New feed additives for mitigating methane from ruminant livestock

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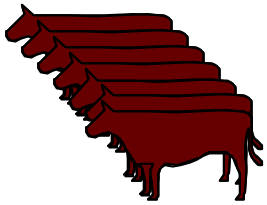
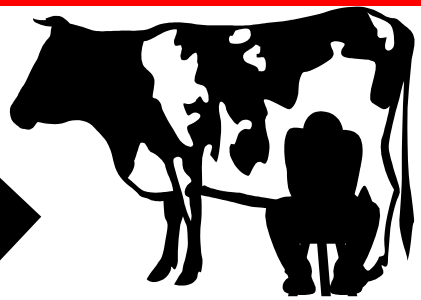
Introduction

$1.5x10^9$ heads



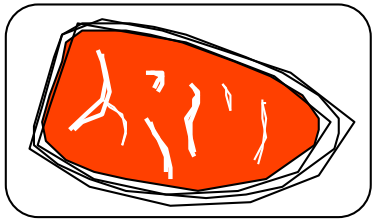
$1x10^{10}$t of plant

Fermented by gut microbes



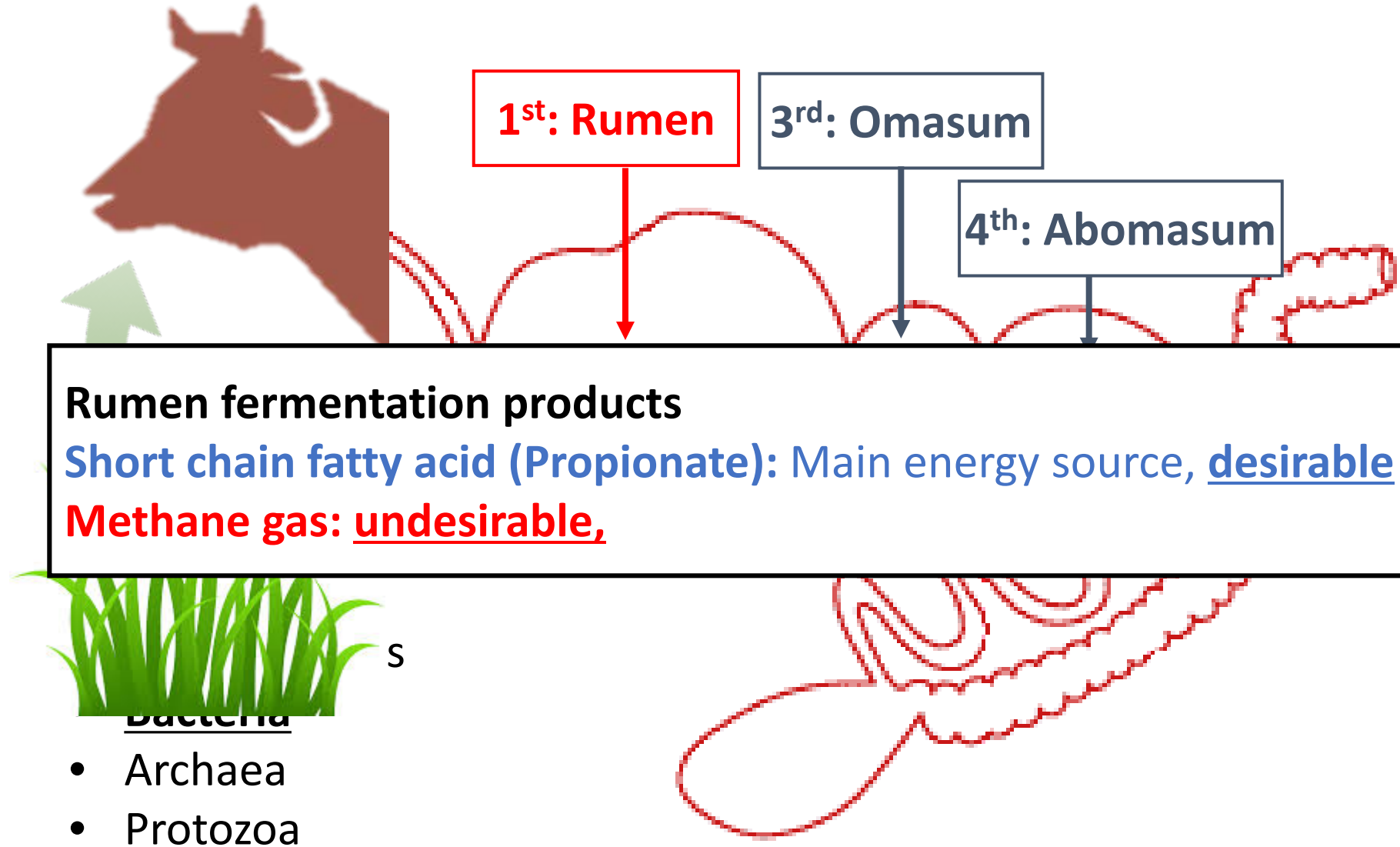
$1.5x10^9$ t of milk

Useful products



$1.5x10^8$ t of meat

Introduction



Rumen fermentation products

Short chain fatty acid (Propionate): Main energy source, **desirable**

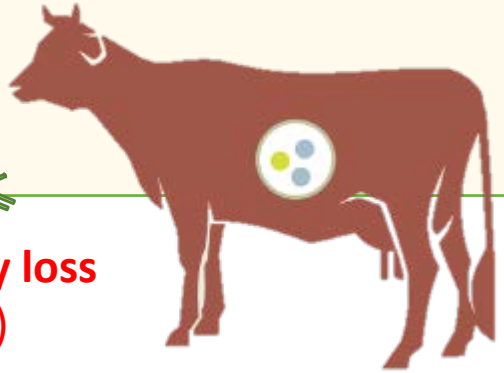
Methane gas: undesirable,

s

- Archaea
- Protozoa
- Fungi

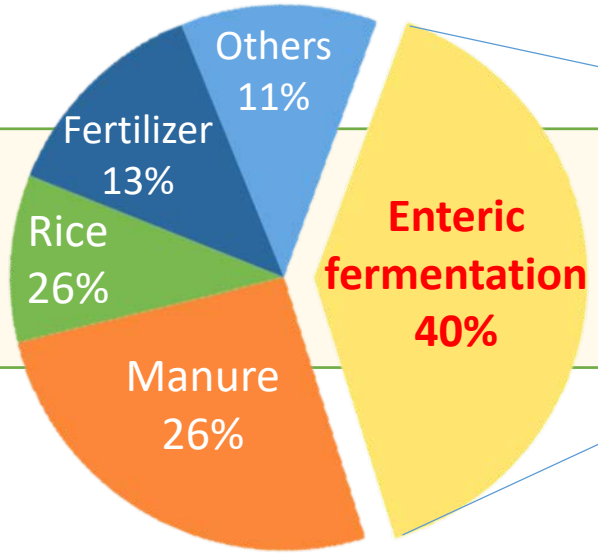
Introduction

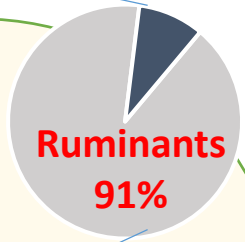
Global warming potential
Methane >>> CO_2



