Methane reduction what could we do, and why aren't we doing it ?

Jamie Newbold
John Newbold

Leading the way in Agriculture and Rural Research, Education and Consulting

The rumen

Bacteria

~300 species
10^{10} to 10^{11} cells/ml

Anaerobic Fungi

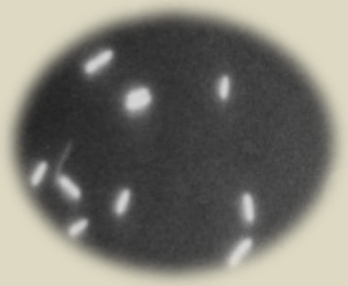
~30 species
$<10^{5}$ cells/ml

Ciliate Protozoa

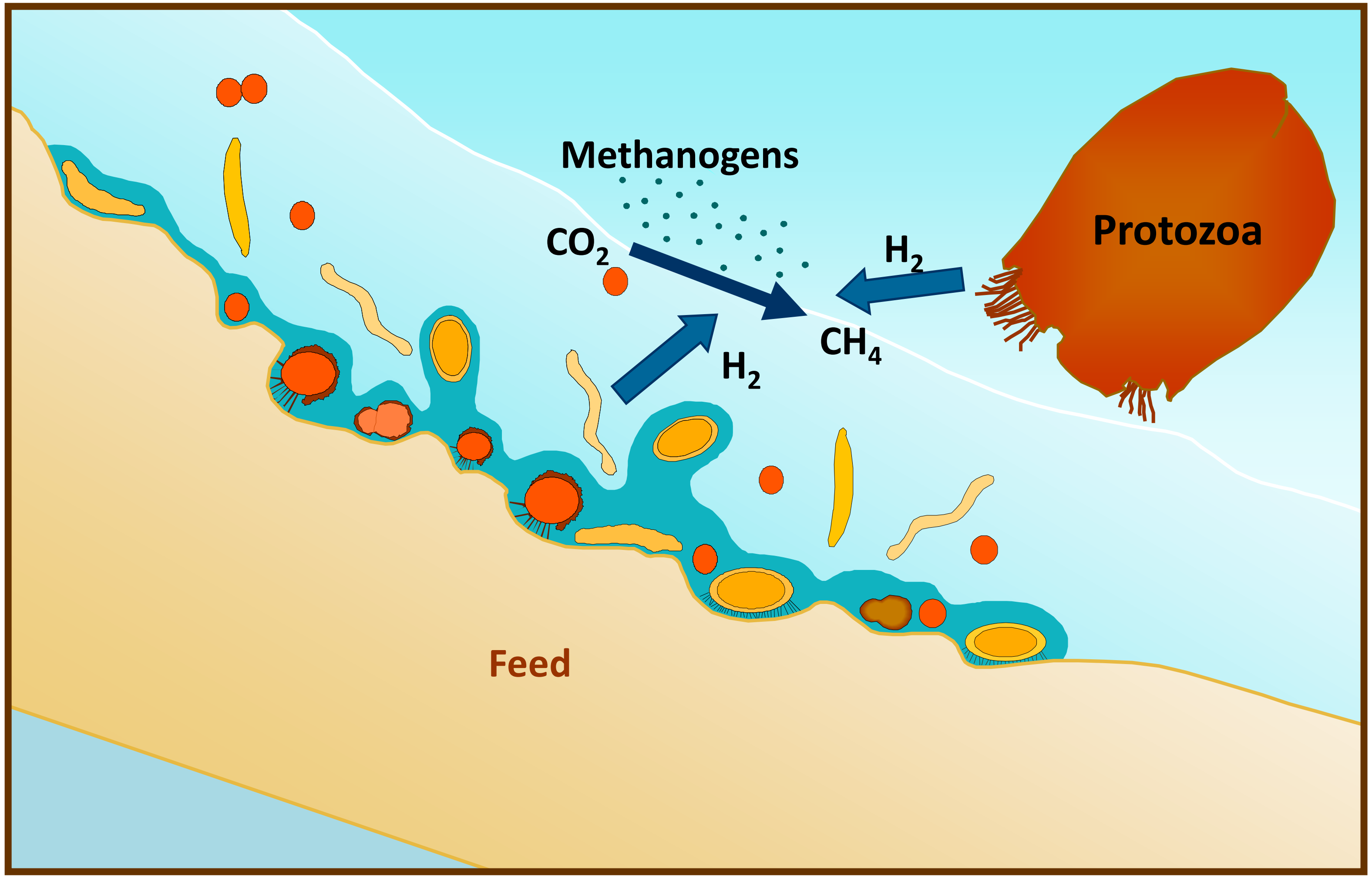
~40 species
$<10^{5}$ cells/ml

Methanogenic Archaea

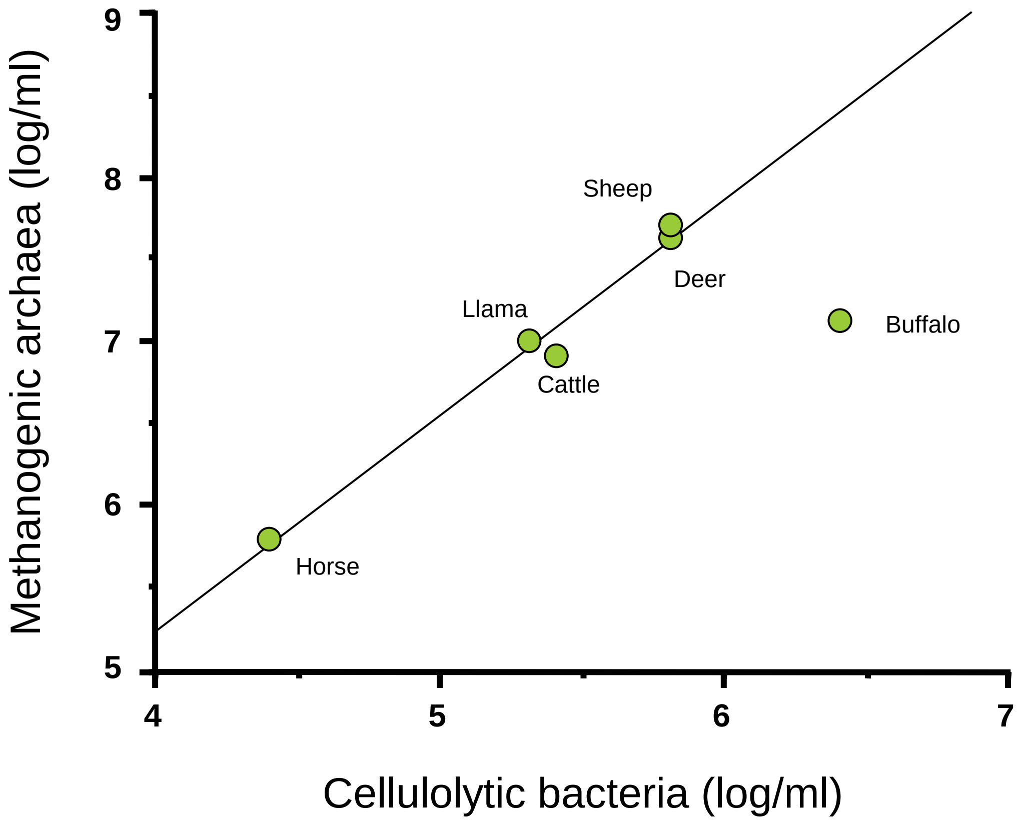
~6 species
10^{6} to 10^{8} cells/ml



Methane production a microbially driven process to remove hydrogen



Relationship between cellulolytic bacteria and methanogens



Morvan et al. (1996)

Unlikely to be a single silver bullet

- Farm management
- Improved fertility
- Improved Nutrition
- Improved health
- Feed additives
- Improved genetics
- Agro forestry
- Soil carbon

Total GHG emissions on two mixed sheep/cattle farms

(kg CO_2 e /ha/year)

	Farm 1	Farm 2
	Mean (Range)	**Mean (Range)**
Total	**1215**	**3091**
	(368- 3726)	(789 – 9305)

Farm 1 - Intensive lowland
Farm 2 - Organic extensive

(Edwards-Jones et al., 2009)

