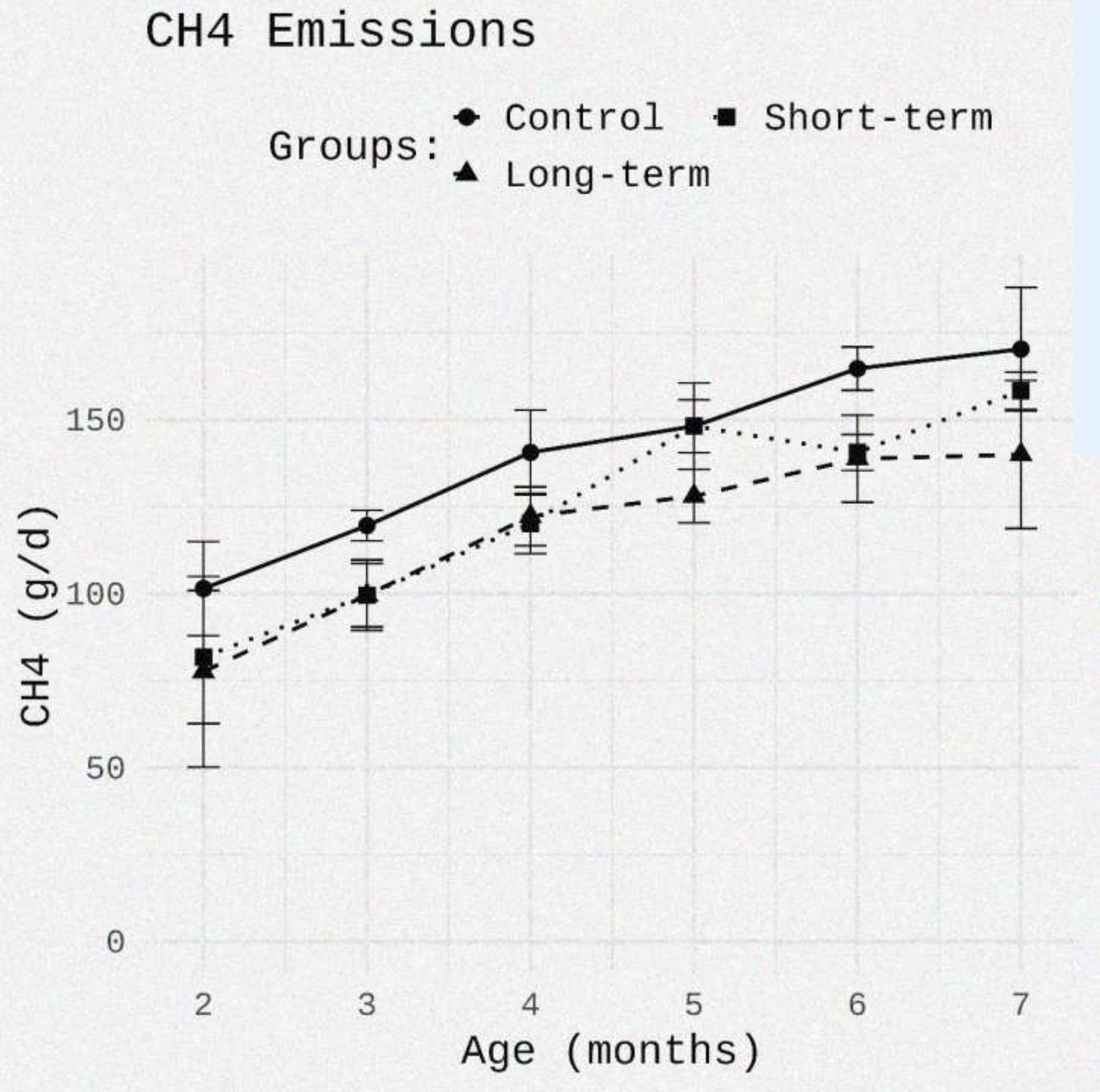
Kebreab et al., submitted


A
CH4 yield (g/kg DMI)
0
5
10
15
20
25
30
0
10
20
30
40
50
CTL AC
CTL LL
CTL DP
CTL EL
CTL ML
3-NOP AC
3-NOP LL
3-NOP DP
3-NOP EL
3-NOP ML
van Gastelen et al. 2024