Feed energy loss
(2-12%)

Methane emission from agricultural sector





Antibiotics

Rumen modulation
- Methane ↓
- Propionate ↑

Concerns on public health
- Banned in EU

New additive candidates (available in Asia)

Today's talk

Significance of methane mitigation by new material alternative to antibiotics

Ease of environmental burden

- greener animal production

Saving of feed energy

- more efficient animal production

Ban of antibiotics

- healthier (safer) animal production

Feed additives to mitigate rumen methane

Potent but NOT applicable

BCM (Bromochloromethane) - inhibitory for CH_4 synthesis
(Mitsumori *et al.* BJN, 2012)

Potent & applicable

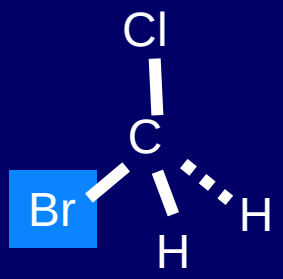
3NOP (3-nitrooxypropanol) - inhibitory for CH_4 synthesis
(Hristov *et al.* PNAS, 2015)

Saponin, fumarate, others - inhibitory/stimulatory for specific pathways
(Wang *et al.* JASB, 2012)

Alkylphenols - inhibitory for microbes involved in CH_4 synthesis
- Cashew (Shinkai *et al.* JDS, 2012)
- Ginkgo (Oh *et al.* JDS, 2017)

Bromochloromethane (BCM)

reduces rumen methane drastically (by 90%),
but not allowed in practical use.
Mitsumori *et al.* BJN, 108: 482-91. 2012.

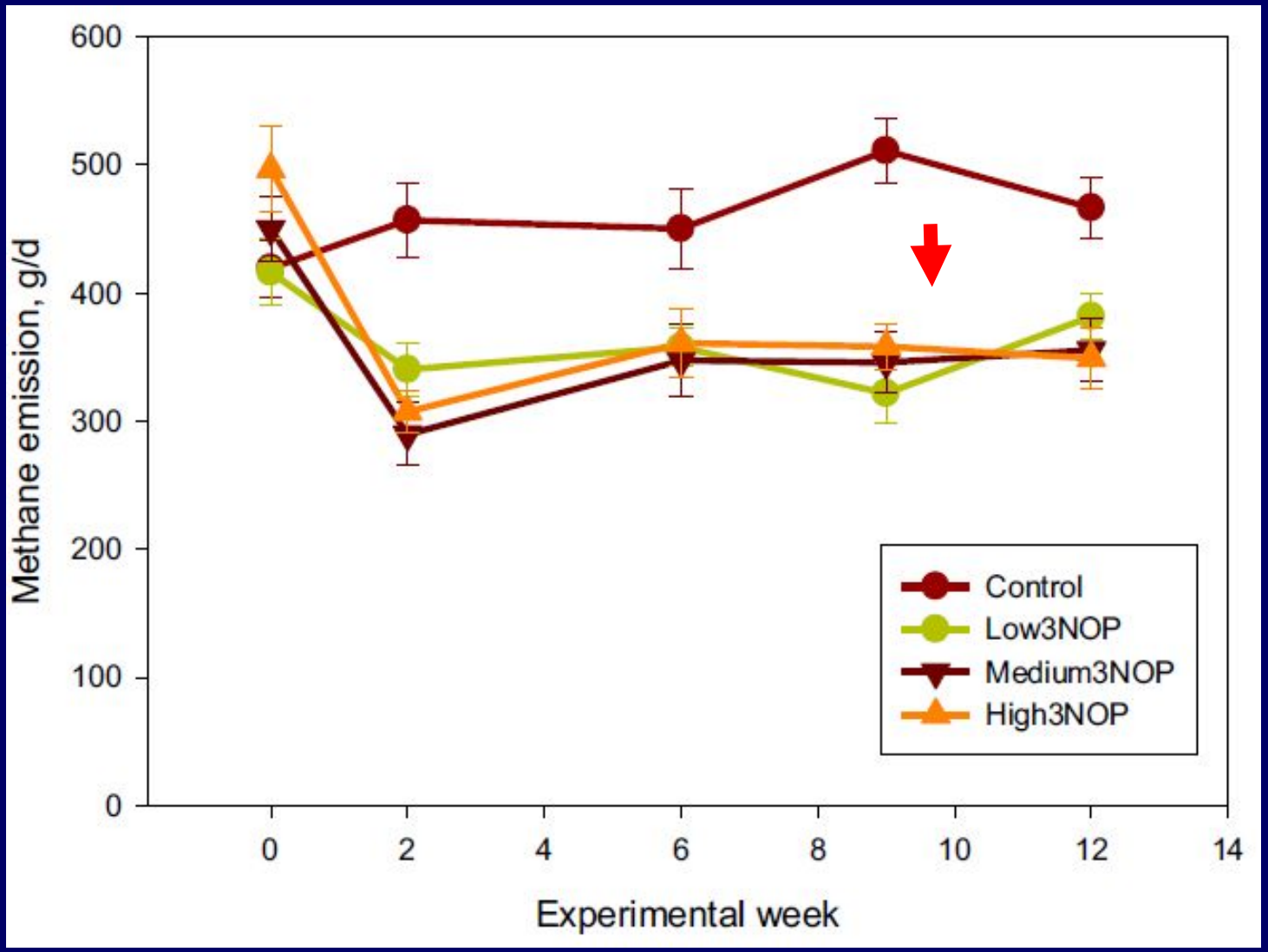


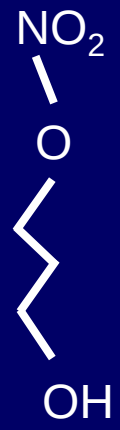
	Control	Low	Mid	High
Methane production				
mmol/head per d				
Mean	949·6[a]	902·1[a]	273·1[b]	86·0[b]
SEM	88·70	72·58	84·61	35·61
mmol/kg of DMI	1412·4	NA	NA	127·3
mmol/kg of ODI	1497·7	NA	NA	135
mmol/kg of NDF		NA	NA	260·6
MR (%)		5	71·3	91
H_2 gas production				
mmol/head per d				
Mean	0[a*]	544·6[a,b]	2941·4[b,c]	3495·5[c]
SEM		261·9	1141·2	237·6

3NOP (3-nitrooxypropanol), molecule inhibitory for methane synthesis, reduces rumen methane by 30%.

