Methane mitigation in ruminants: from rumen microbes to the animal

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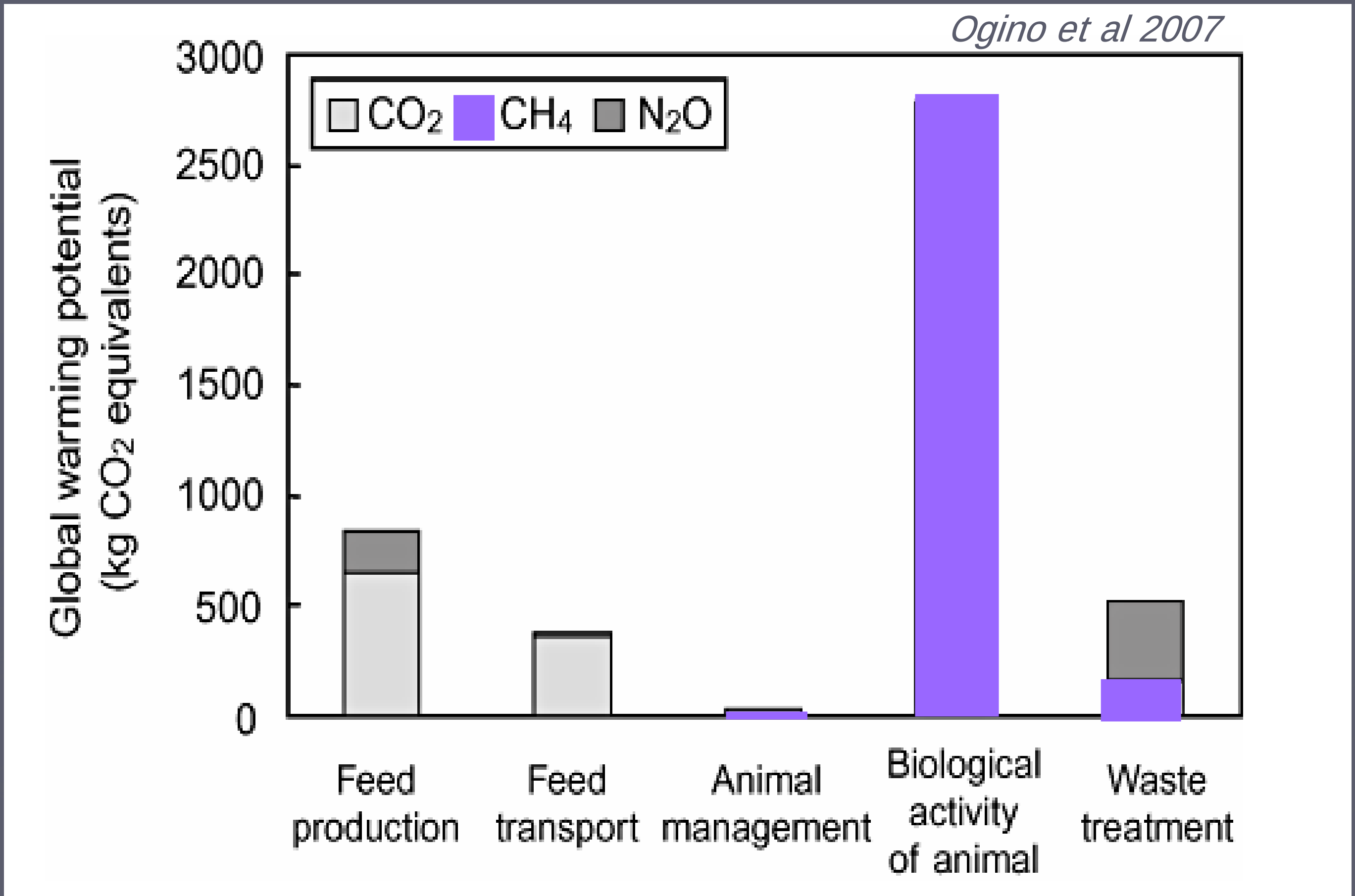
Livestock & Global Climate Change Conference , 17-20 May 2008, Hammamet, Tunisia

INTRODUCTION

The production of greenhouse gases (GHG) from livestock is a major concern (FAO 2006)



Enteric methane (CH_4) is the most important contributor of GHG emissions in ruminant production

INTRODUCTION

Enteric CH_4 production by ruminants

- 33% of the European Union's agricultural GHG emissions

- loss in productive energy for ruminant : mean 6-7%, 2-12% GEI
Johnson and Johnson 1995