Early Life Programming



Martinez-Fernandez et al. 2024

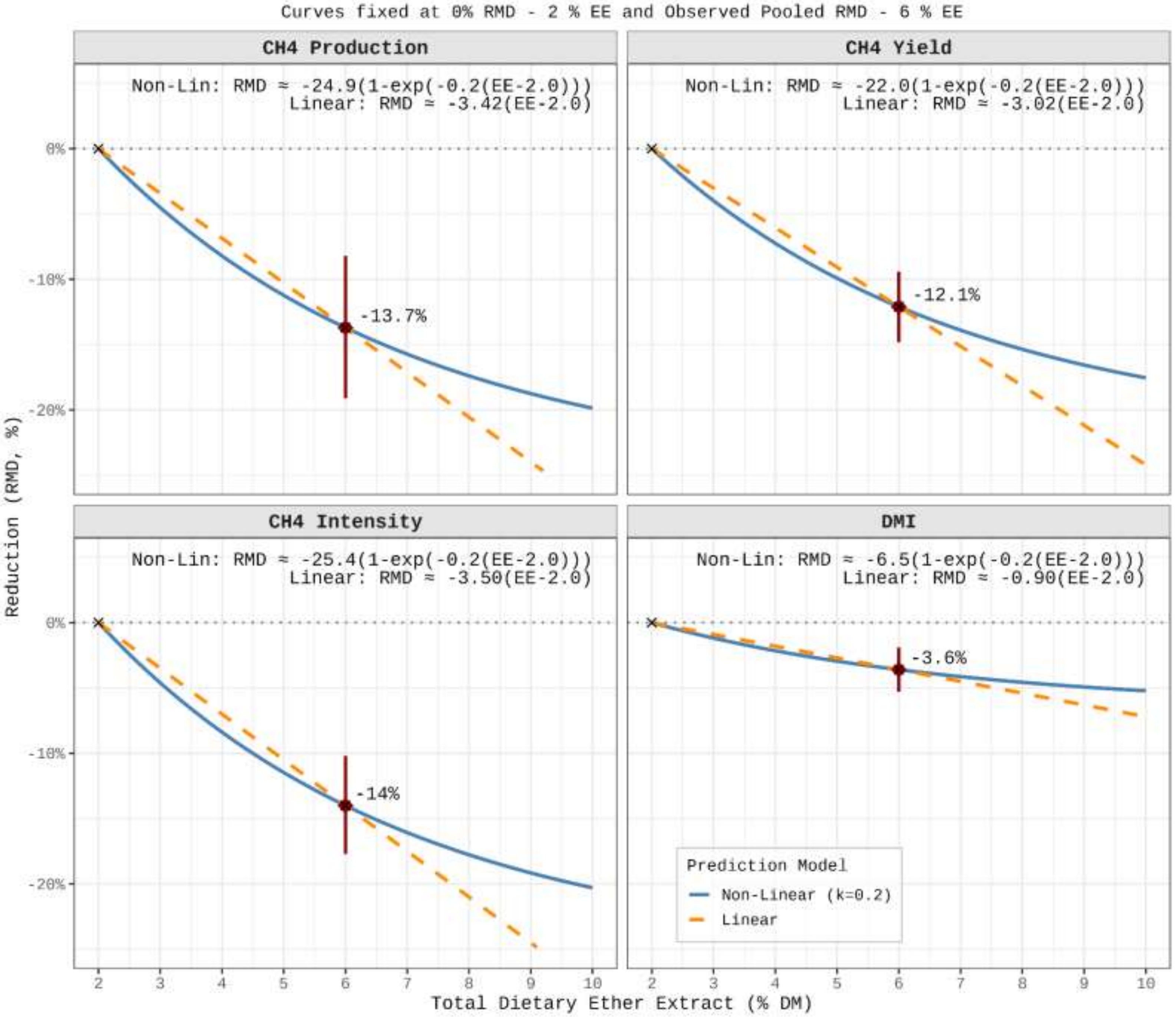

CH4 Emissions
Groups:
Control
Short-term
Long-term
CH4 (g/d)
150
100
50
0
2
3
4
5
6
7
Age (months)

Dietary Lipids

Second-Order Meta-Analysis

- Synthesizes results from multiple first-order meta-analyses.
- Controls for overlapping data using robust methods
- Provides high-level evidence from ≈184 primary studies across 13 meta-analyses.

Dietary lipids offer a moderately effective, scalable methane mitigation strategy.