Unlikely to be a single silver bullet

Farm management

Improved fertility

Improved Nutrition

Improved health

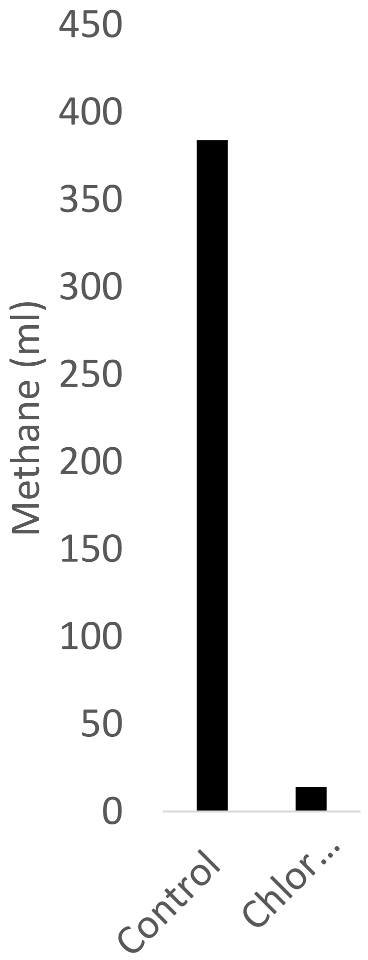
Feed additives

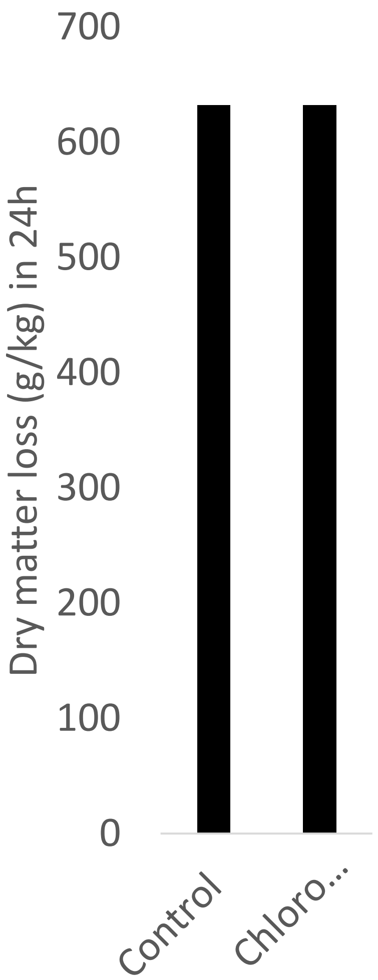
Improved genetics

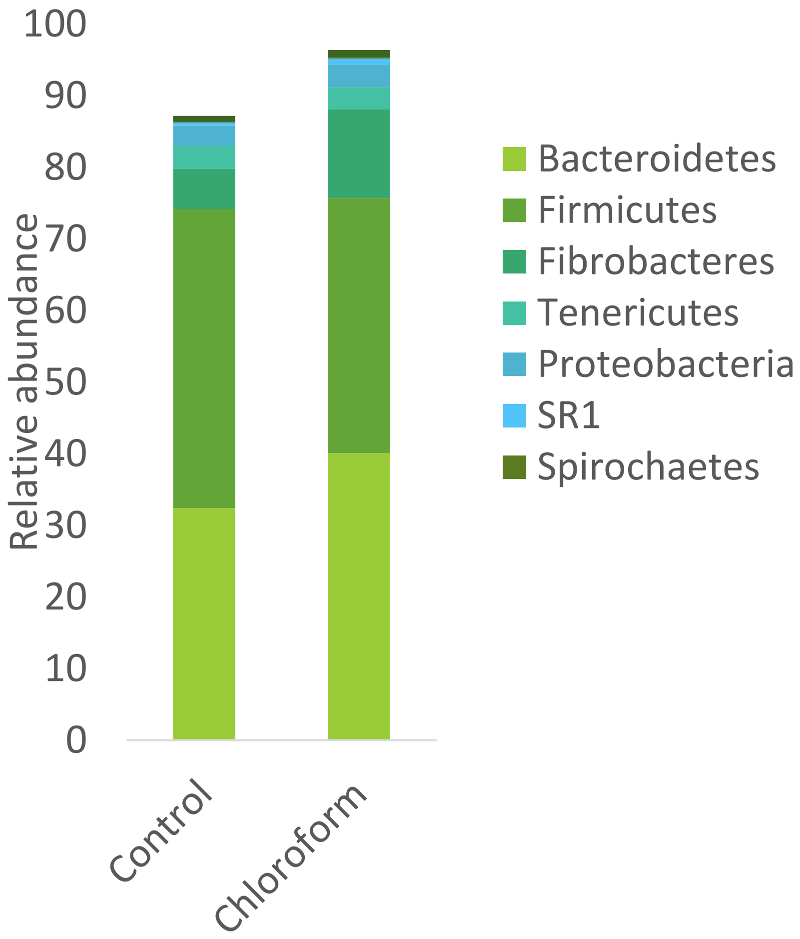
Agro forestry

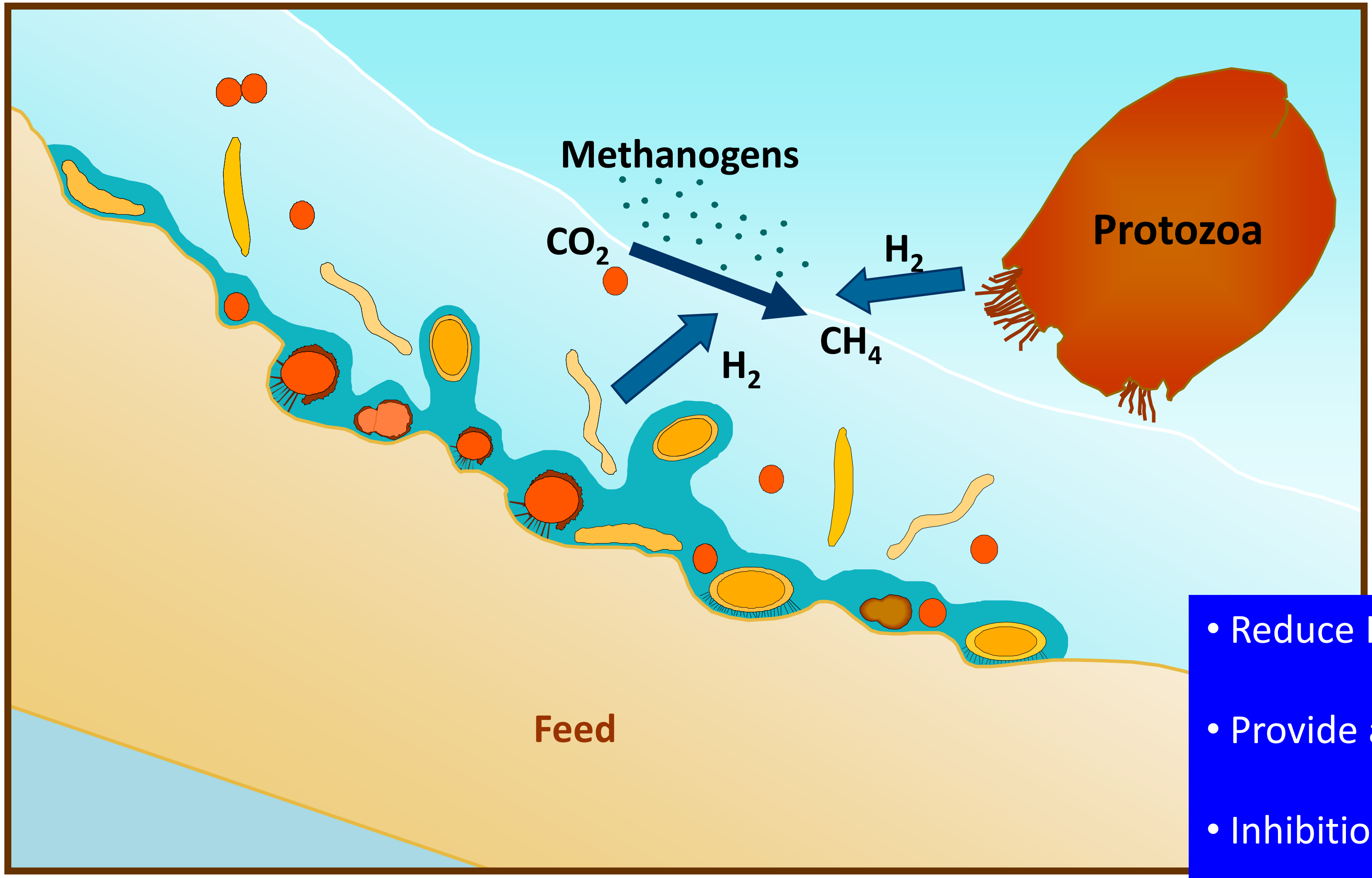
Soil carbon

Effect of inhibiting methane in a long term rumen simulation



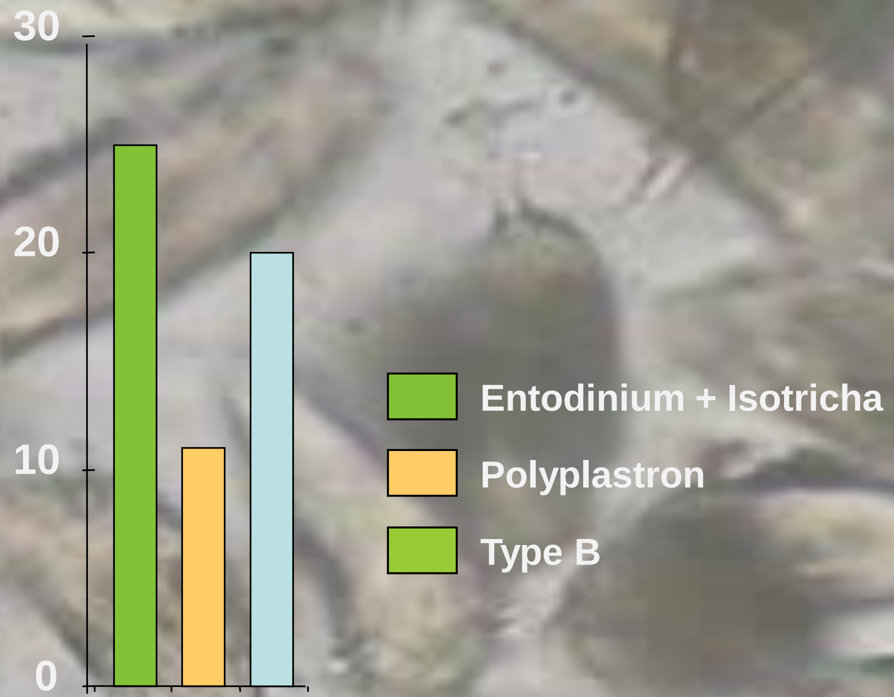




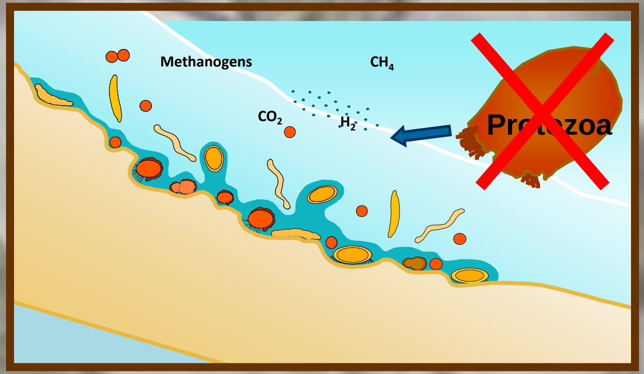


- Reduce H^+ production
- Provide alternative H^+ sinks
- Inhibition of methanogens