Development of strategies to mitigate CH_4 emissions

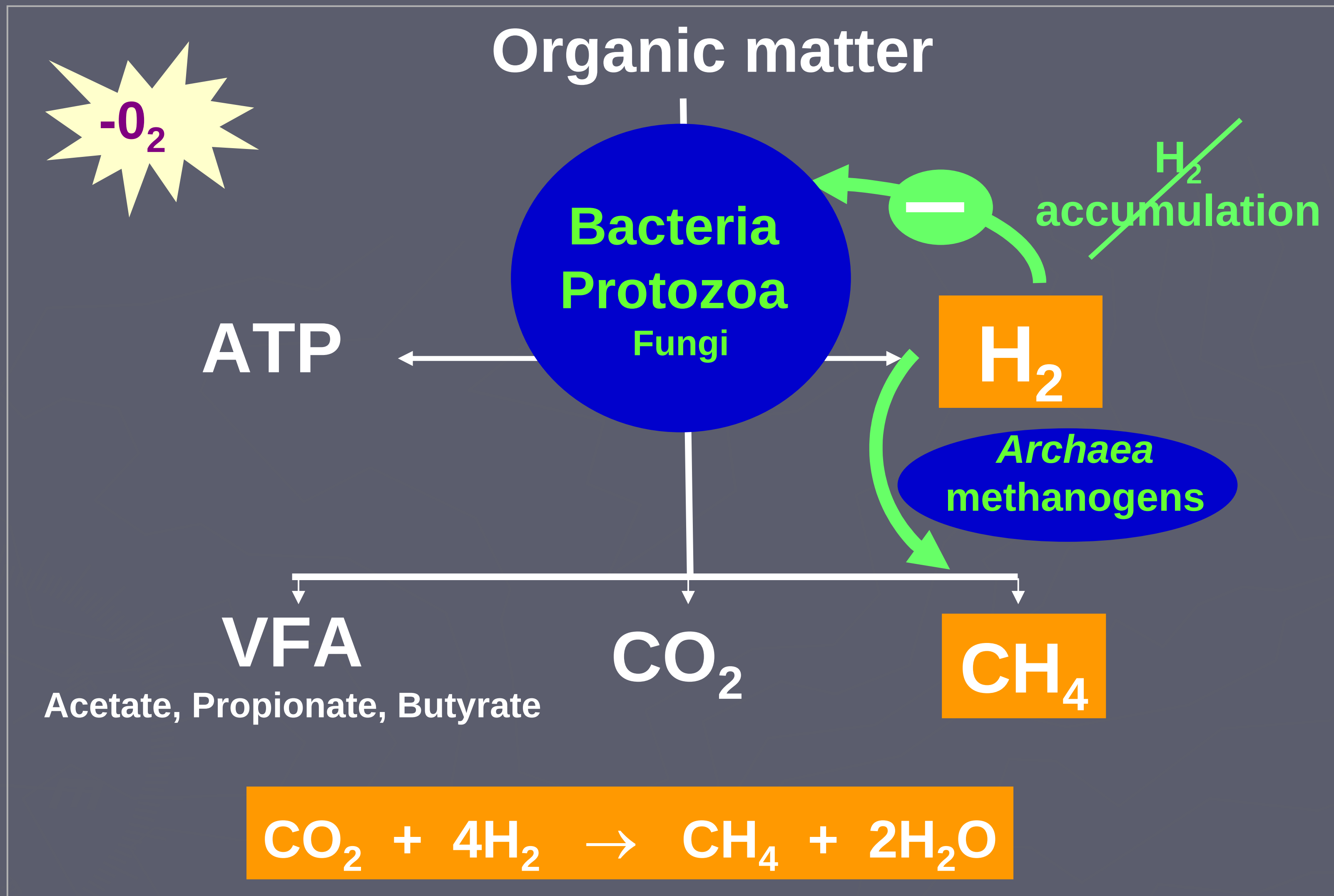
- environmental benefit for the planet

- nutritional benefit for the animal

Where is CH_4 produced in the digestive tract ?