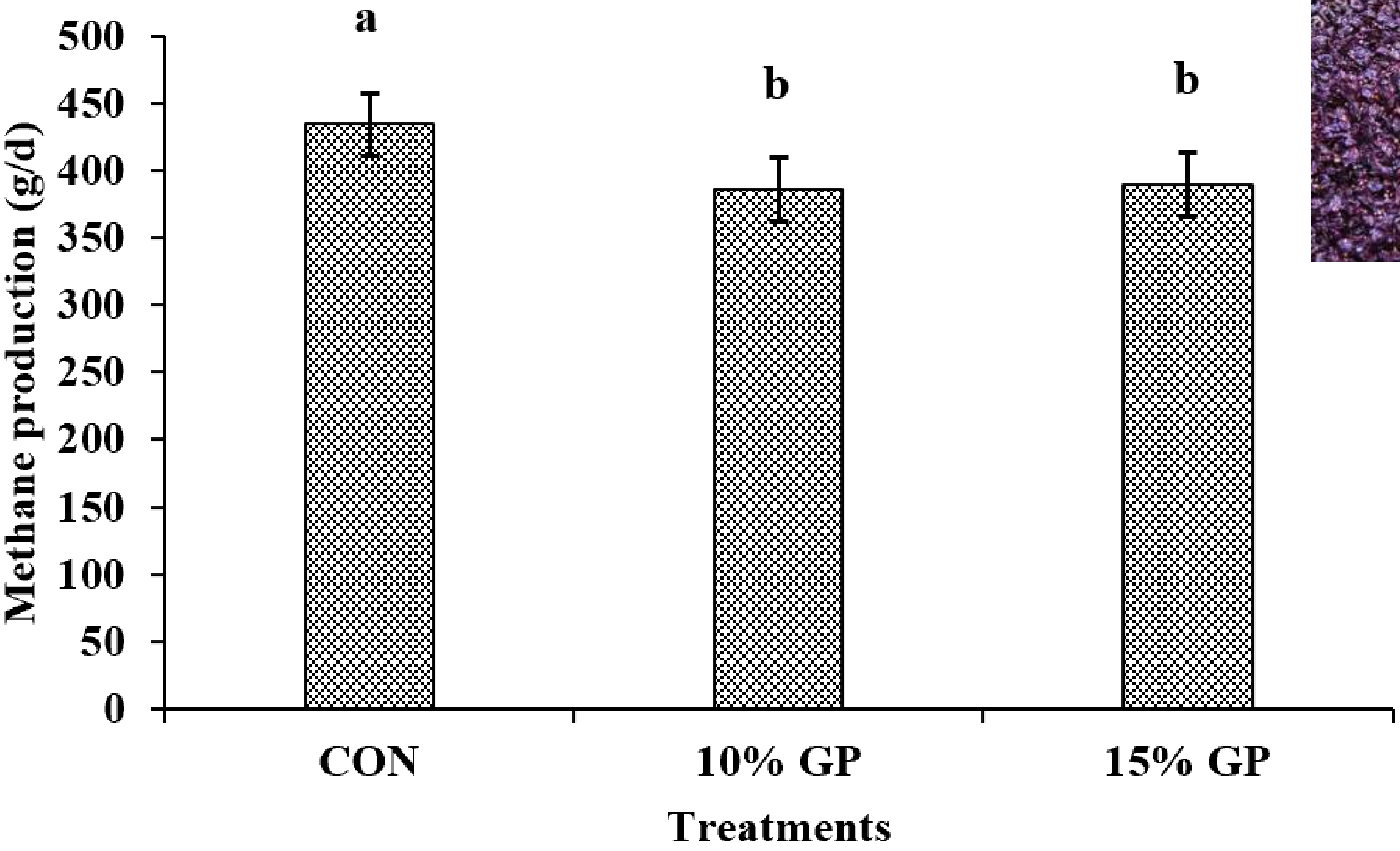


Ramirez-Agudelo and Kebreab, in prep

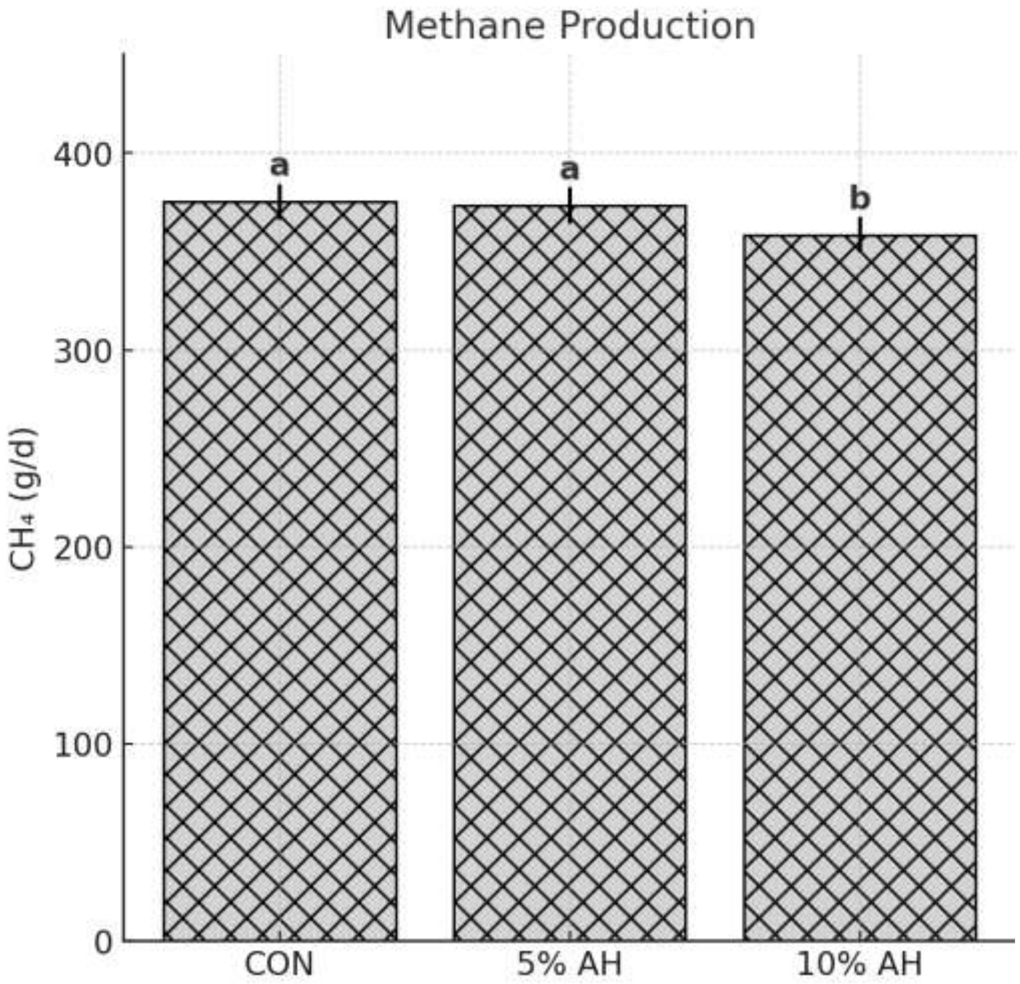

GALLO

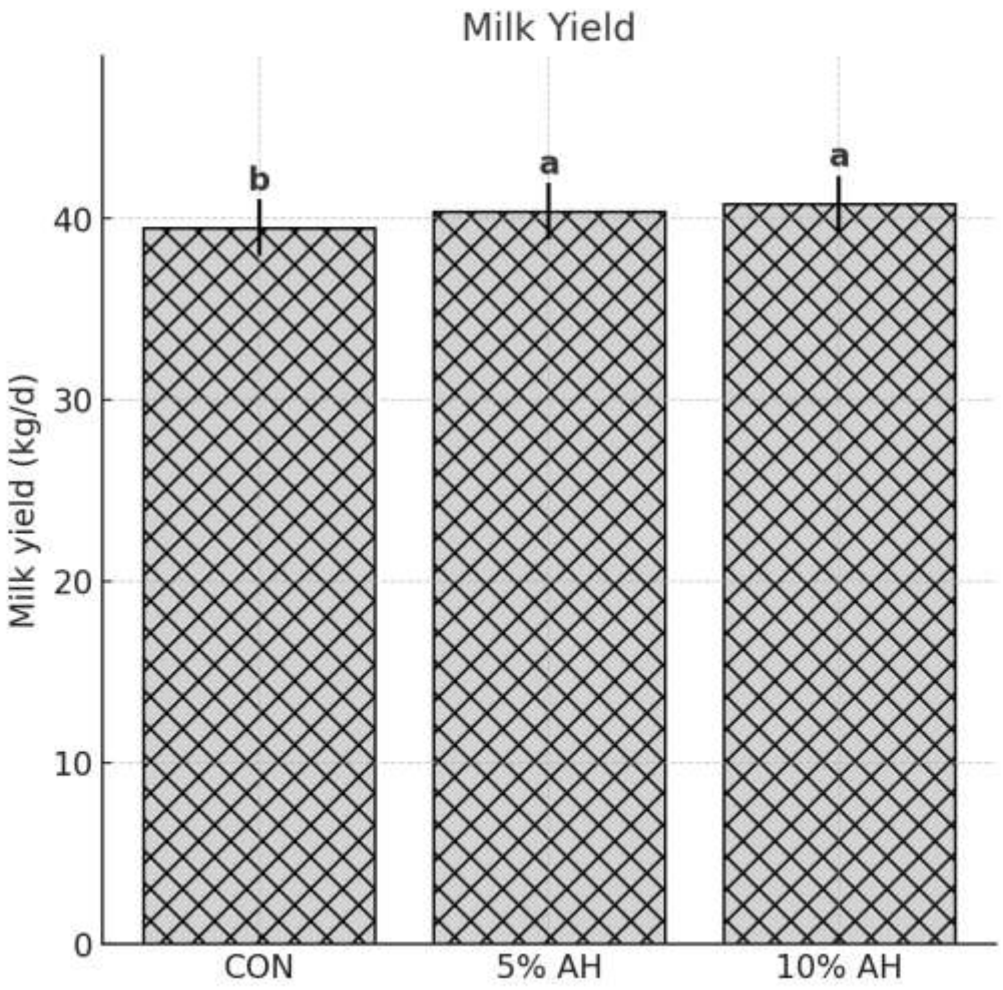
Grape pomace supplementation reduced methane emissions and improved milk quality in lactating dairy cows

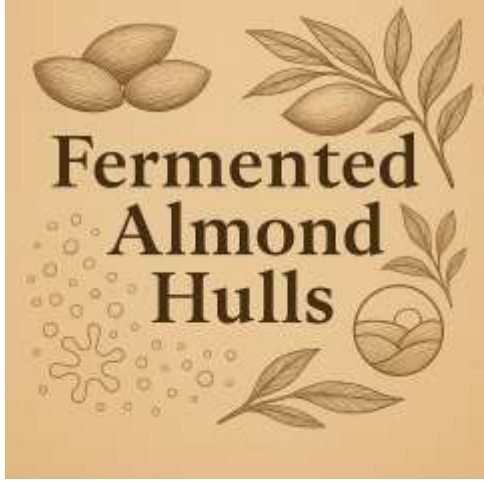
A. Akter,[1*] X. Li,[2] E. Grey,[3] S. C. Wang,[2] and E. Kebreab[1]