Methods of methane mitigation:



Methanogenesis associated with protozoa (%)

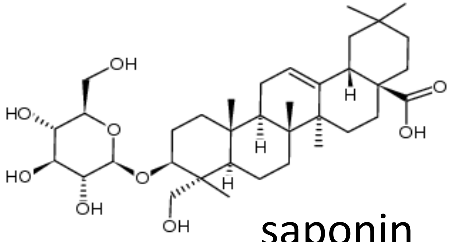


Decrease H_2 production

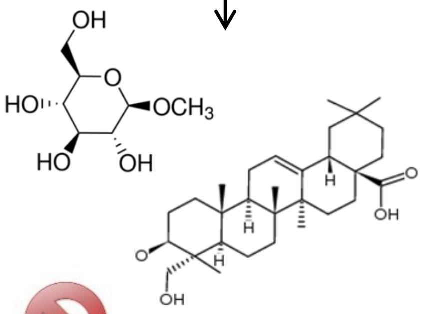
CH_4 production	PF	F	s.e.m.	*P*
L per day	26.0	35.2	2.82	0.049
L per kg LW	0.52	0.71	0.044	0.024
L per kg DMI	21.6	29.0	1.41	0.006

PF: protozoa-free lambs; F: faunated lambs.
LW: liveweight; DMI: dry matter intake

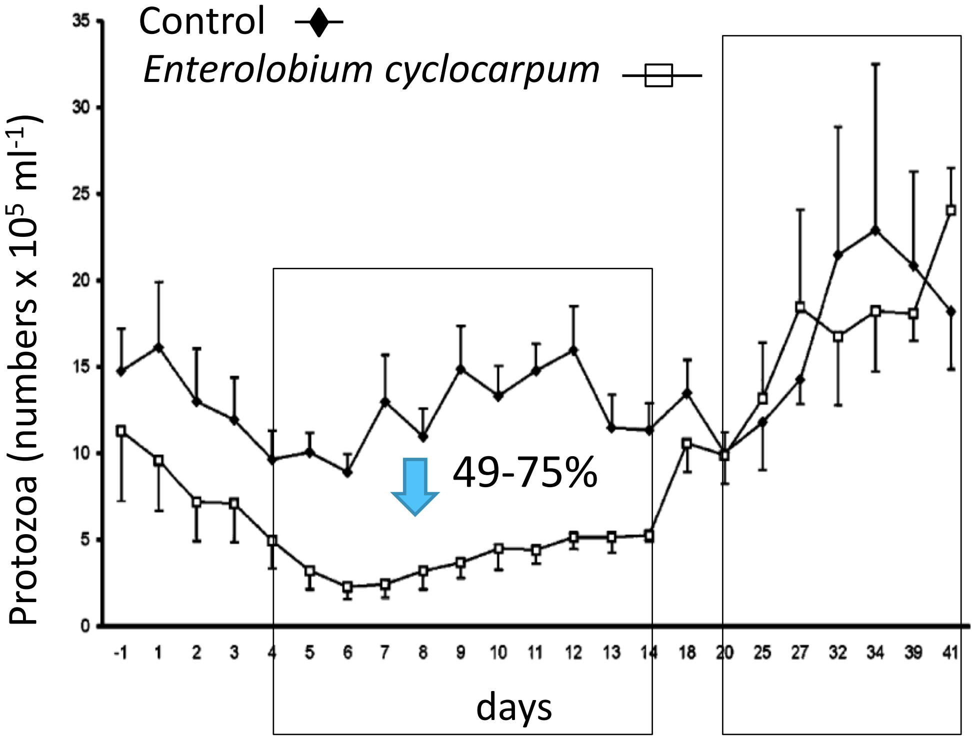
Saponins v protozoa



saponin

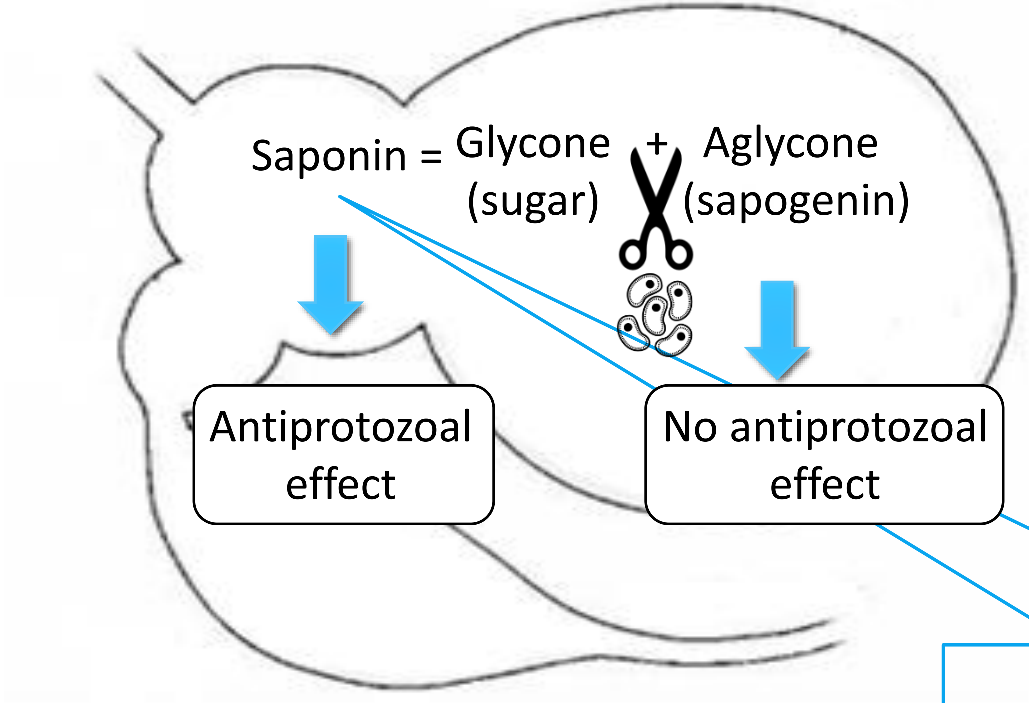


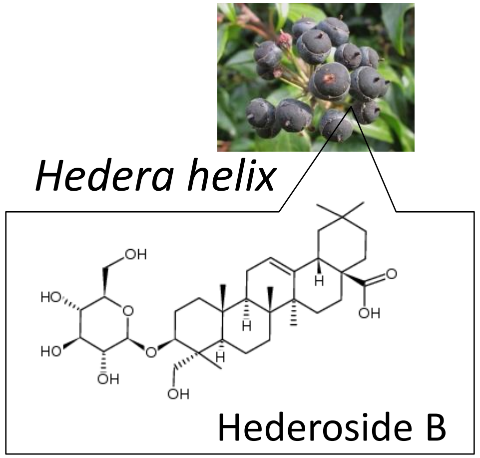
sapogenin

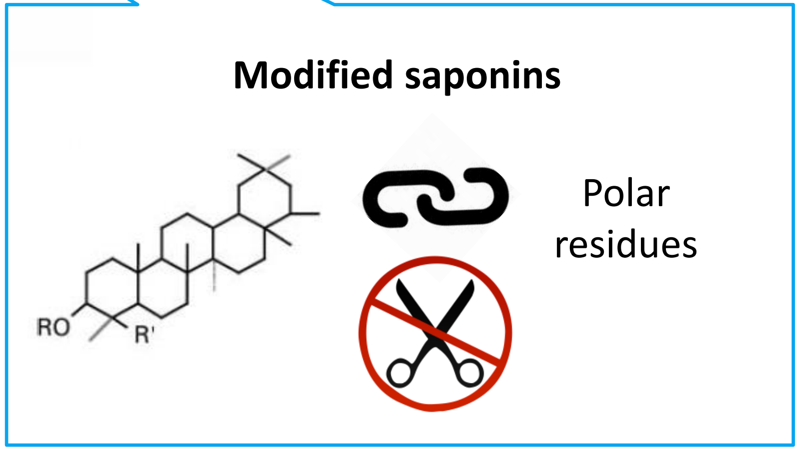


Ivan et al. (2004)