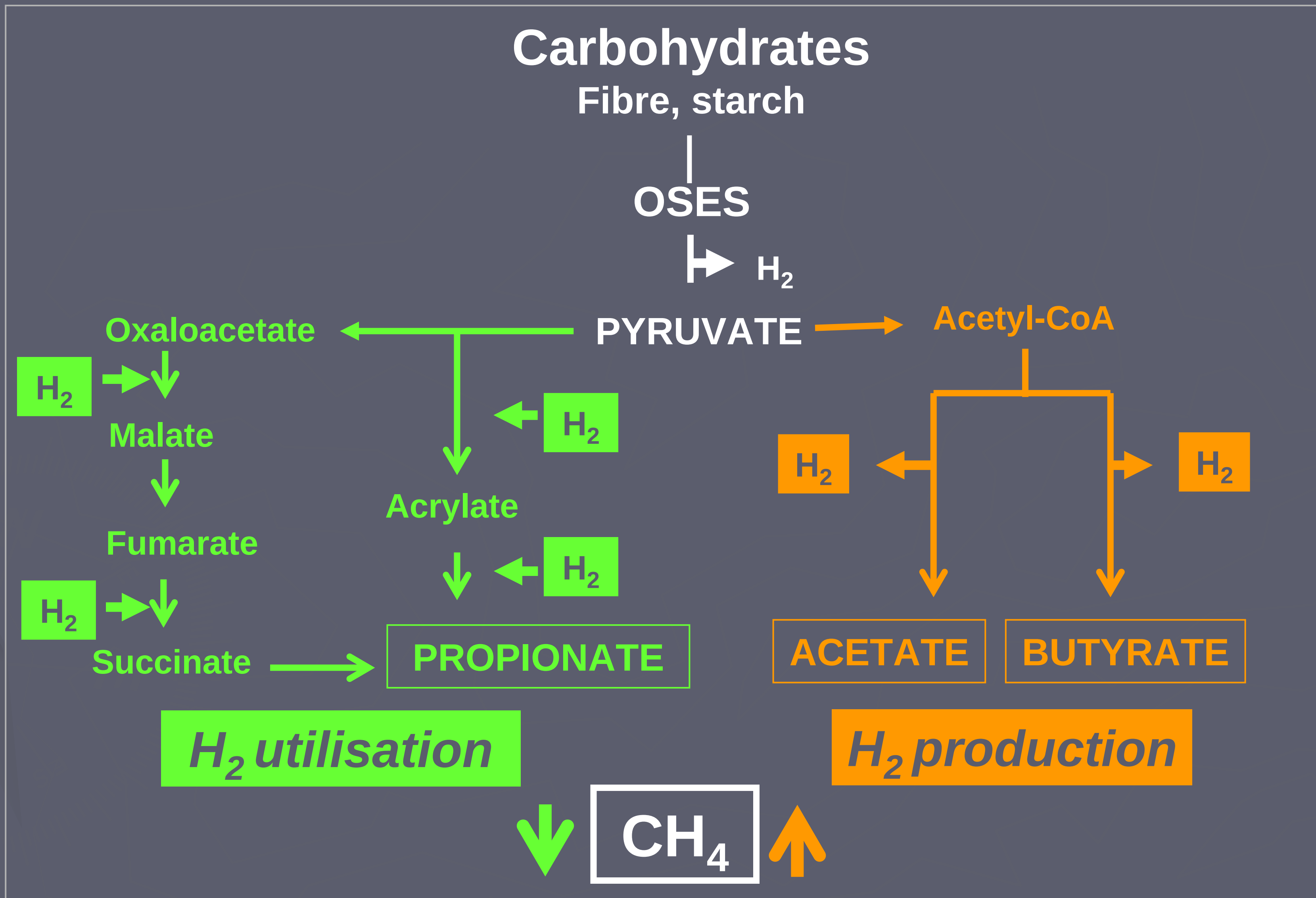
CH_4 is mainly produced in the rumen and eliminated orally into the atmosphere

Why is CH_4 produced in the rumen?