Akter et al. 2025

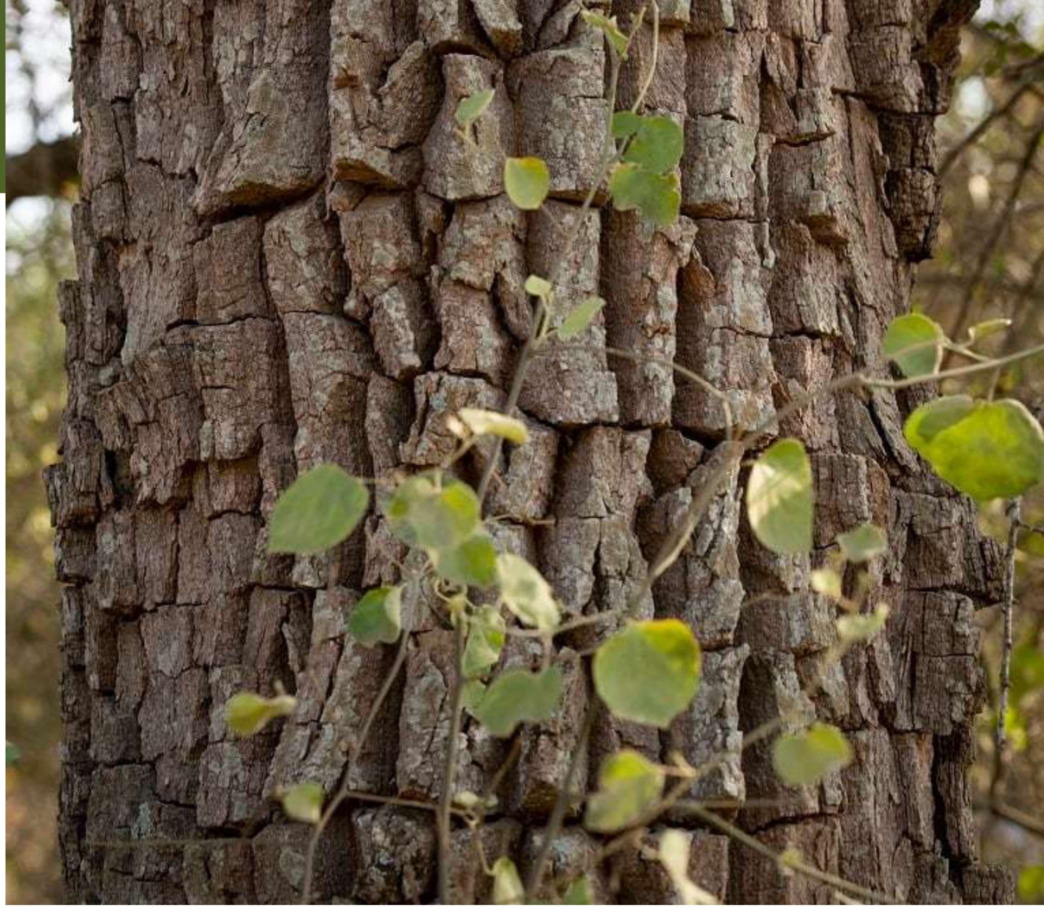






Akter and Kebreab, in prep

Tannin-Based Additives



Meta-Analysis on Tannin-Based Additives

- 25 peer-reviewed in vivo studies; 79 treatment means

Key Findings

- CH_4 Production – 9.3%
- CH_4 Yield – 9.0%
- CH_4 Intensity (dairy) – 8.1%
- No significant impact on milk yield, DMI, or ADG

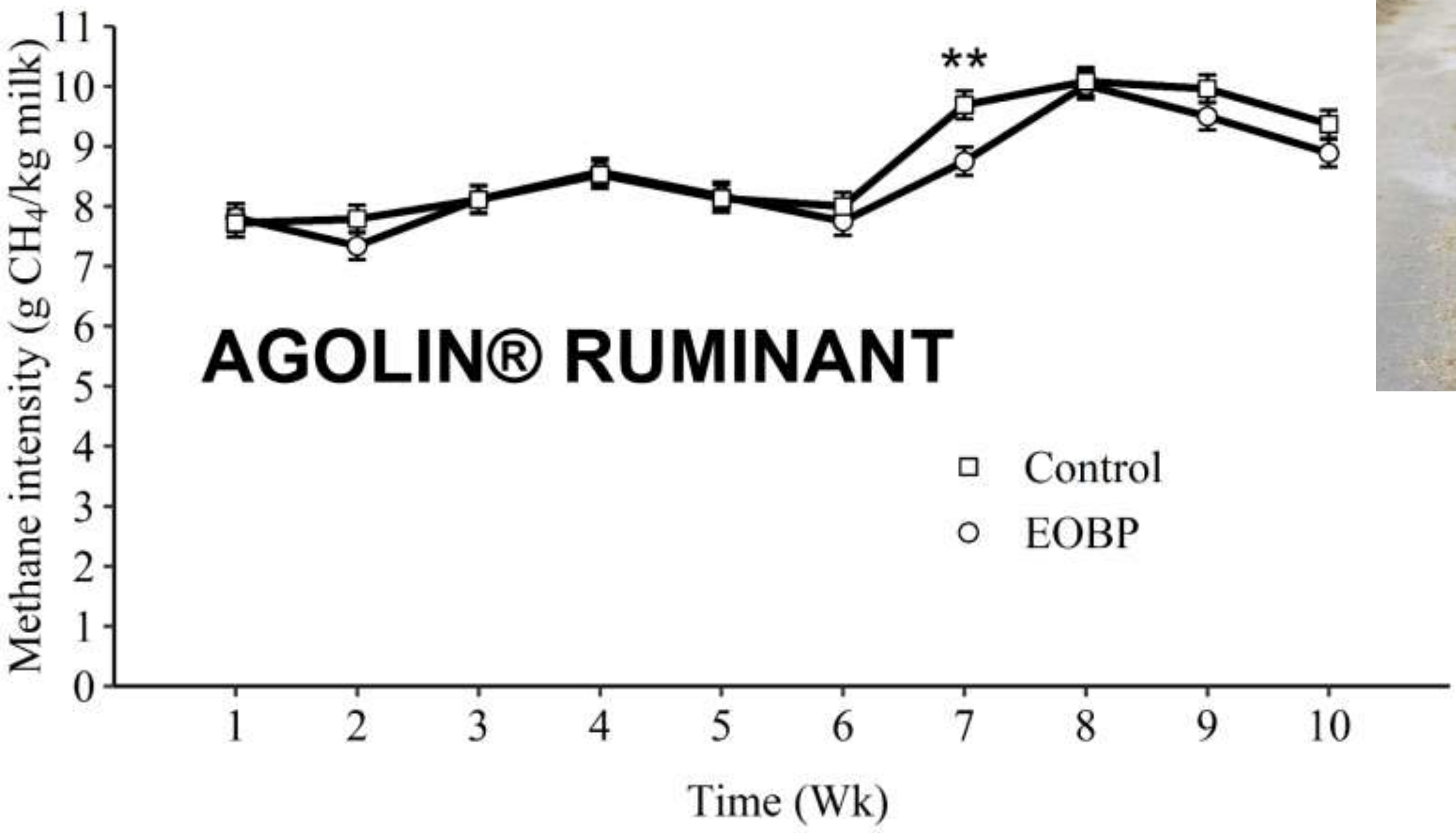
Mechanism and Moderators

- CH_4 reduction linked to ↓ fiber digestibility (NDFD ↓ 9.8%)
- Condensed tannins slightly more effective than blends or hydrolysable tannins
- Dose-response: CH_4 ↓ ~1% per 1 g/kg DM tannin