Effect persists long (12wk) without decrease of milking performance.

(Hristov *et al.* PNAS, 112:10663-8. 2015)

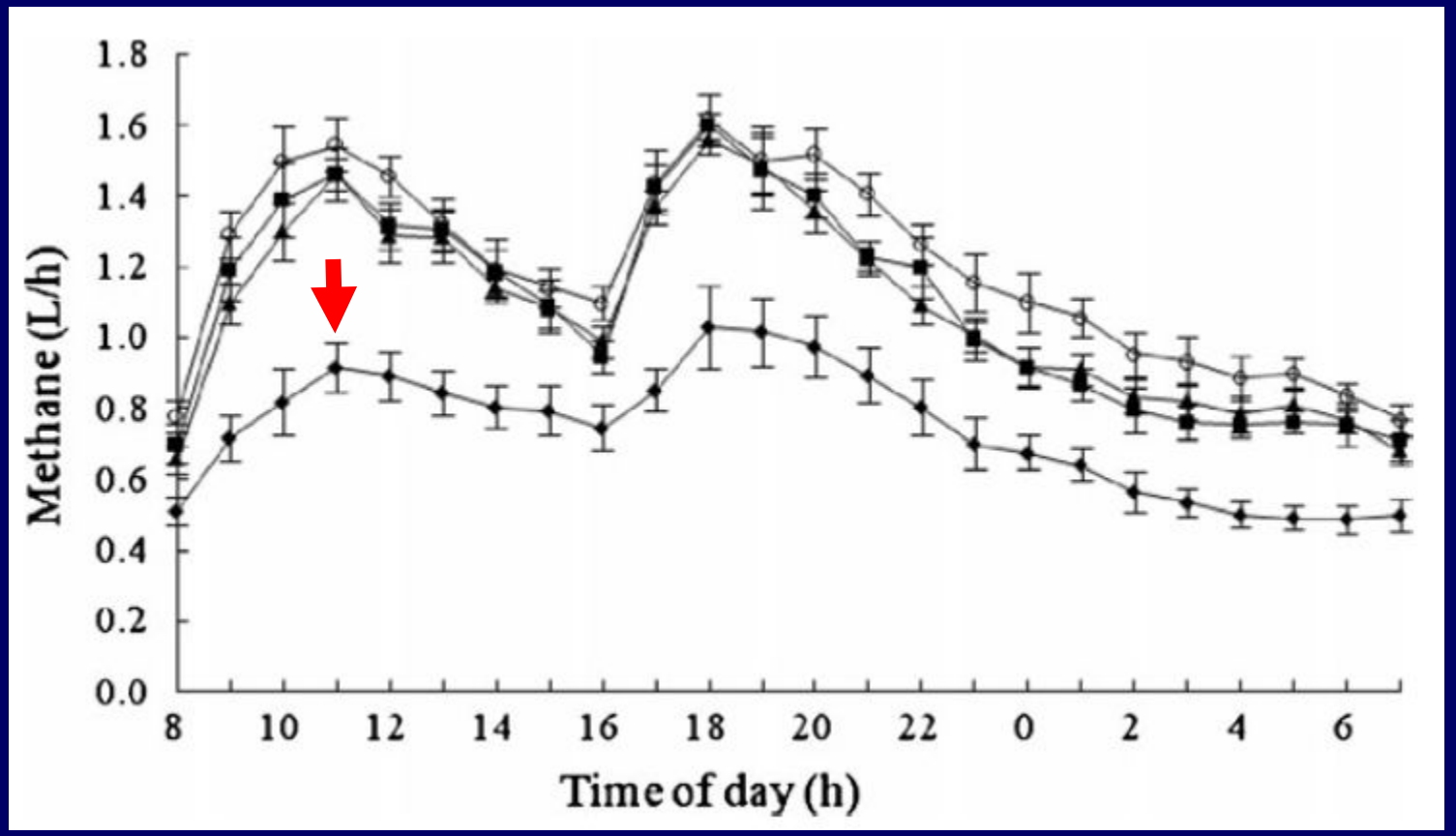




Combination of tea saponin, fumarate and coconut oil

reduces rumen methane by 38%.

Wang *et al.* JASB, 44:697-706. 2012.



Cashew contains alkylphenols inhibitory for rumen microbes involved in methane production

Nut
(kernel)

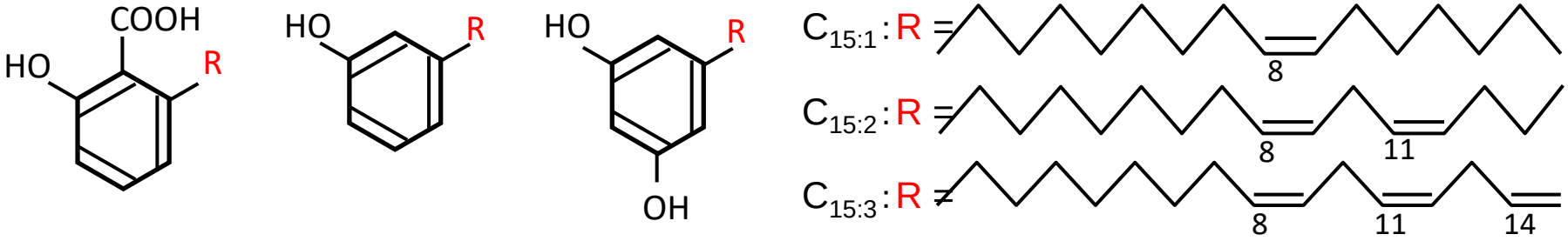
Shell

Cashew Nut
Shell Liquid (CNSL)