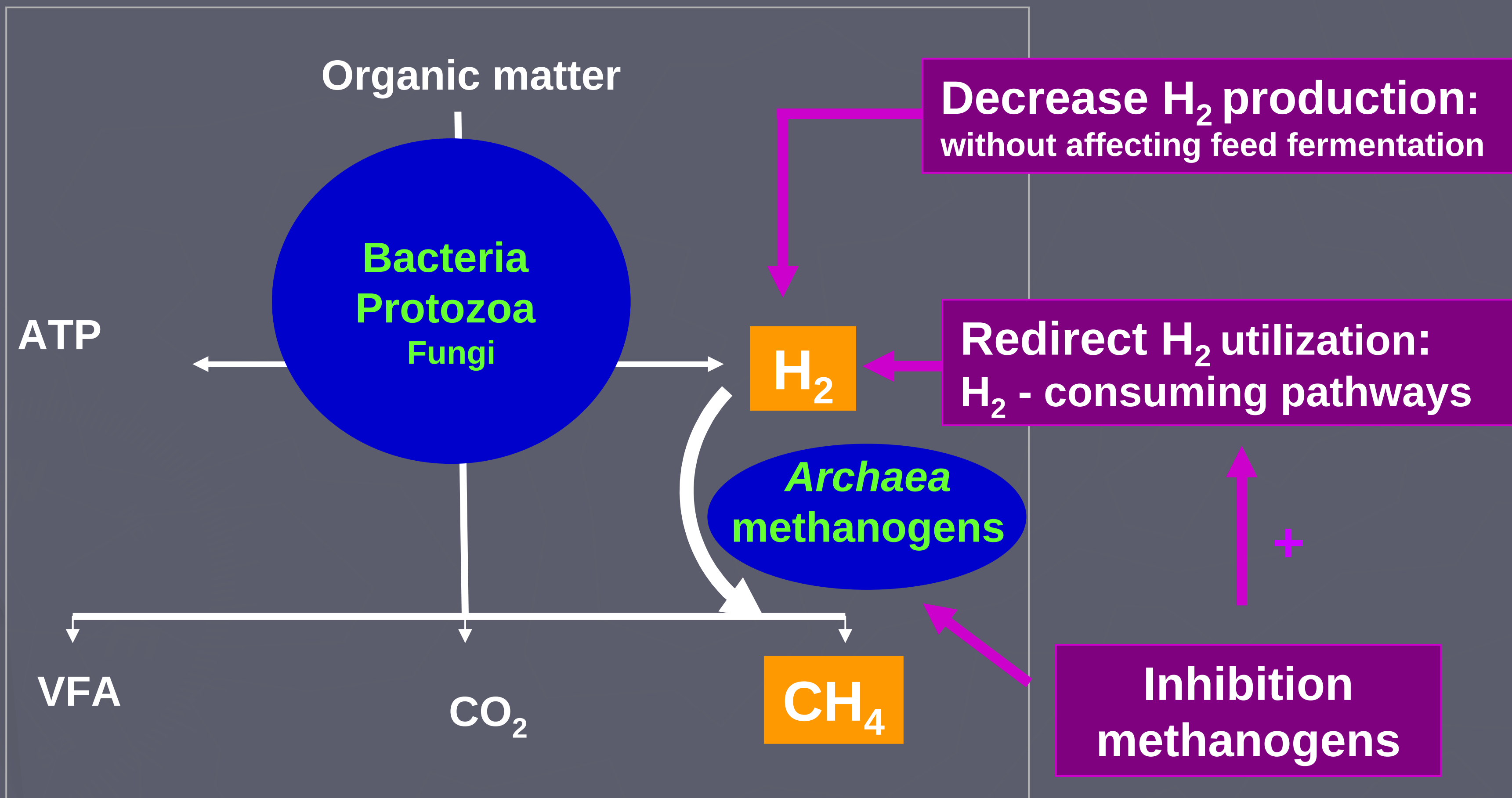


CH_4 is the main pathway for removing H_2 generated during ATP production by anaerobic microbes

Microbial fermentation patterns are not equivalent in term of H_2 metabolism and methanogenesis



Two key points:
H_2 metabolism and methanogens



1. Biotechnologies
2. Additives
3. Feeding

INTRODUCTION MECHANISMS MITIGATION OPTIONS

1. Biotechnologies

Vaccination Australian patent	Inhibition of methanogens	► ~ 8% reduction Wright et al 2004 ► But immunization failures in other trials Clark et al 2007 ► Need genomic information to identify universal immunization targets

Probiotics Addition exogenous microorganisms	Acetogenic bacteria $2CO_2 + 4H_2 \rightarrow CH_3\text{-}COOH + 2H_2O$	► Low efficiency in the rumen ► Isolation of new high-H_2 utilizing species Klieve and Joblin 2007
	Oxidizing bacteria	► Shown in vitro Valdez et al 1996 ► rumen ? Kajikawa et al 2003
	Yeasts	►In vitro studies on strain selection show a high variability in response Newbold and Rode 2006 ►Only a few in vivo trials

Promising but need more research

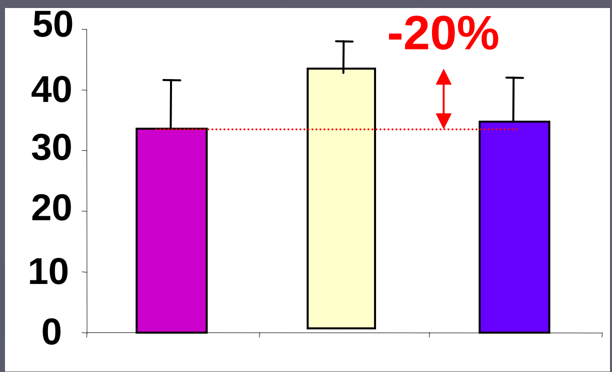
INTRODUCTION MECHANISMS MITIGATION OPTIONS