Tannins offer mild but consistent methane reduction

Souza and Kebreab, in prep

Essential Oils



No effect in multiple studies

Fouts et al., 2025

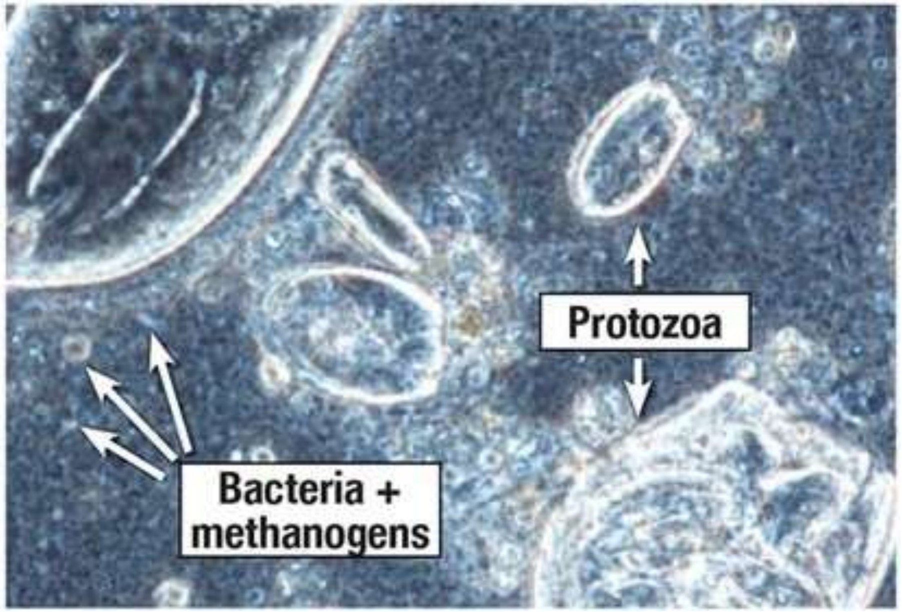
AI-driven model based on deep microbiome sequencing, which predicts the effect of feed additives on methane emissions

Metha.ai, 2025

Microbial Engineering

RUMEN Gateway

A global effort led by Queen's University Belfast and 20+ partners to explore the microbial world of the rumen and accelerate methane mitigation



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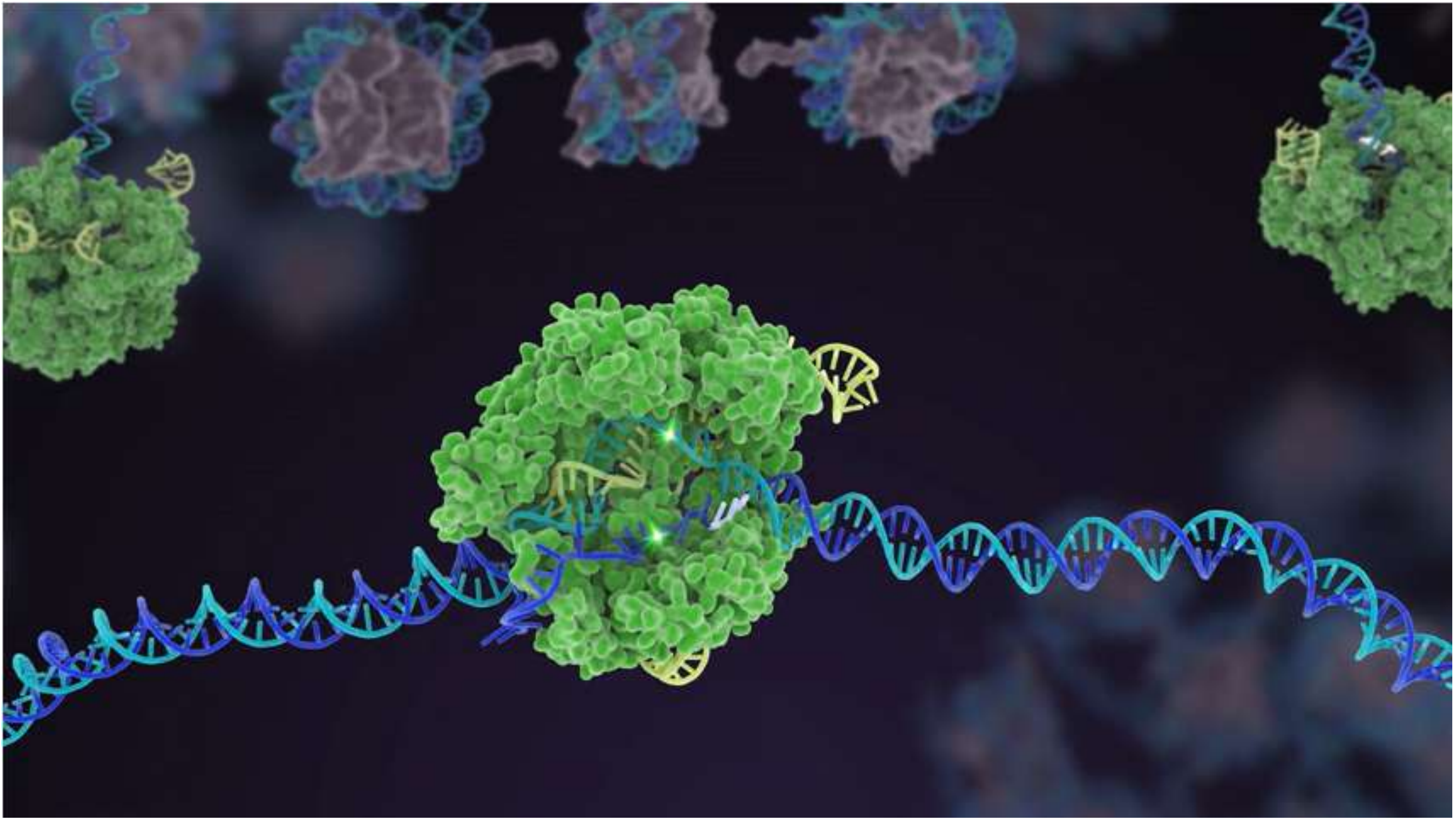
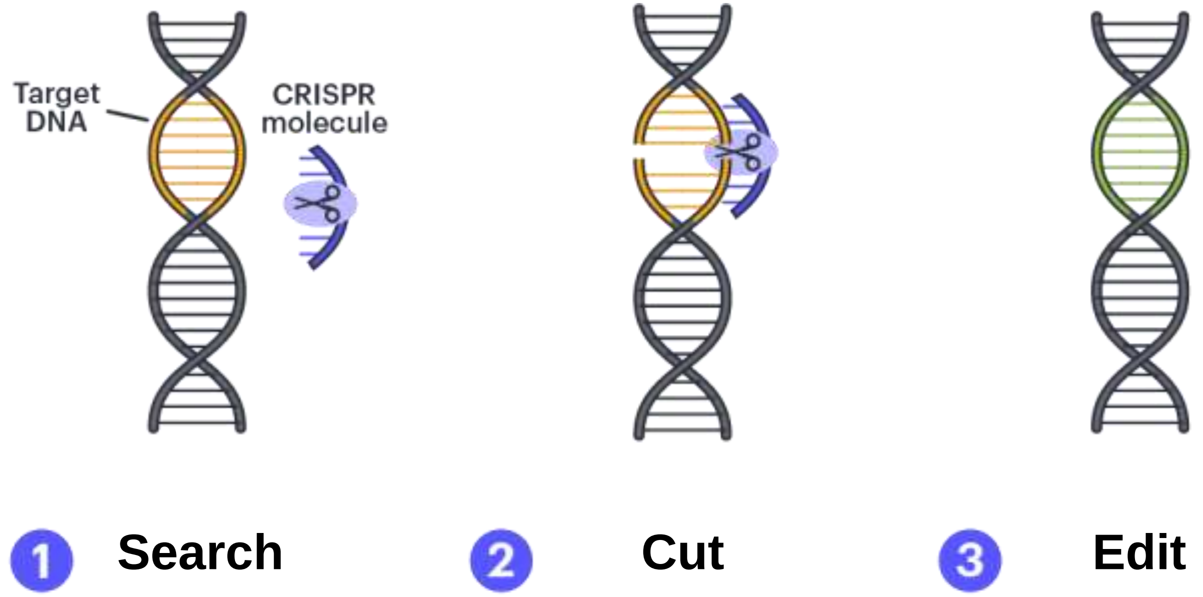
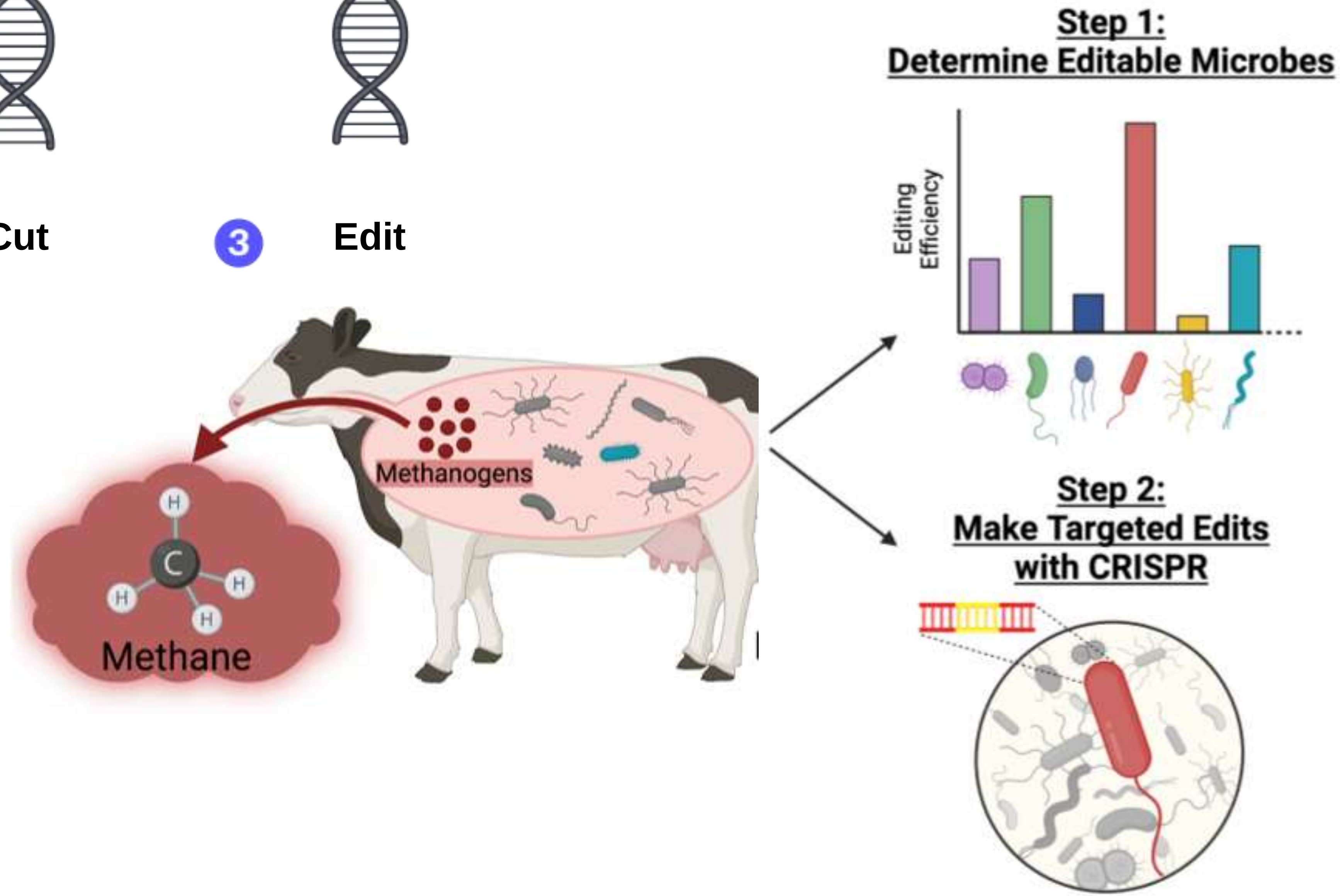
Global Methane Hub