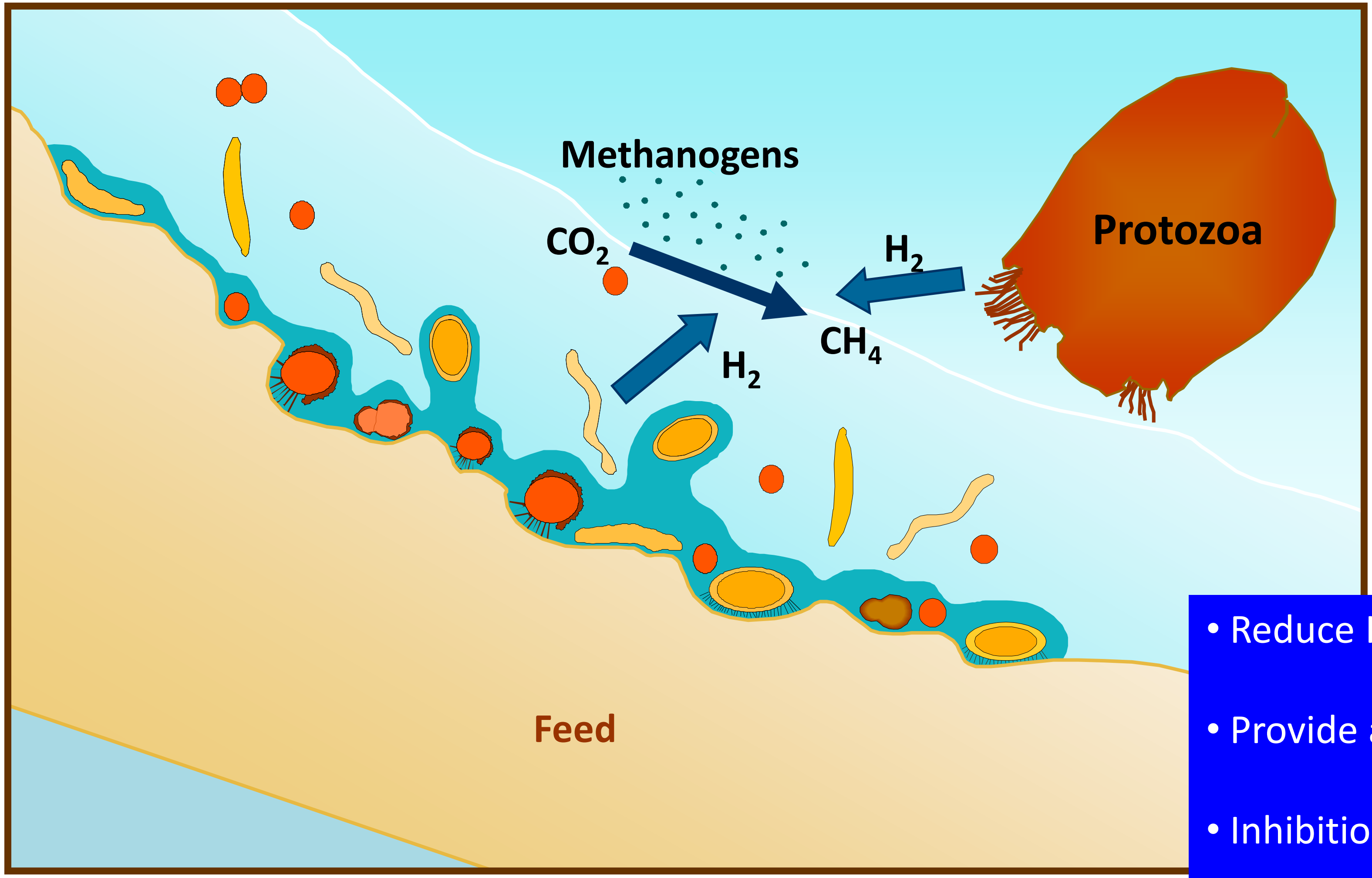
Modified saponins







Ramos-Morales E, de la Fuente G, Duval S, Wehrli C, Bouillon M, Lahmann M, Preskett D, Braganca R, Newbold CJ.
Antiprotozoal Effect of Saponins in the Rumen Can Be Enhanced by Chemical Modifications in Their Structure. Front Microbiol. 2017 Mar 16;8:399.



- Reduce H^+ production
- Provide alternative H^+ sinks
- Inhibition of methanogens

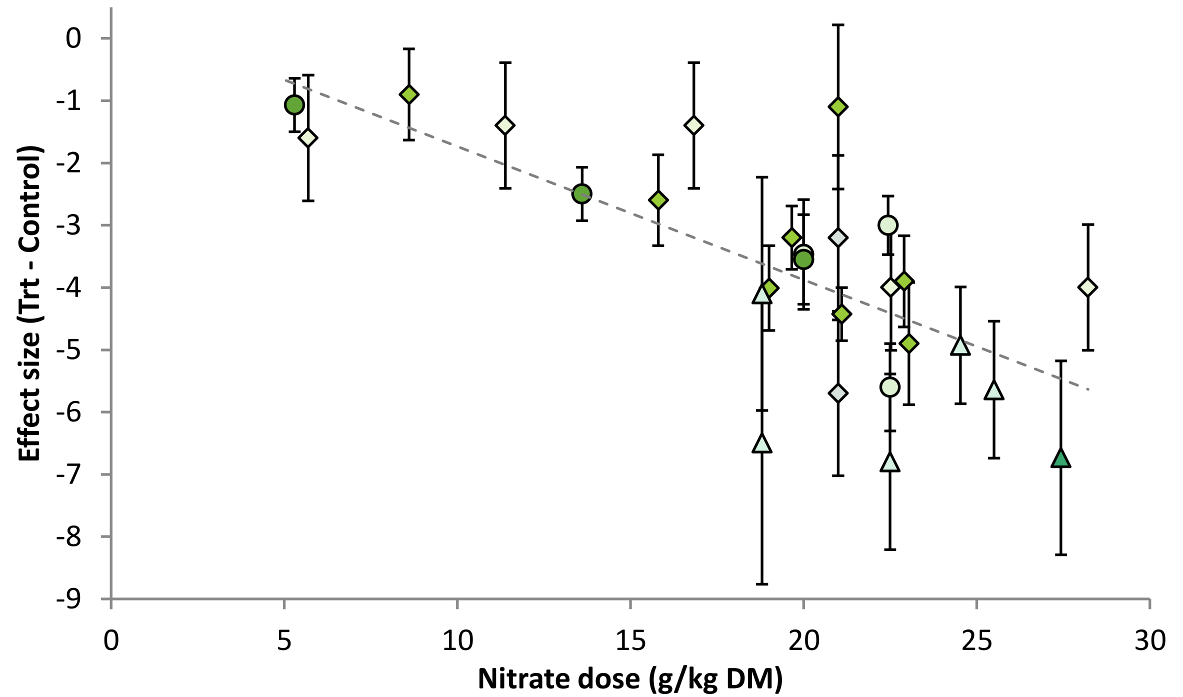
Nitrate

Calcium Nitrate : $NO_3^- + H_2 \rightarrow NO_2^- + H_2$

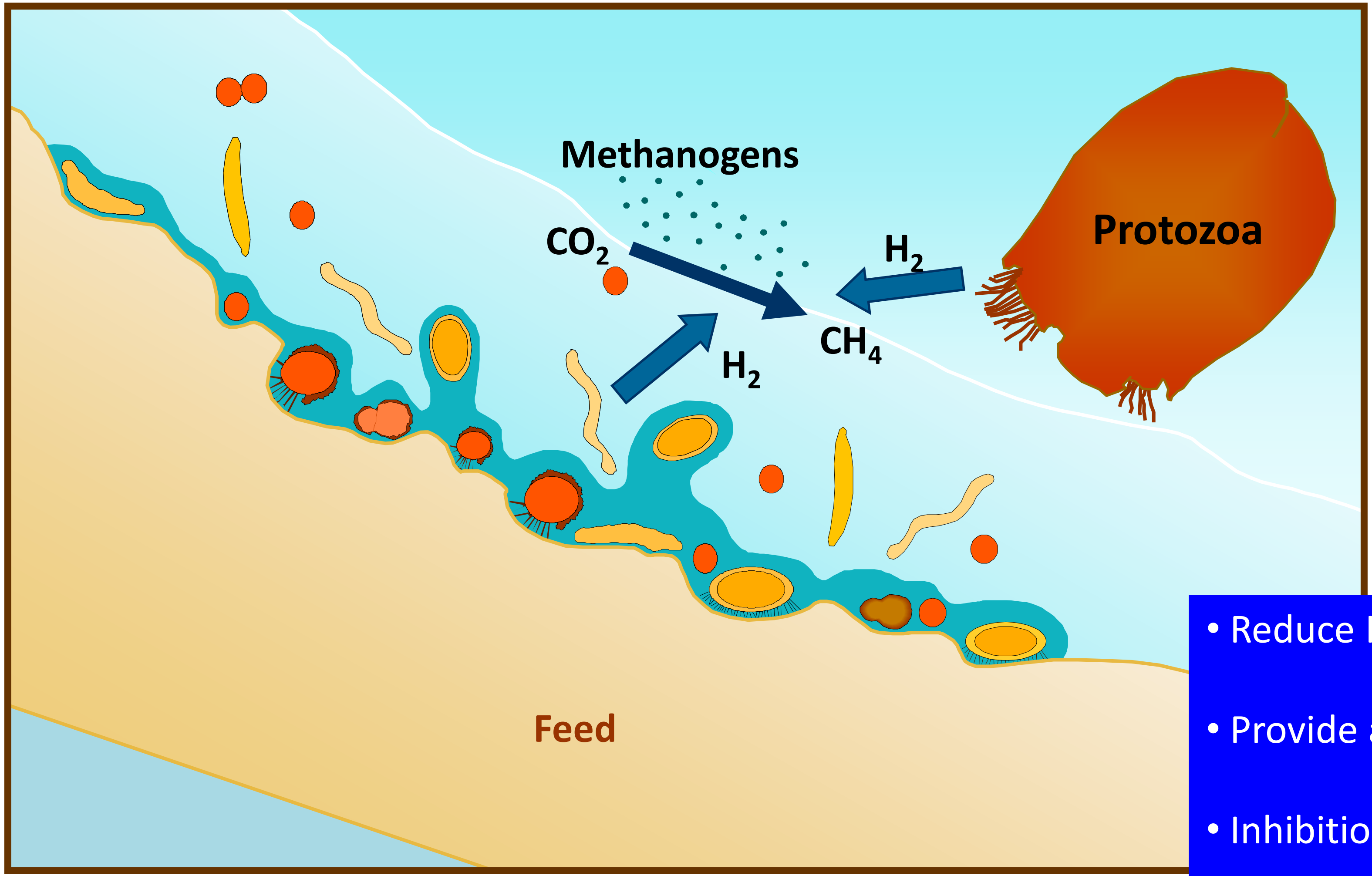
$NO_2^- + 3H_2 + 2H^+ \rightarrow NH_4^- + 2H_2O$

- nitrate decreases methane by **0.21g** (±0.035SE; P<0.001) per g nitrate

Animal type (beef cattle, dairy cattle or sheep)
Feeding management (fixed or ad lib)