Cashew apple (fruit)

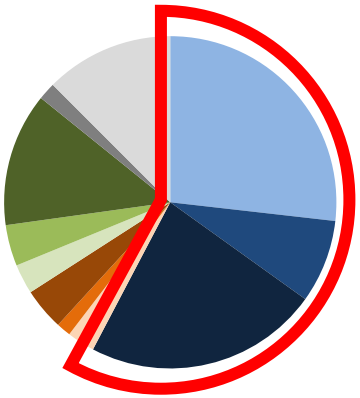
Alkylphenols in CNSL

Anacardic acid **Caldanol** **Caldol**



Active against Gram + bacteria via surfactant action

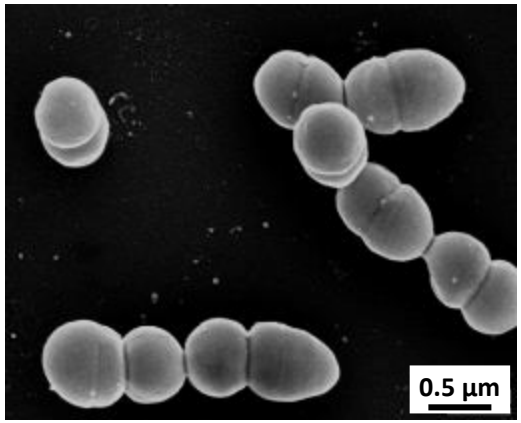
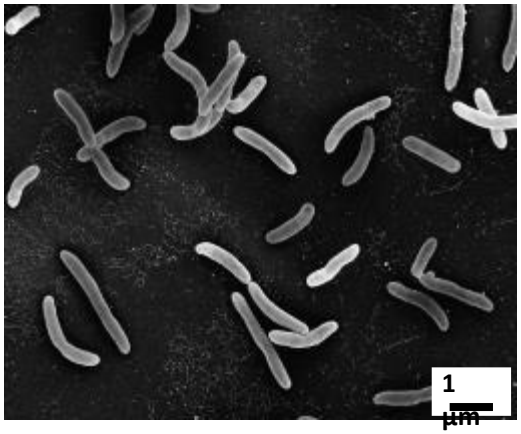
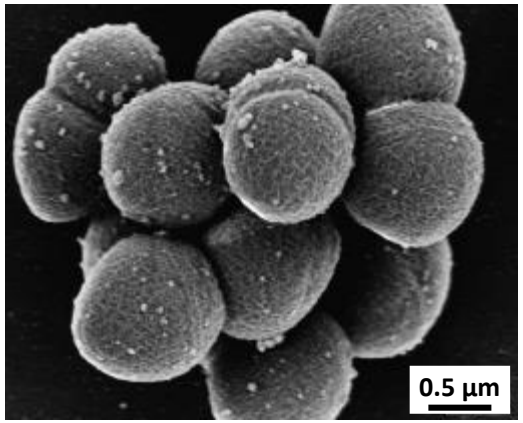
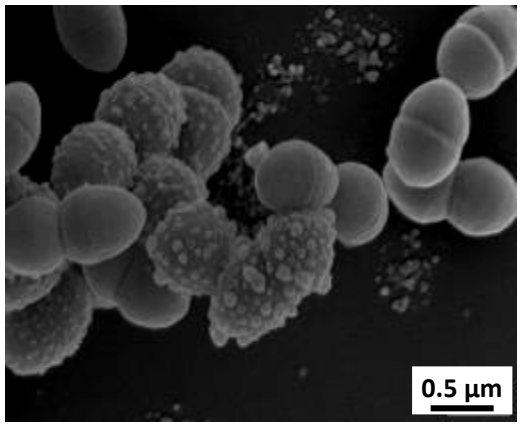
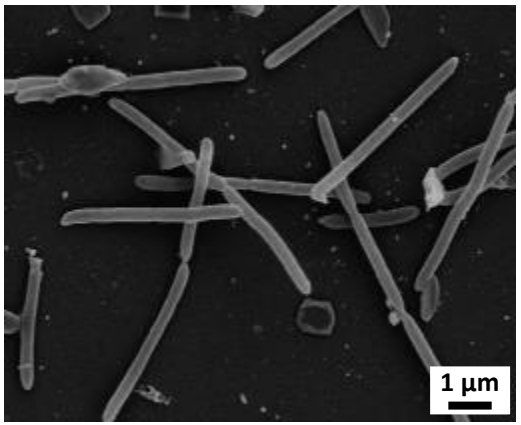
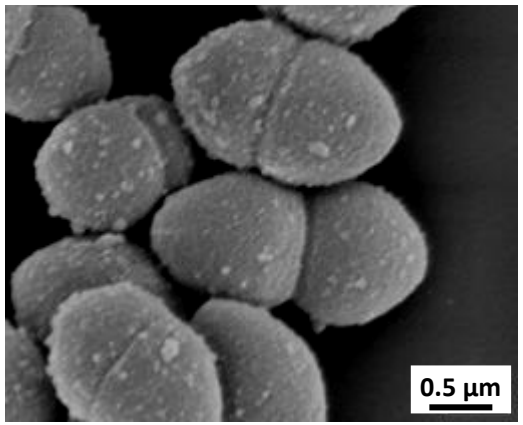
Components