ENGINEERING MICROBIOMES WITH CRISPR TO IMPROVE OUR CLIMATE



An initiative of TED





Brady Cress, UC Berkeley

Innovative Delivery Mechanisms

Total Mixed Ration (TMR)
Best for feedlots and dairy, ensures consistent additive intake

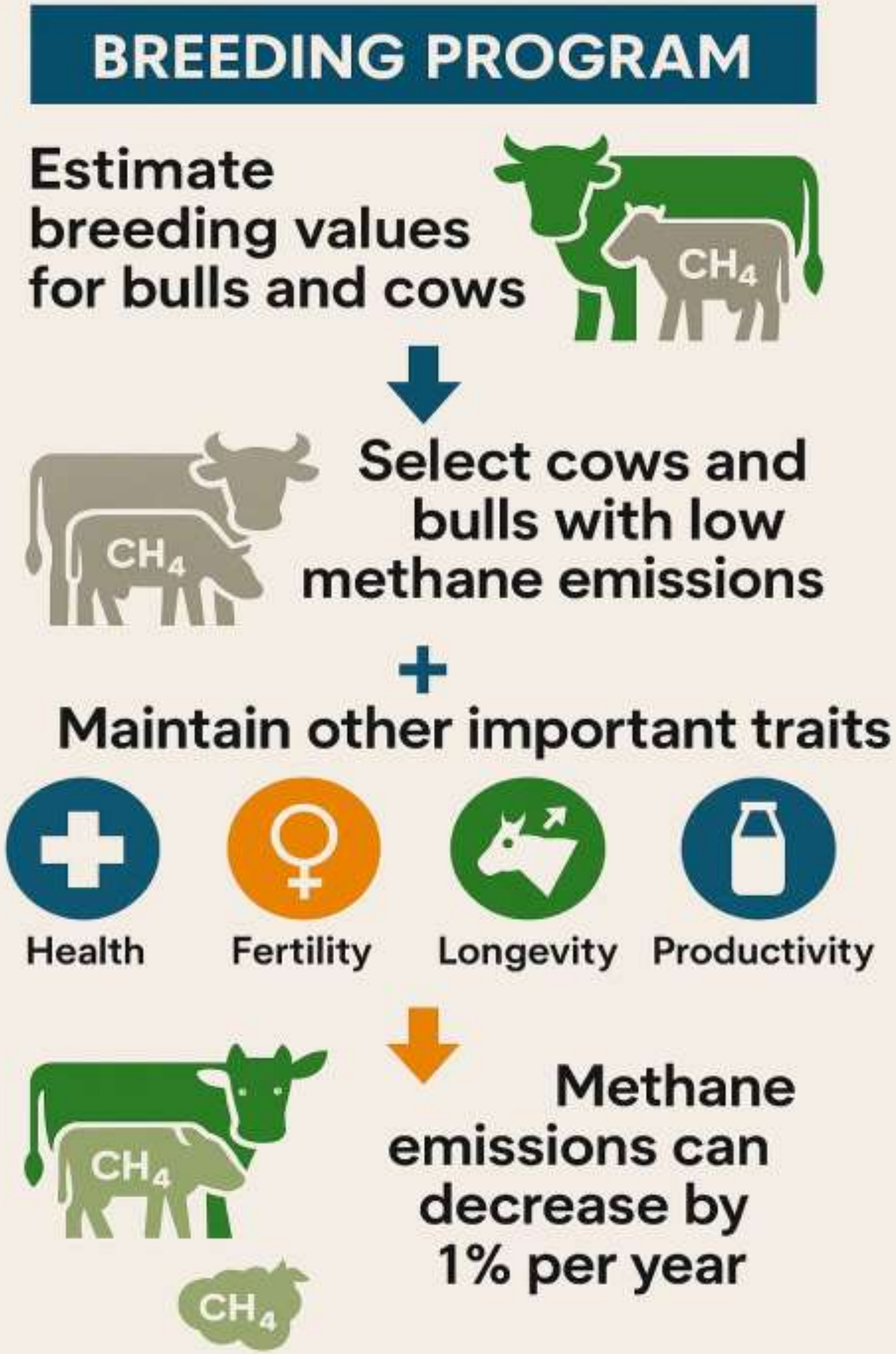
Slow-Release Capsules / Boluses
Suitable for grazing systems, sustained delivery