Veneman et al., 2016



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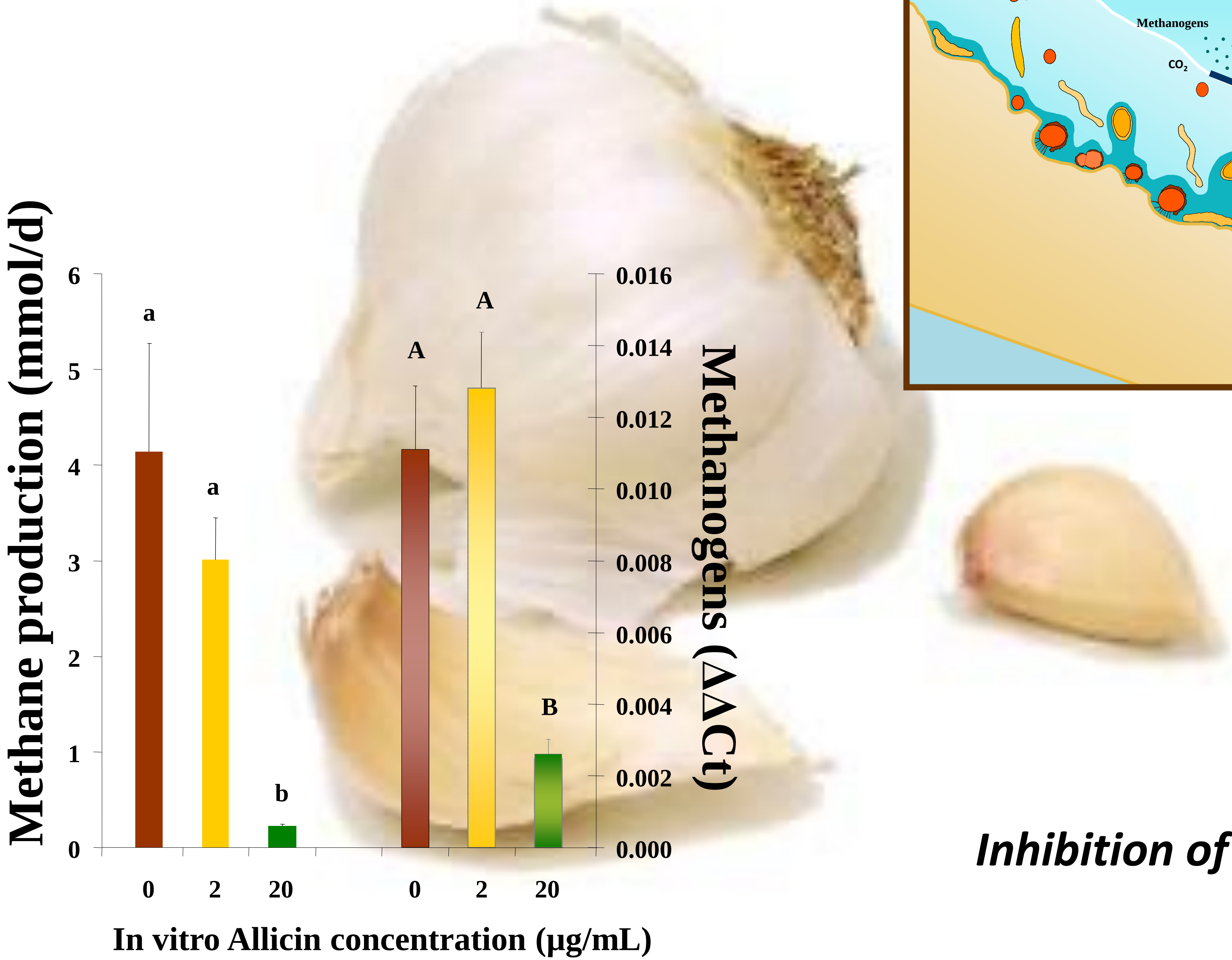
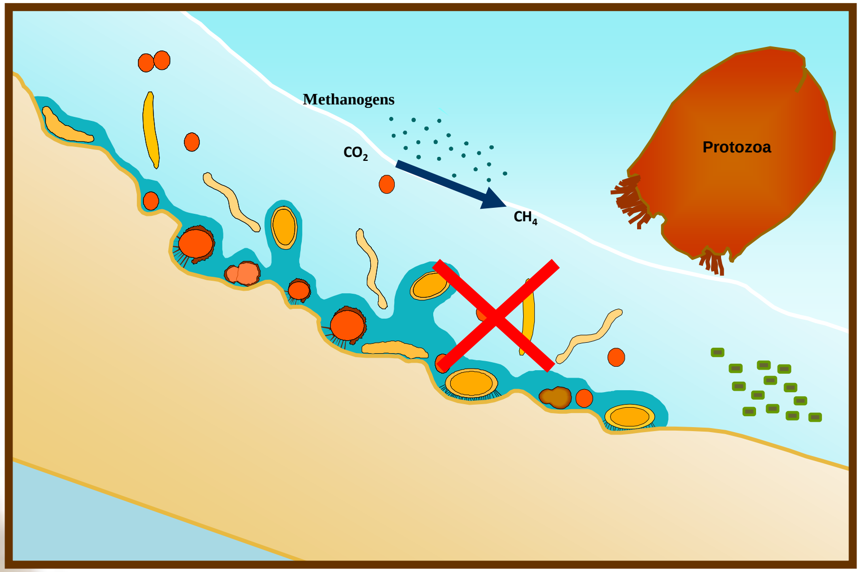
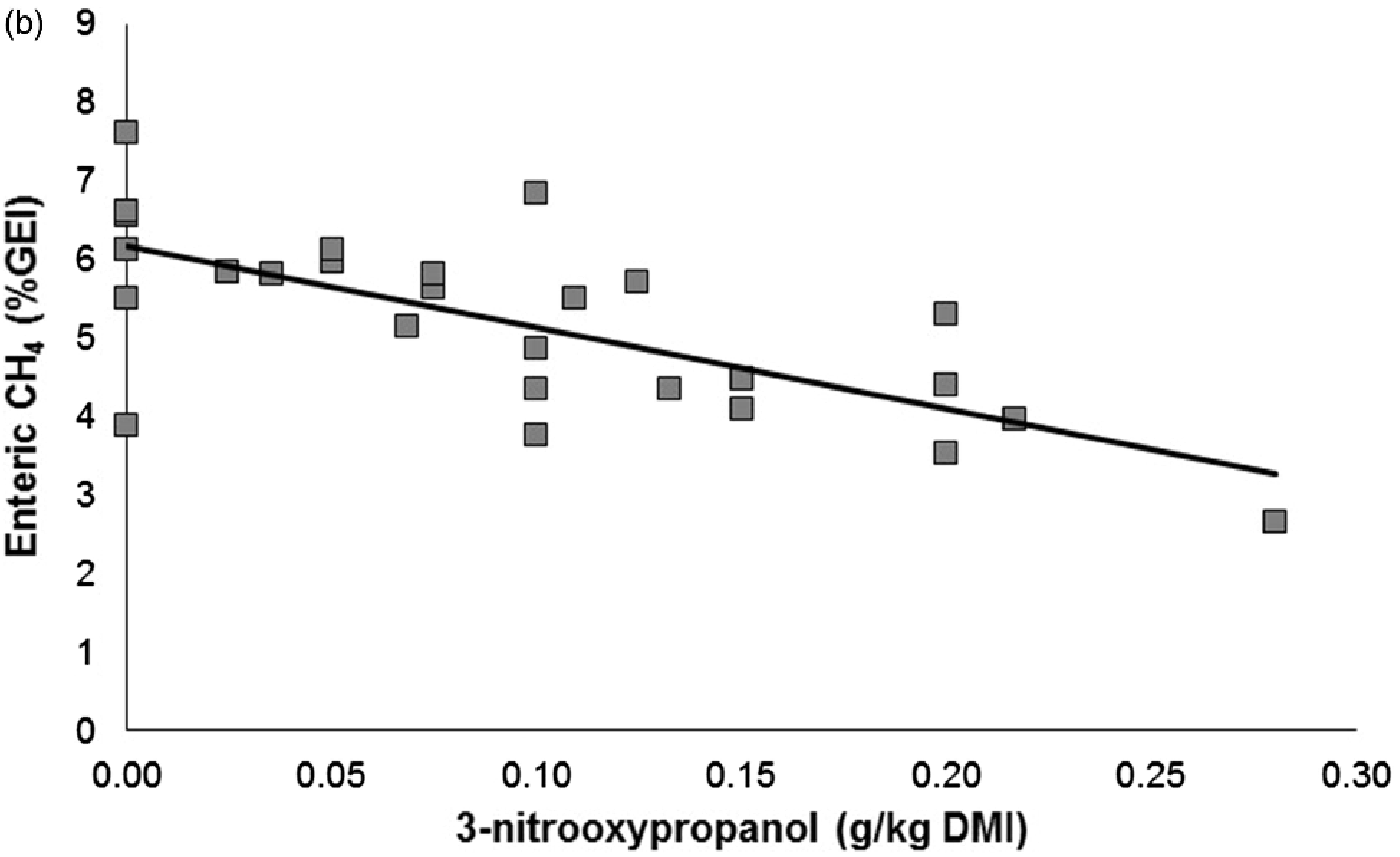
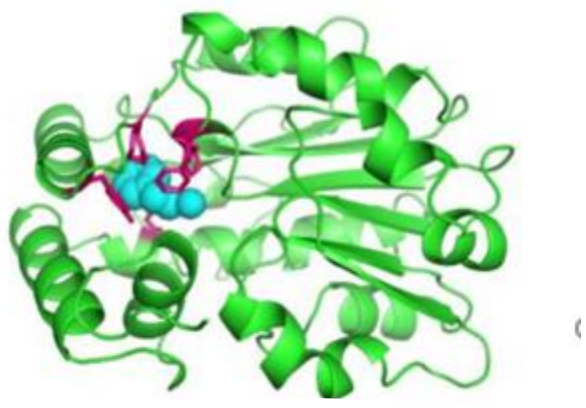