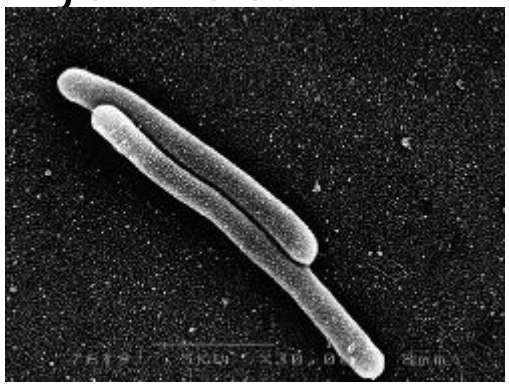
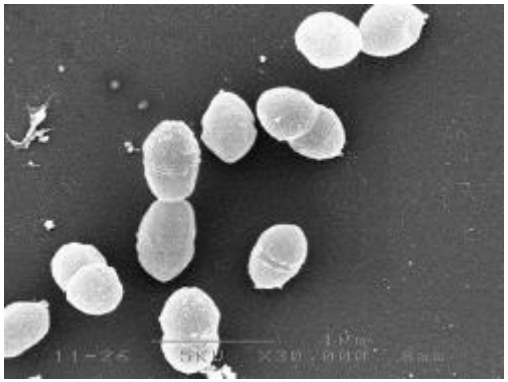
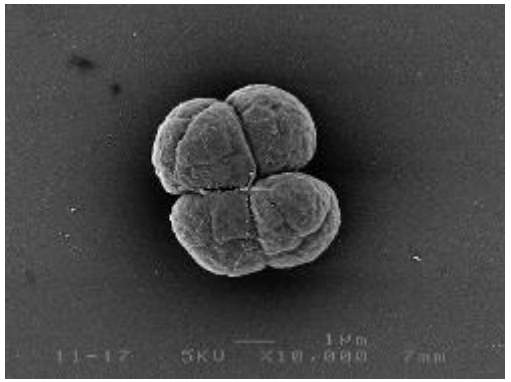
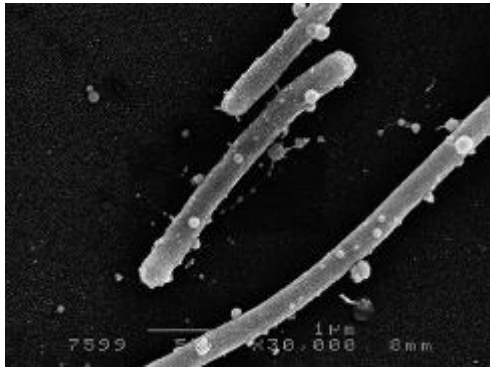
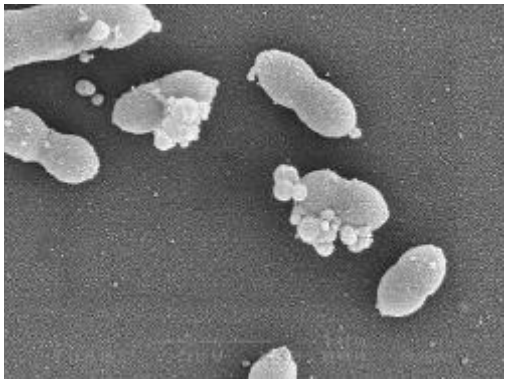
Anacardic acid as main surfactant

Anacardic acid			Caldanol			Caldol			Mois ture	Others
15:1	15:2	15:3	15:1	15:2	15:3	15:1	15:2	15:3		

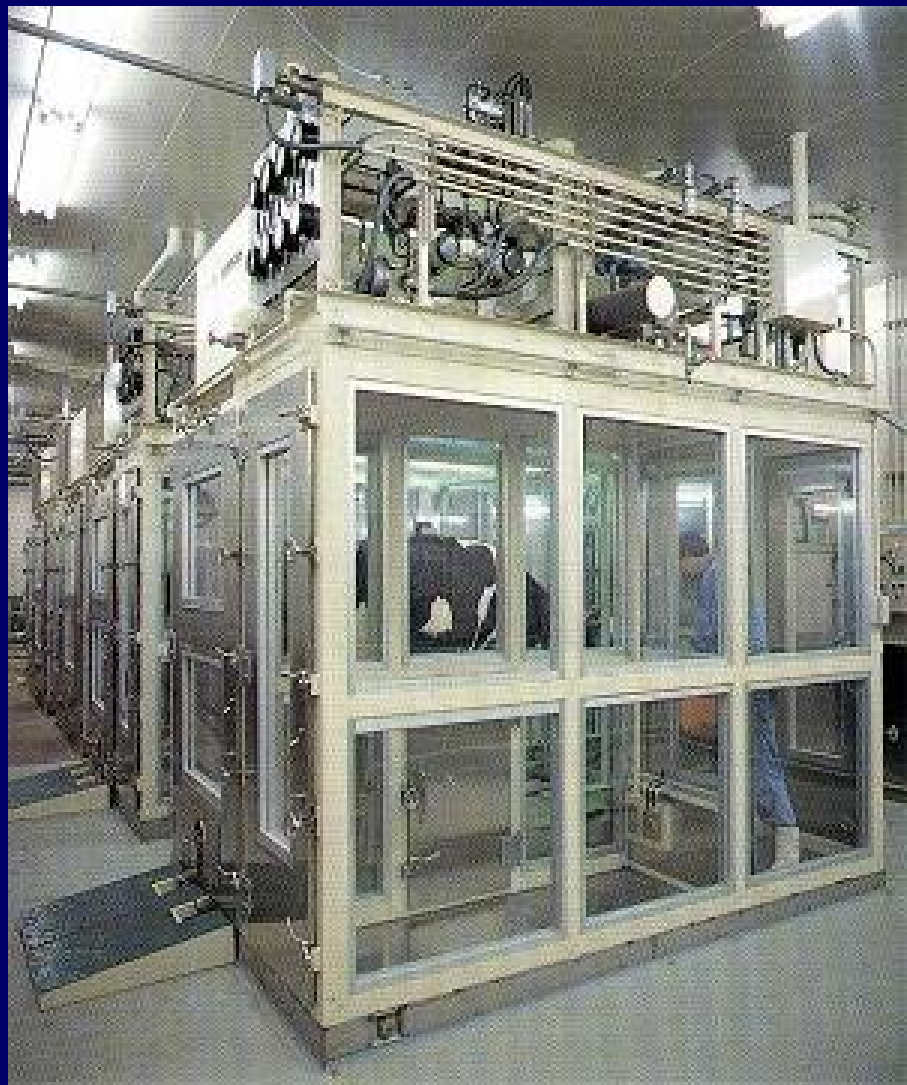
Cashew alkylphenols selectively inhibit growth of bacteria

	S. bovis (MIC=25 μg/ml)	*B. fibrisolvens* (MIC=3.13 μg/ml)	*M. elsdenii* (MIC> 50 μg/ml)
No CNSL			
CNSL			
	Surface disruption ↓ Content leakage & aggregation	**Inhibition of cell division ↓ elongation**	**No change**