Mineral Blocks
Low-cost, field-friendly, variable intake

Water-Soluble Additives
Under development, easy delivery through water

Microbial Engineering
CRISPR targeting methanogenesis

INCREASING FEED EFFICIENCY AND REDUCING METHANE EMISSIONS THROUGH GENOMICS: A NEW PROMISING GOAL FOR THE CANADIAN DAIRY INDUSTRY



Genome Canada

BEZOS EARTH FUND

Global Methane Hub

Vaccines

Development Steps

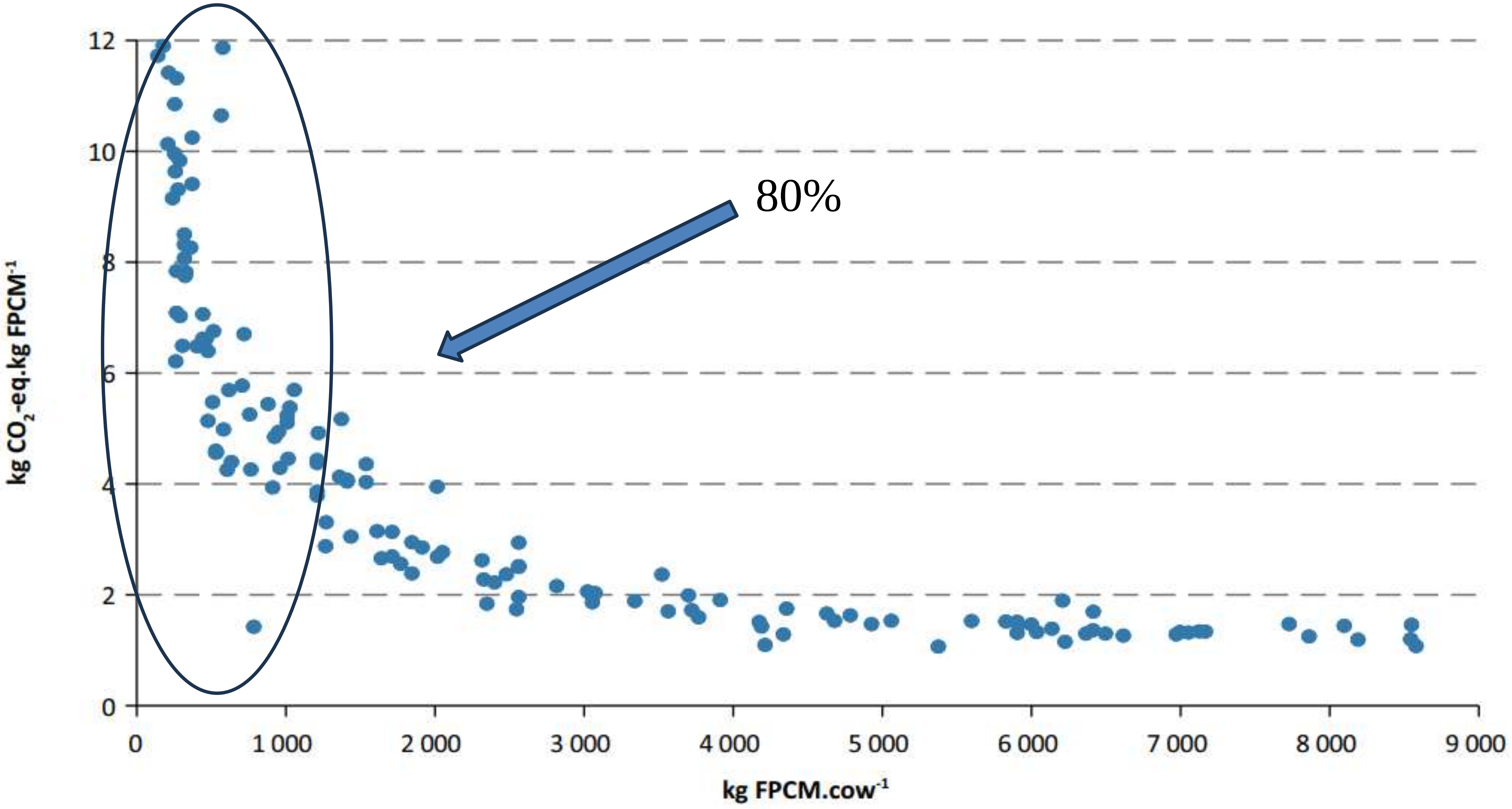
- ✓ Antigen Identification: Target key methanogens; limited in vitro cultures available.
- ✓ Vaccine Formulation: Explore recombinant proteins, synthetic peptides, consider adjuvants etc.
- ✓ Challenge Models: Develop reliable in vitro models to assess efficacy
- × Vaccine Stability: Shelf-life of at least 1 year needed
- × Vaccination schedule: determine optimal dosing regimen, early life intervention?
- × Safety and Efficacy Studies: Ensure minimal adverse reactions, comparable to existing vaccines