Inhibition of methanogens

3-nitrooxypropanol

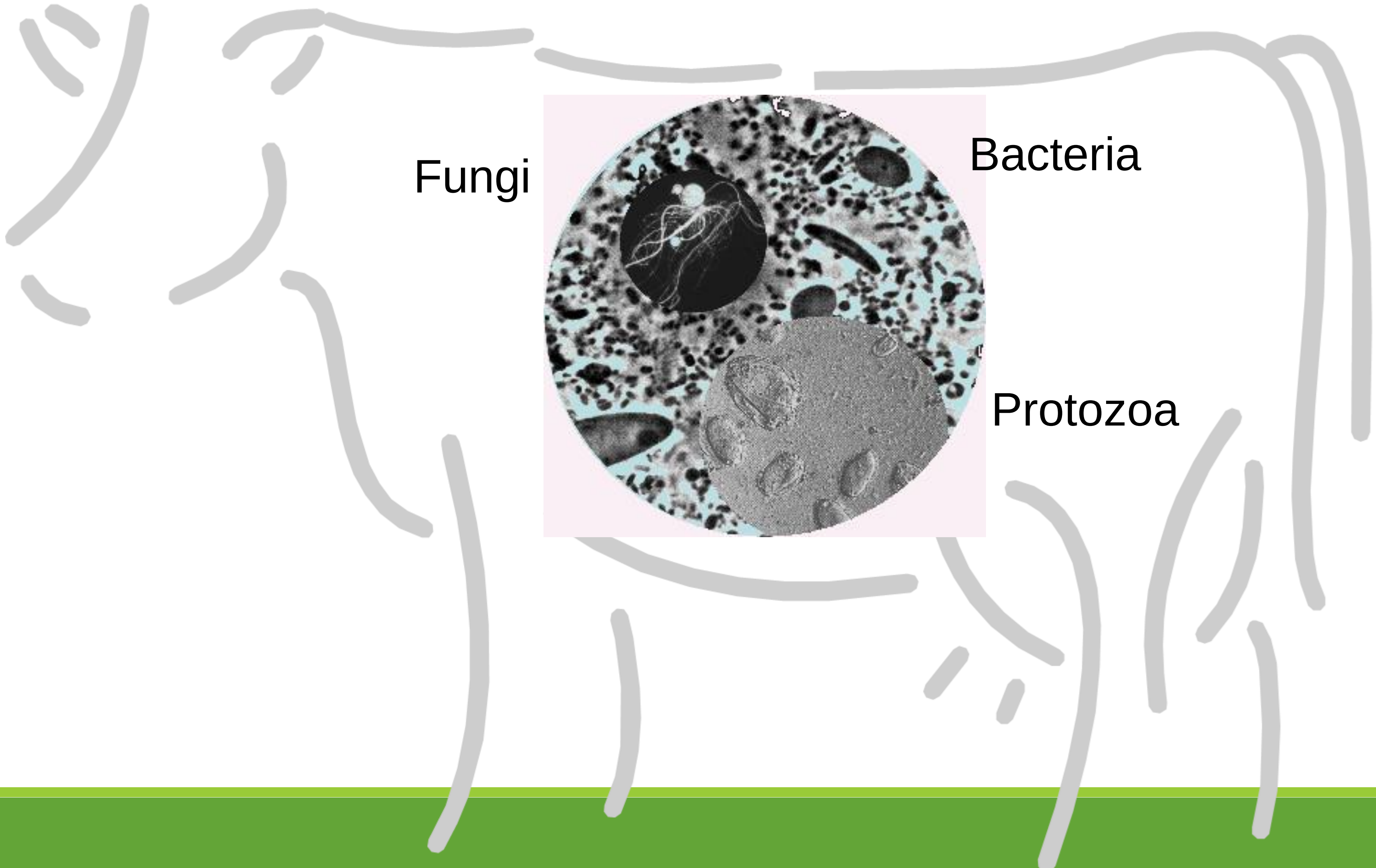




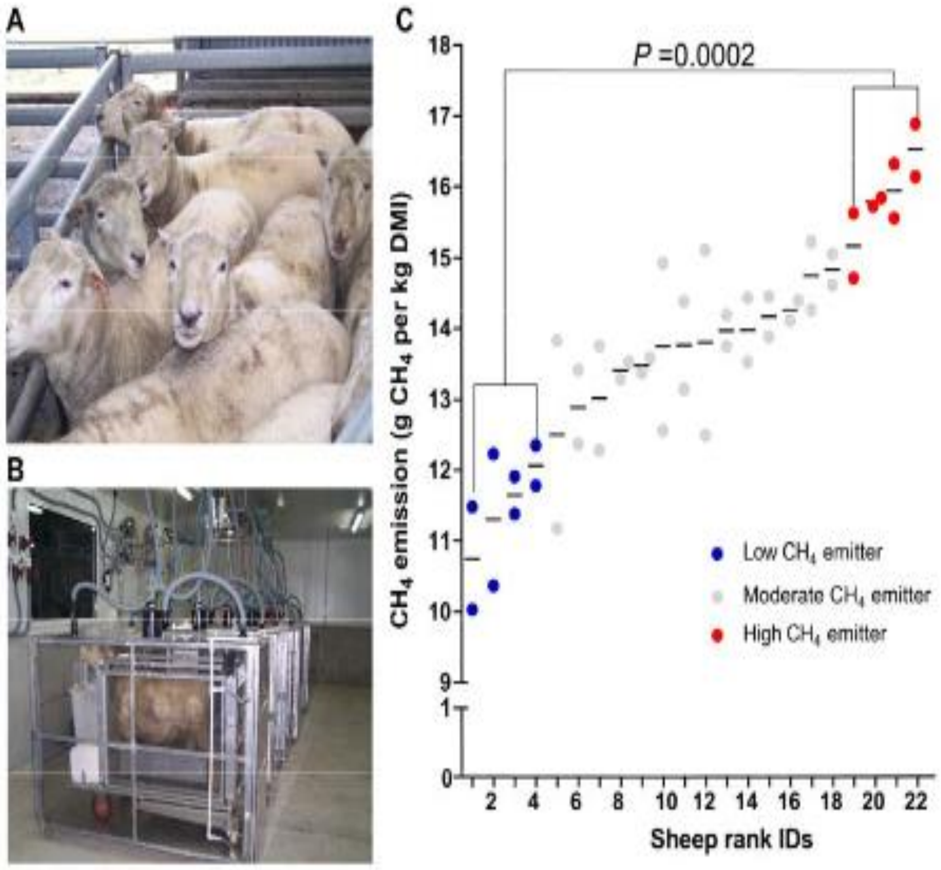
3-NOP binds to the active site of the Methyl-coenzyme reductase

Anuraga Jayanegara, Ki Ageng Sarwono, Makoto Kondo, Hiroki Matsui,
Muhammad Ridla, Erika B. Laconi & Nahrowi (2018) Use of 3-nitrooxypropanol as feed additive for mitigating enteric methane emissions from ruminants: a meta-analysis, Italian Journal of Animal Science, 17:3, 650-656, DOI: 10.1080/1828051X.2017.1404945

Host

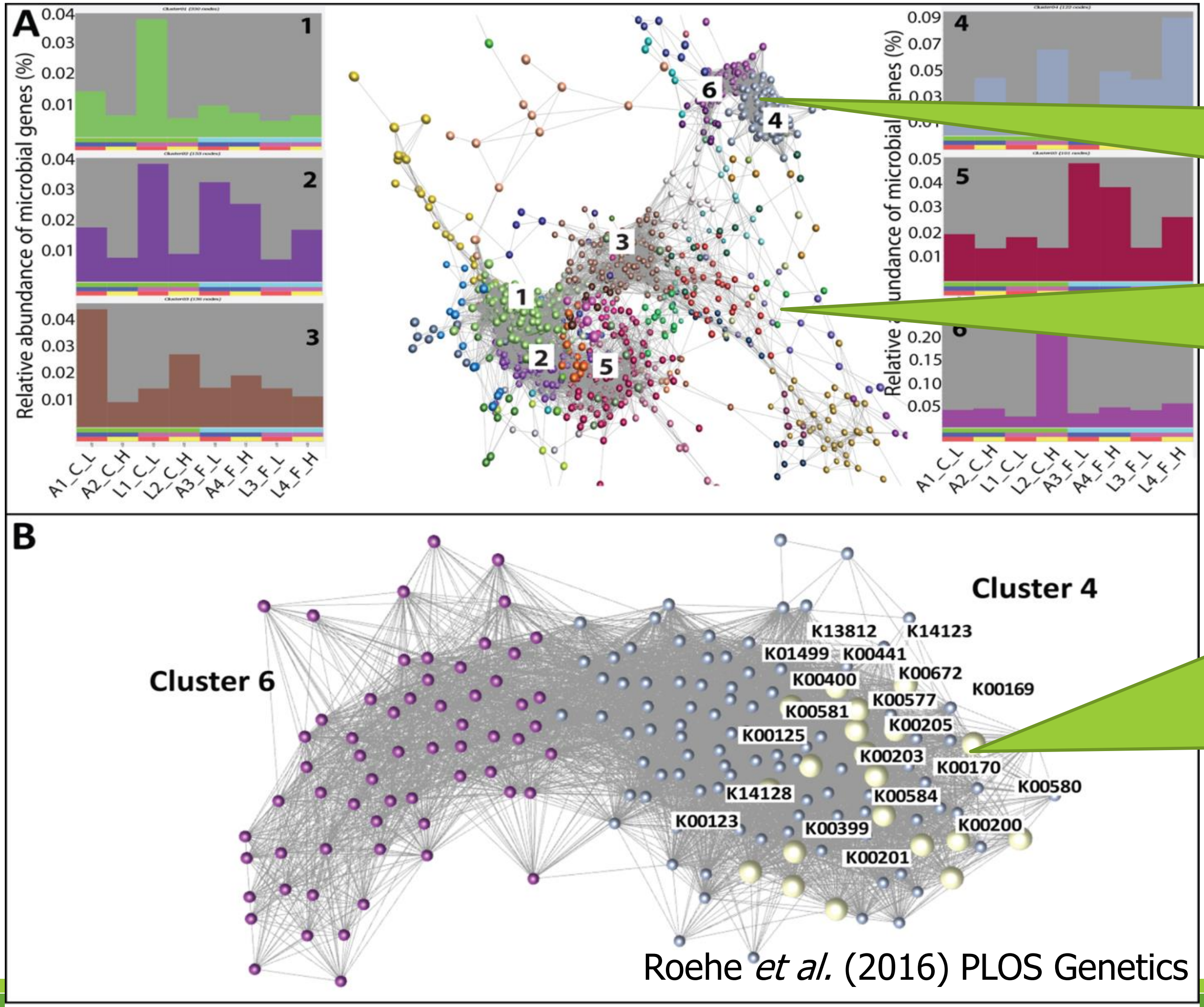


Host



Shi W, Moon CD, Leahy SC, Kang D, Froula J, Kittelmann S, et al. Methane yield phenotypes linked to differential gene expression in the sheep rumen microbiome. Genome Res. 2014;24:1517–25