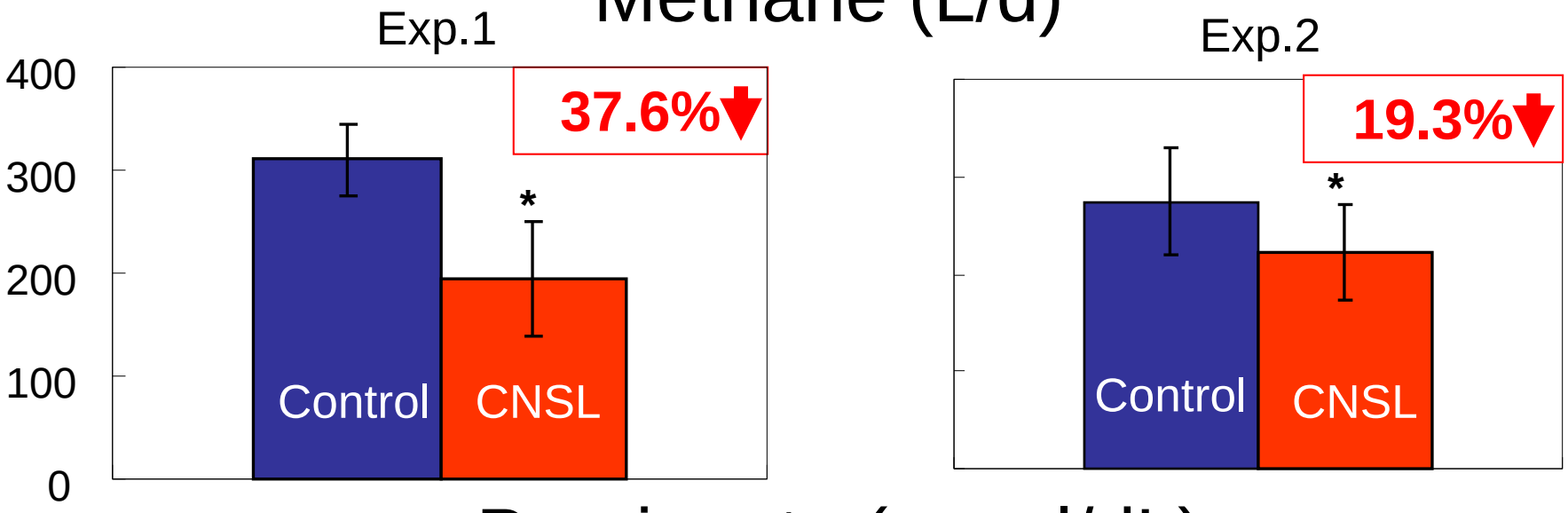
Cashew alkylphenols selectively inhibit growth of methanogen

	Methanobacterium formicicum	*Methanobrevibacter ruminantium*	*Methanosarcina barkeri*
No CNSL			
CNSL			
	Surface disruption ↓ Content leakage	**Surface disruption ↓ Content leakage**	**No change**

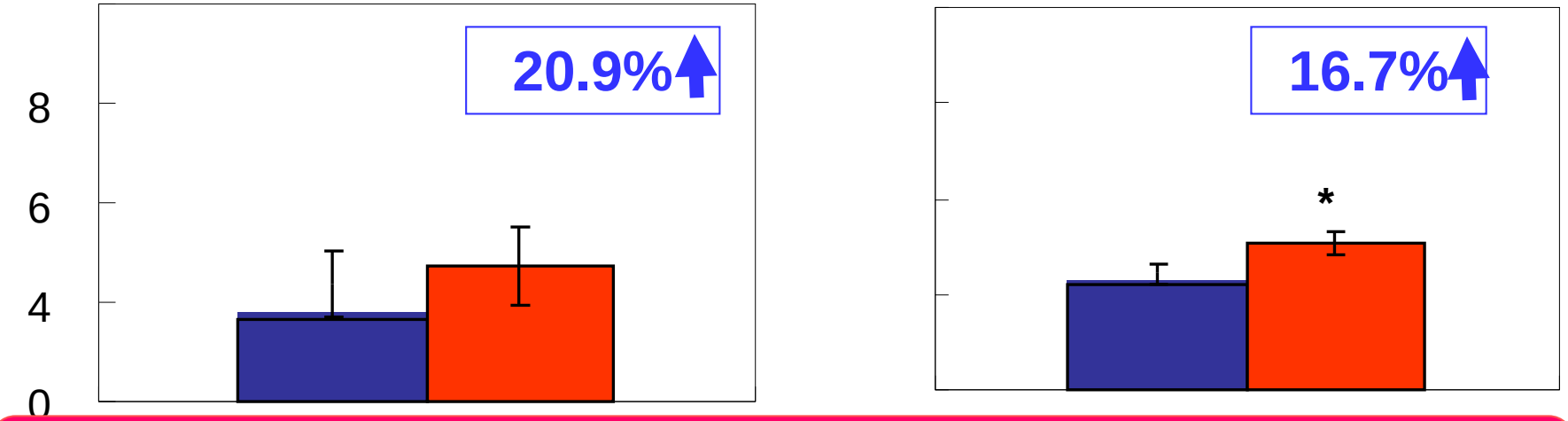
Feeding study using Holstein cows in respiration chamber



Methane (L/d)