ArkeaBio

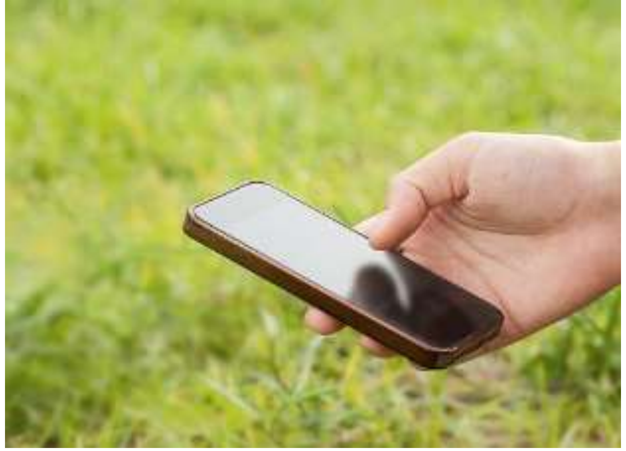
Pasture Biosciences

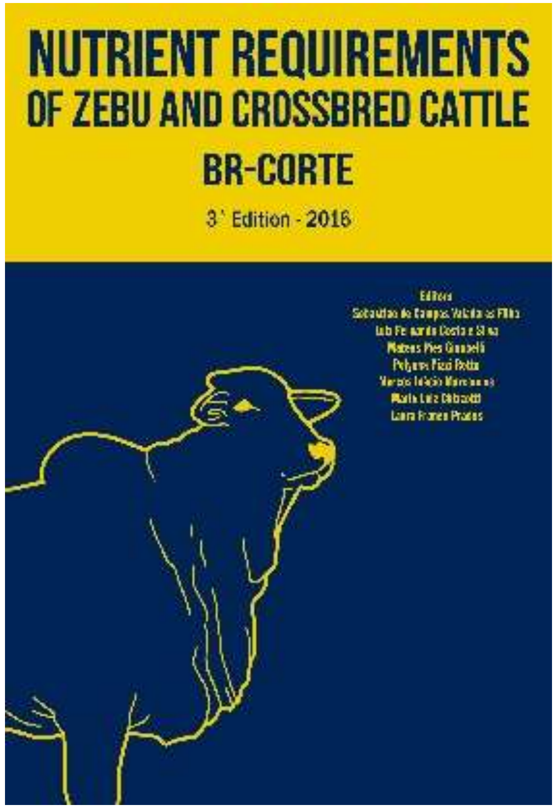
Global Methane Hub

BEZOS EARTH FUND

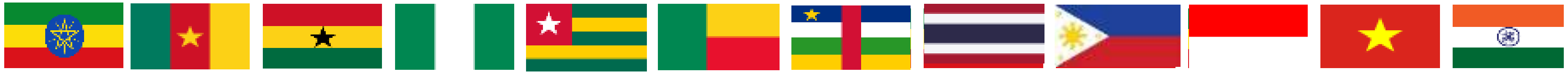


Source: Gerber *et al.*, 2011.

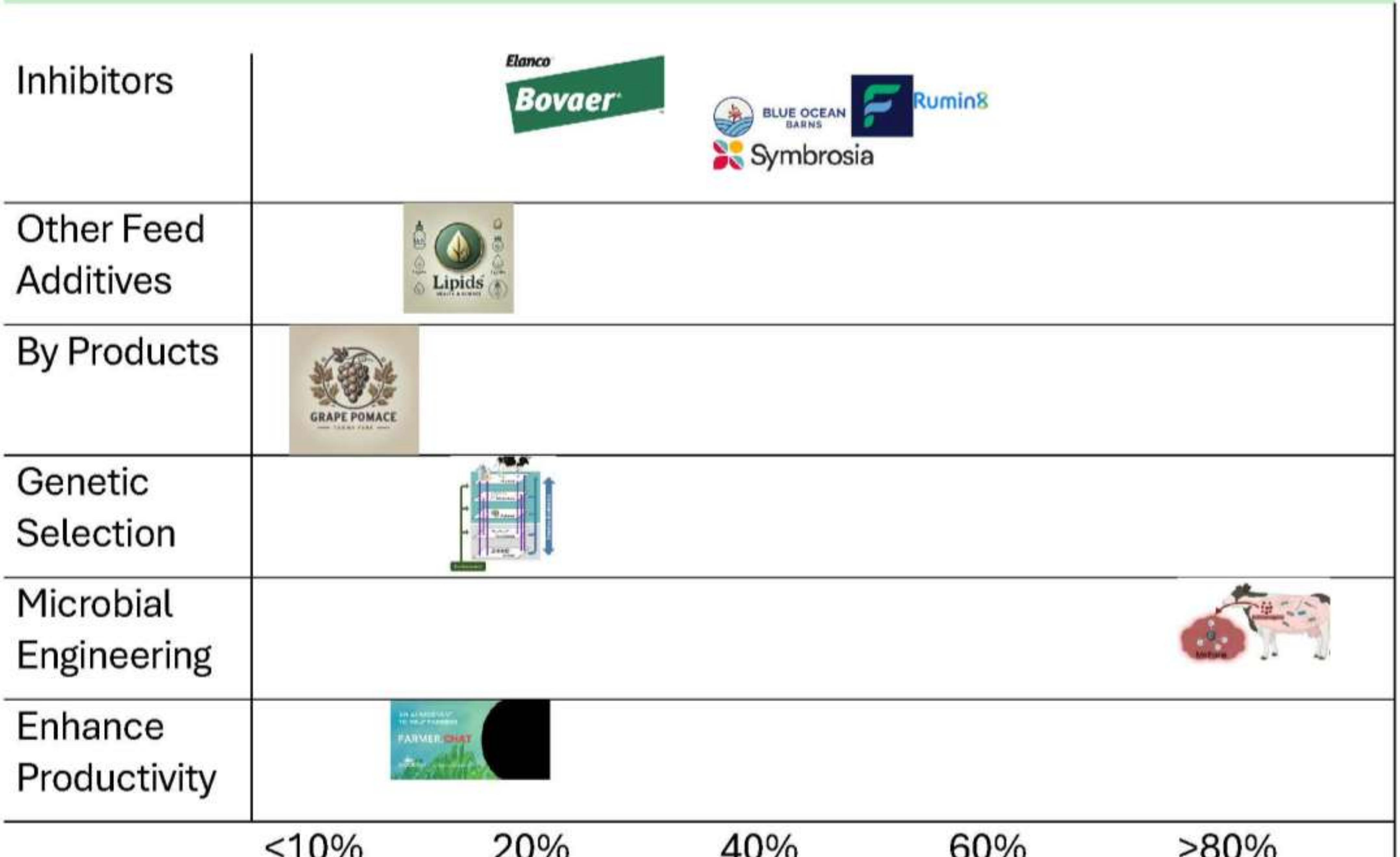




Global Methane Hub



Enteric Methane Reduction Strategies



Acknowledgments

cdfa
CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

BILL & MELINDA GATES foundation

USAID
FROM THE AMERICAN PEOPLE

USDA

Global Methane Hub

CALIFORNIA AIR RESOURCES BOARD

Food and Agriculture Organization of the United Nations

NSF

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HEALTHY PEOPLE • HEALTHY PRODUCTS • HEALTHY PLANET

STRAUS FAMILY CREAMERY ORGANIC

CALIFORNIA DAIRY RESEARCH FOUNDATION
Science for a Sustainable Future

50 MATADOR RANCH
EST. 1879

Rumin8

QUEEN'S UNIVERSITY BELFAST

DSM

BLUE OCEAN BARNS
Solving agriculture's biggest climate challenge.

THE AUDACIOUS PROJECT

SUSTAINABLE AGRICULTURE at UC DAVIS

Thank You!

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Q&A with Professor Kebreab

Chair: Professor Steven Morrison

Head of Sustainable Livestock Systems Branch, Agri-Food and Biosciences Institute (AFBI)

Closing Remarks

Professor Gerry Boyle

Chair, AgriSearch

THANKS TO OUR HOSTS AND EVENT SUPPORTERS

QUEEN'S UNIVERSITY BELFAST

ESTD 1845

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