Rumen microbial genes



Roehe *et al.* (2016) PLOS Genetics

Methane emissions

3970 microbial genes

20 genes explaining 81% of VAR in methane emissions

Value of Genetics (20 years)

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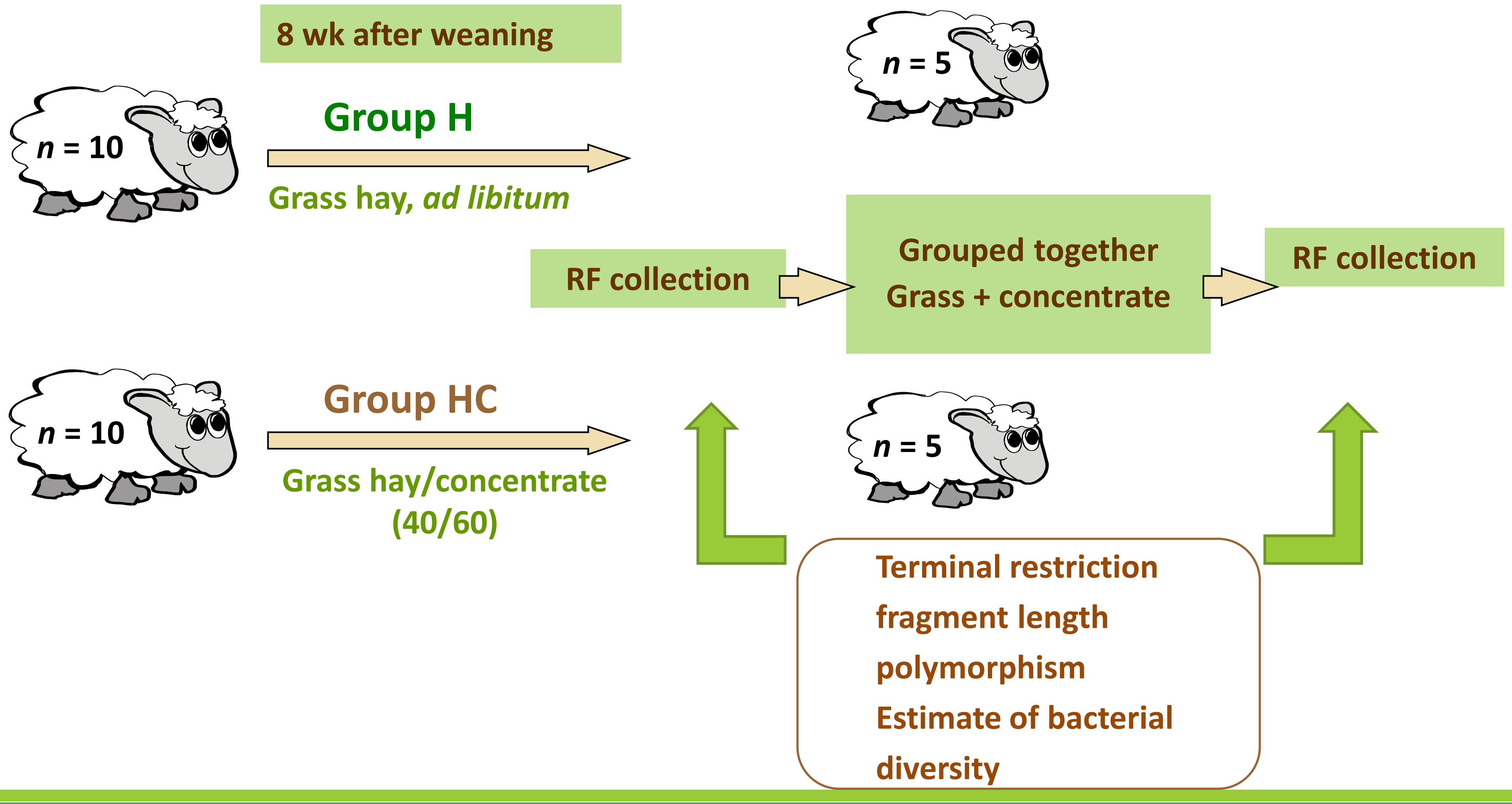
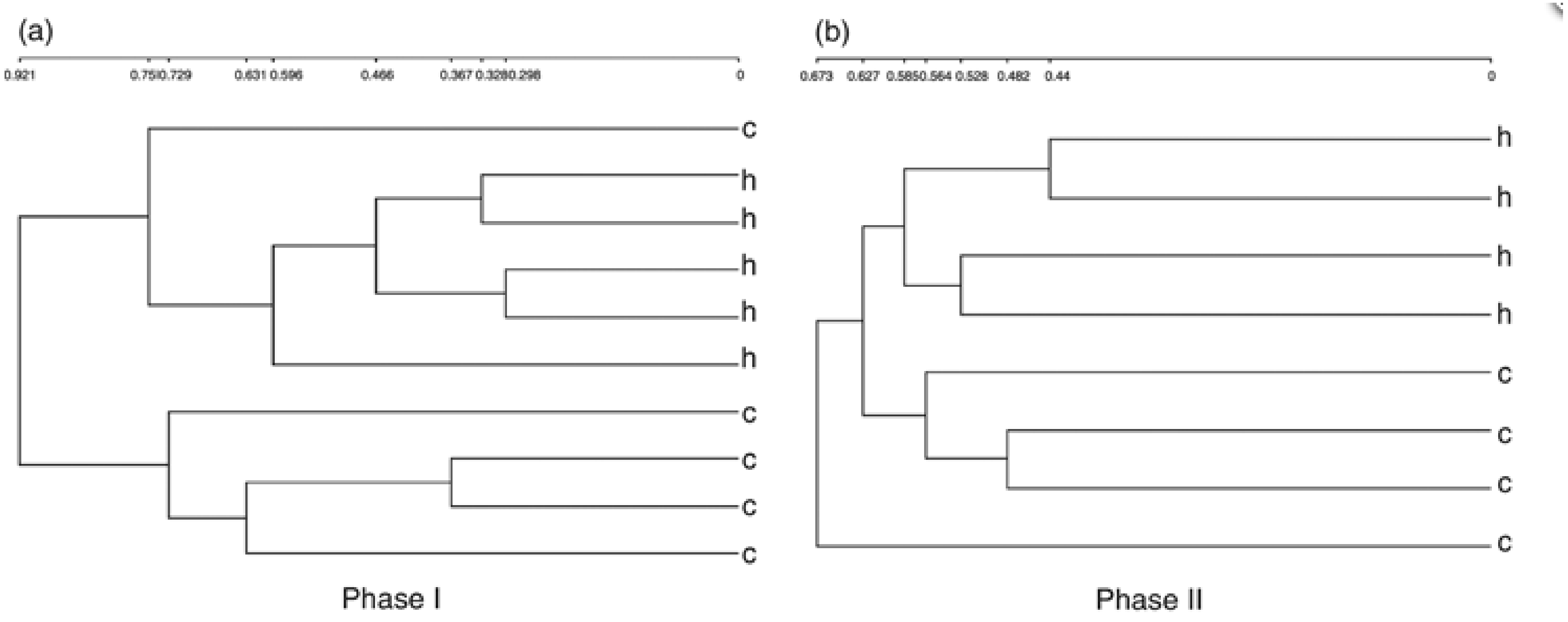
	Available	Estimated cumulative £	Estimated cumulative GHGs
Improving carcass efficiency	NOW	↑22% profit	↓10% in CO_2eq
Improving breeding efficiency	NOW	↑35% profit	↓18% in CO_2eq
Improving feed efficiency	SOON	↑40% profit	↓26% in CO_2eq
Genomic informed improvement	NOW (for some breeds)	~↑50% profit	~↓35% in CO_2eq
Integrating new plant varieties	Some development needed	~↑55% profit ?	~↓40% in CO_2eq ??
Integrating rumen bug genetic info	Some science still needed	~↑55% profit ?	~↓50% in CO_2eq ??