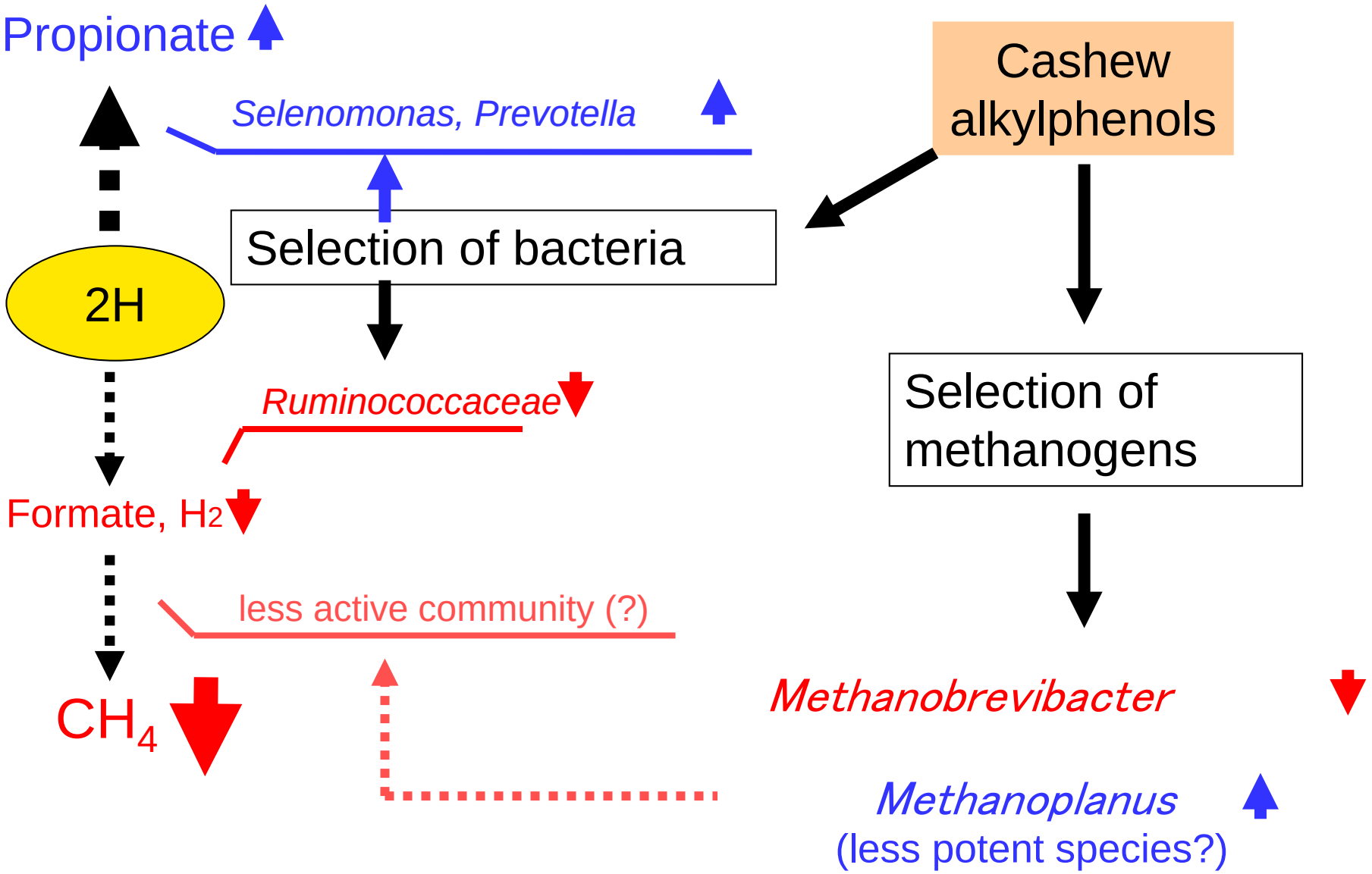
Propionate (mmol/dL)



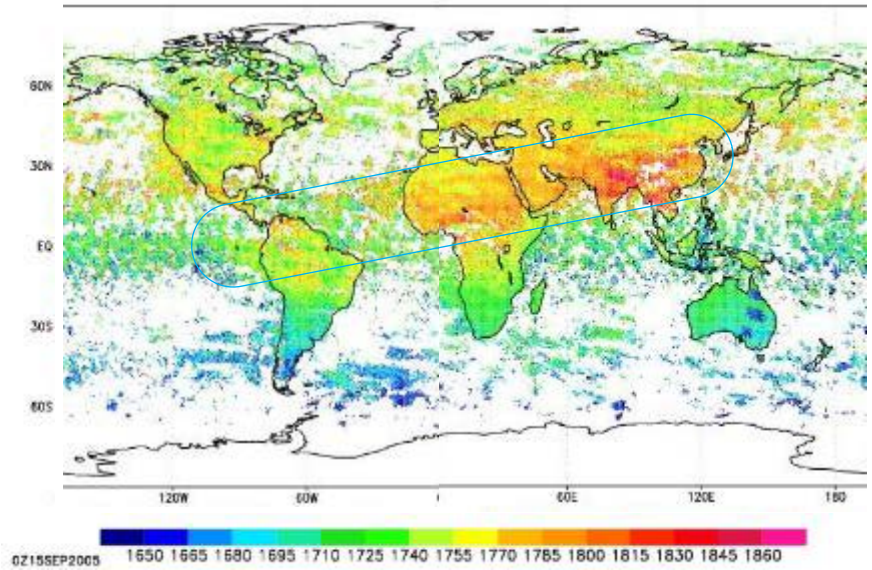
Cashew decreases methane (by 19-38%), while increase propionate in the rumen of Holstein cows

Shinkai *et al*., JDS (2012).

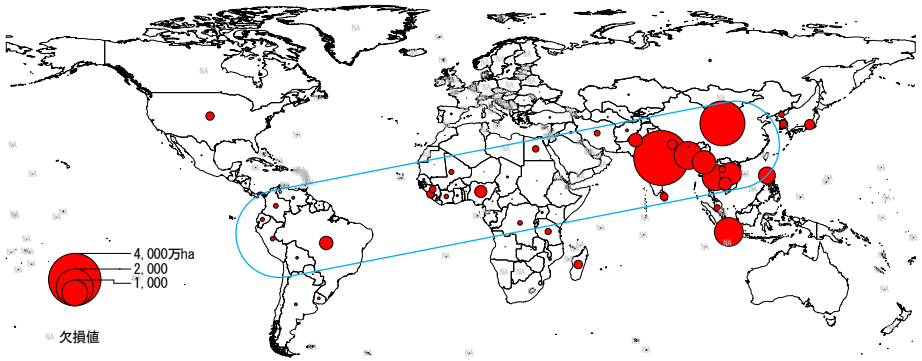
How cashew alkylphenols decrease methane ?



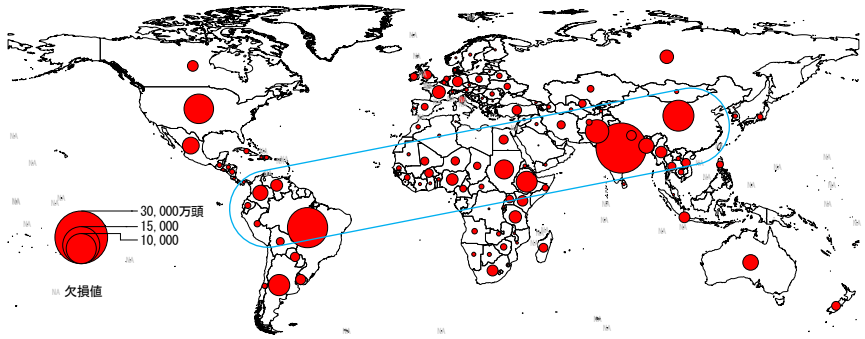
Application in Asia



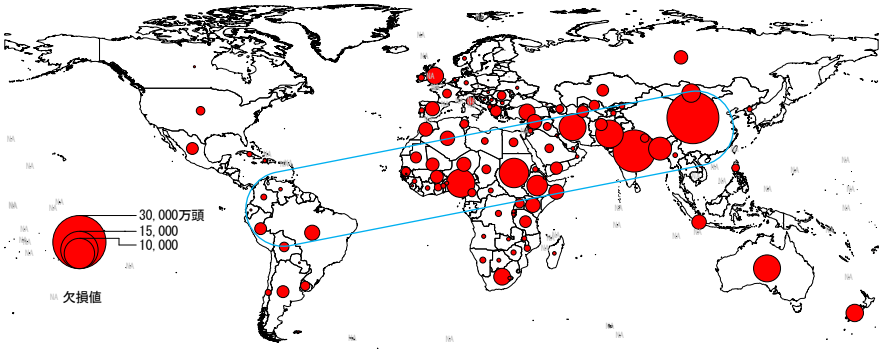
CH_4 conc. (Sep. 2005)



Rice field (x10^4 ha)



Large ruminant population (2008)



Small ruminant population (2008)

Takenaka *et al*., Proc. GGAA (2010)

Ongoing projects

for applying cashew additive to local ruminants

Kasetsart Univ, Thailand & Hokkaido Univ (2013-present)

Can Tho Univ, Vietnam & JIRCAS (2017-)

in collaboration with Idemitsu Co.Ltd.

出光

The Top 5 Cashew Nut producing countries

	Country	Cashew Production 2011 (metric tonnes)	% of World Total
1	Viet Nam	1,237,300 mt	28.9%
2	Nigera	835,000 mt	19.5%
3	India	674,600 mt	15.7%
4	Côte d'Ivoire	393,000 mt	9.1%
5	Brazil	230,785 mt	5.3%

Ginkgo also contains alkylphenols inhibitory for rumen microbes involved in methane production

Introduced

Native

Anacardic acid, main alkylphenols

R=C13H27(C13:0)
R=C15H29(C15:1)
R=C17H33(C17:1)

(Oh *et al*. JDS, 2017)

Methane (mL/tube)

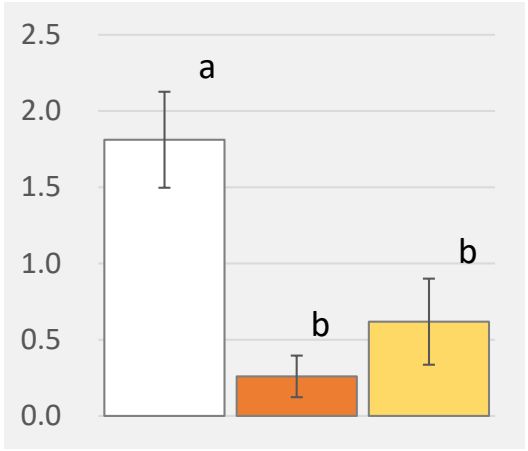
(Oh *et al*. JDS, 2017)

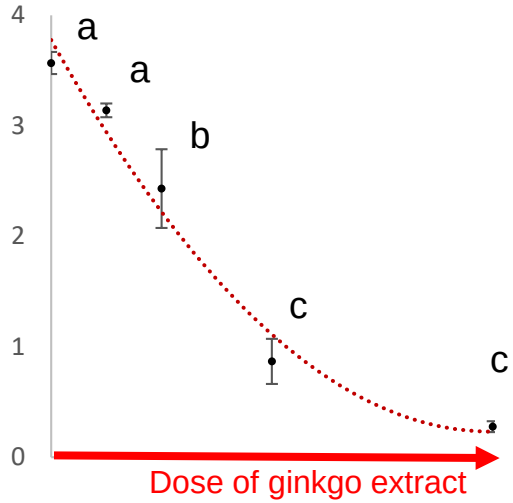
Control

Ginkgo K

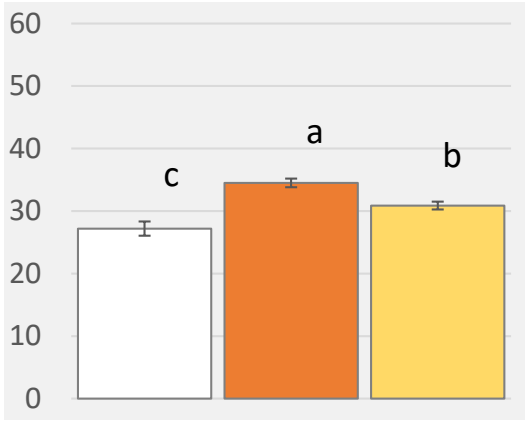
Ginkgo T

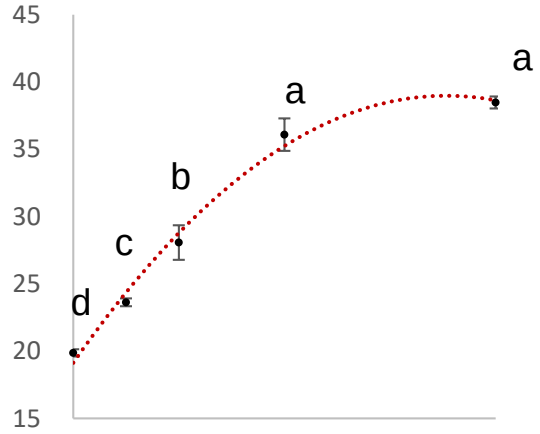
a,b,c: $P<0.05$





Propionate (molar %)





Ginkgo alters rumen fermentation pattern toward less methane and more propionate production dose-dependently as found in cashew

Summary

1. Use of **potent additive** is expected to **meet urgent need**.

2. **Cashew shell and ginkgo fruit as agricultural byproduct** are being proposed in Asian region.

3. Both containing alkylphenols **decrease CH_4** and **increase propionate** production.

4. Alkylphenols **change microbial community structure**

5. **Evaluation and application** are to be made **in target area** by considering local situation.

More information regarding methane mitigation from dietary & nutritional viewpoints are available at GRA site:

https://globalresearchalliance.org/research/livestock/networks/feed-nutrition-network/

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