Early Life

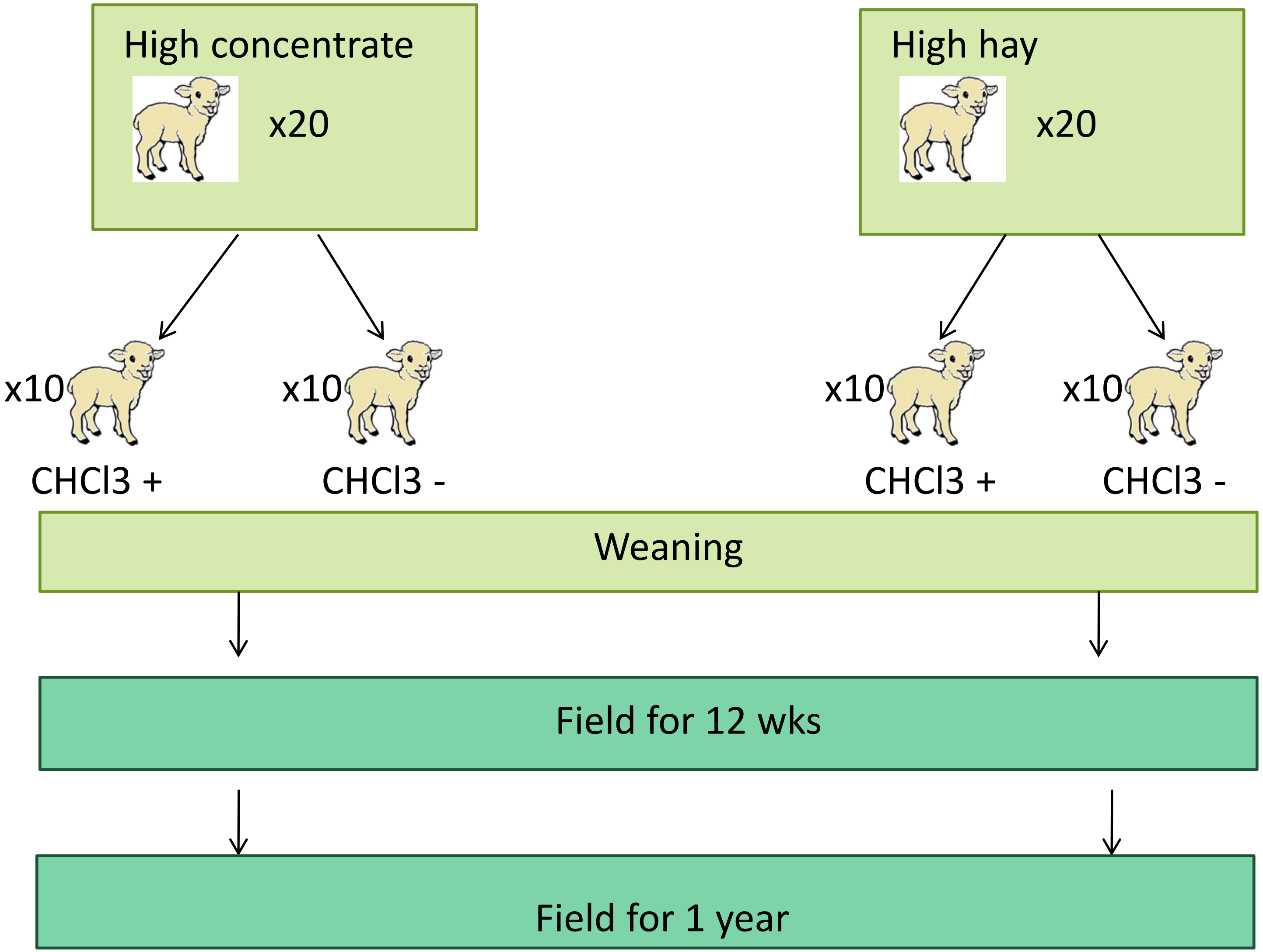

8 wk after weaning
n = 10
Group H
Grass hay, ad libitum
n = 10
Group HC
Grass hay/concentrate (40/60)
RF collection
n = 5
Grouped together
Grass + concentrate
n = 5
RF collection
Terminal restriction fragment length polymorphism
Estimate of bacterial diversity

Early Life



TRFLP-derived dendrogram illustrating the effect of diet received at weaning on the total bacterial community composition h: hay c: hay and concentrate

Early life


High concentrate
x20
High hay
x20
x10
CHCl3 +
x10
CHCl3 -
x10
CHCl3 +
x10
CHCl3 -
Weaning
Field for 12 wks
Field for 1 year

Early life

Methane l/ kg DMI

	Hay + Concs		Hay		Trt	Diet
	Con	$CHCL_3$	Con	$CHCL_3$		
Weaning	12.3	5.7	20.2	17.1	✔	✔
Three months latter	22.9	19.4	20.5	17.3	✔	✔
One year latter	19.8	22.0	18.4	19.7	✗	✔

Why aren't we doing it?

- Farm management
- Improved fertility
- Improved Nutrition

- Improved health
- Feed additives
- Improved genetics
- Agro forestry
- Soil carbon

Improved genetics

We are… 'EnviroCow'
https://ahdb.org.uk/news/breeding-cows-to-help-reach-net-zero

Expected to reduce CO_2e/kg FPCM by just over 1% each year

But could we go faster?

AHDB

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Breeding cows to help reach net zero

Tuesday, 3 August 2021

Two new genetic indexes to help farmers breed more environmentally friendly cows will be launched in August.

The first, EnviroCow, reflects the important role **genetics** and breeding play in improving the environmental efficiency of milk production.

Incorporating cow lifespan, milk production, fertility and the new Feed Advantage index, EnviroCow is one of the first **genetic indexes** in the world to focus solely on breeding cows for their environmental credentials.

Marco Winters, Head Of Animal Genetics for AHDB said: "The environmental focus of EnviroCow reflects the important role cattle breeding can play in helping the farming industry reach its goal of net zero greenhouse gas (GHG) emissions."

Learn more about breeding and genetics

EnviroCow will be expressed on a scale of about -3 to +3, where the highest positive figures are achieved by bulls which transmit the best environmental credentials to their daughters. These will be cows which are predicted to create the least GHG emissions in their lifetimes for each kilogram of solids-corrected milk they produce.

Improved genetics

Gonzalez-Recio et al. (2021) Mitigation of greenhouse gases in dairy cattle via genetic selection: 2. Incorporating methane emissions into the breeding goal. J. Dairy Sci. 103: 7210–7221

- possible to achieve a 20% reduction in CH_4 production (kg/cow/lactation) in 10 years…
- …but at the expense of decelerating genetic gain for production traits by 6 to 18%

de Haas et al. (2021) Selective breeding as a mitigation tool for methane emissions from dairy cattle. Animal, *in press*

- ‘By putting economic weight on CH_4 production in the breeding goal, selective breeding can reduce the CH_4 intensity by 24% by 2050’

Martinez-Alvaro et al. (2021) Bovine host genome acts on specific metabolism, communication and genetic processes of rumen microbes host-genomically linked to methane emissions. *In press*

- Microbiome-driven (indirect) genomic selection for CH_4 emissions…resulted in our small population in substantial mitigation of CH_4 (up to 17% of its mean per generation…), even larger than direct genomic selection based on the accurately measured CH_4 emissions.

Suggests that we can go faster

Feed supplements

Incentive ↓

Proof of principle → Intellectual property → 'Sufficient' data → Regulatory pathway → Supply chain: to farm → Supply chain: to animal → Verification → Market acceptance

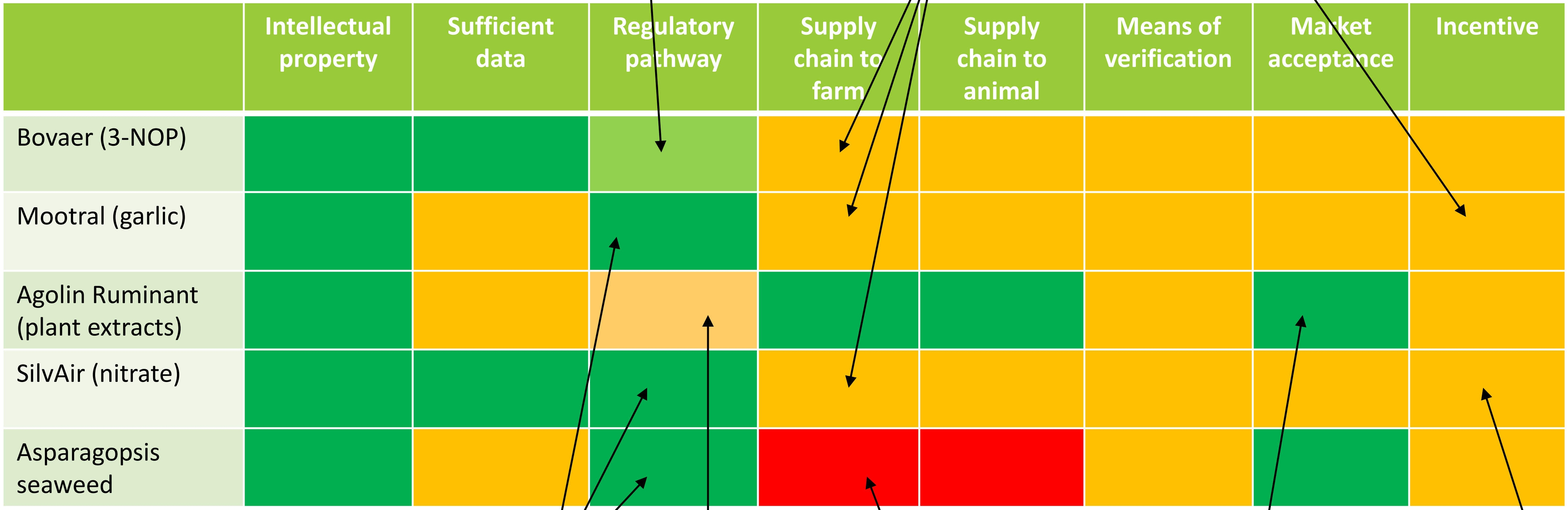
Proof of principle	Intellectual property	'Sufficient' data	Regulatory pathway	Supply chain: to farm	Supply chain: to animal	Verification	Market acceptance
Many positive effects reported *in vitro*	Mix of patents and closely-held secrets	Does it work? How big is the effect? Will it work for me? Interactions with the environment never fully understood Interactions between supplements poorly researched When are data 'sufficient' and who decides?	Feed Additive Feed Material	Ingredient manufacture and sourcing Interactions between active ingredients and processing (e.g., pelleting) Does the supplement fit into the feed product?	What proportion of target animals can the feed product reach? e.g., extensively-grazed hill sheep and beef	Has the supplement been consumed by the target animal? If it has, has it worked?	Farmers Direct customers Food consumers Wider society

Feed supplements

Progressing towards authorisation as zootechnical feed additive (for dairy)
Positive EFSA opinion 19Nov21

Initially, dairy cow only

Being explored as a method approved in a voluntary carbon trading scheme



Active ingredients are Feed Materials

Not available in commercial quantities

More acceptable than ‘synthetic’ products?

In NL, will be an approved technology within the ANCA nutrient management system

Progressing towards authorisation as zootechnical feed additive (for dairy)

Simplistic personal opinion
Many shades of grey

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