1. Biotechnologies

Defaunation Chemical agents, plant extracts (saponins), FA	►Inhibition of protozoa (H2-producers, association with methanogens)	► ~ 25% reduction Hegarty 1999 ► Transient effect Ranilla et al 2004

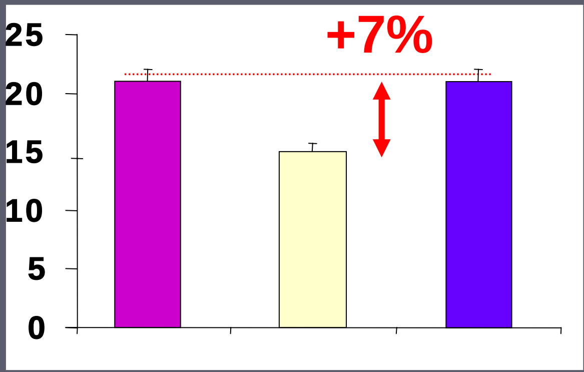
Defaunated 2 years	Faunated 3 months	Defaunated 2 months

Methane



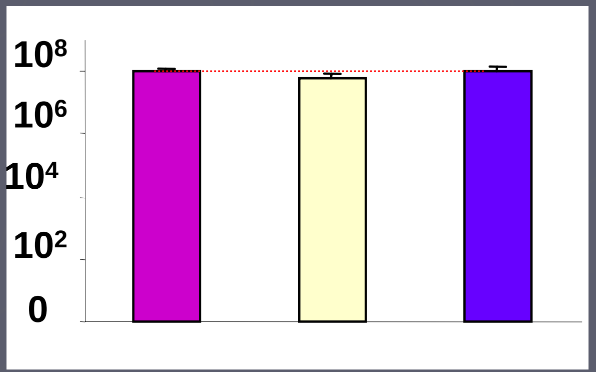
-20% in long- and short-term defaunated sheep: permanent effect

Propionate



Shift towards propionate

Methanogens



Number similar
Diversity similar

- decrease availability of H_2 rather than to a direct effect on methanogens
- commercial technique of defaunation need to be developed

Morgavi et al 2008
Mosoni et al 2008

2. Additives

Antibiotics ✓**Monensin, lasalocid, salinomycin, avoparcin…**	►Inhibition of H_2-producing bacteria (Gram+) and protozoa ►Shift of fermentation towards C3	► **Permanent effect ?** ► **Forbidden as additives in the EU (01/2006)**
Chemical additives ✓**Sulfated AA** (cysteine…) ✓**9,10 anthraquinone** ✓**Halogenated analogue of methane** (chloroform…)	►H_2 metabolism ►Inihibition of methanogens	► **Mainly studied in vitro** ► **Toxicity proven or probable ??** ►**Not marketable (!)**

Not an alternative

2. Additives

INRA

Plant extracts ✓ Essential oils (garlic extract, cinnamon…) ✓ Tannins ✓Saponins (yucca, lucerne)	Inhibition ►Methanogens ► Protozoa	►Good image as natural products ► Mainly in vitro and highly variable ► More in vivo trials are needed (optimal dose, transient effect, residues in animal products …) Calsamiglia et al 2007

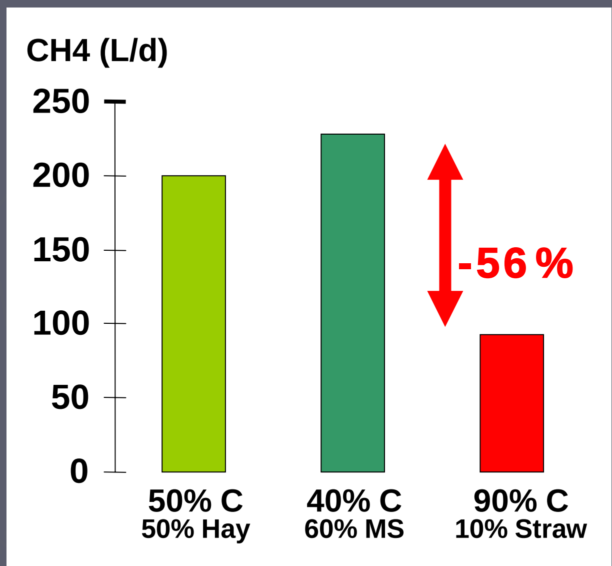
Organic acids ✓ Malate, fumarate	Shift of H_2 towards C3	► Inconsistent effect : 0 to -75% ► Efficient at 10% of intake : problems of cost and acidity – encapsulated fumarate Wallace et al 2006

To be confirmed

3. Feeding: concentrate

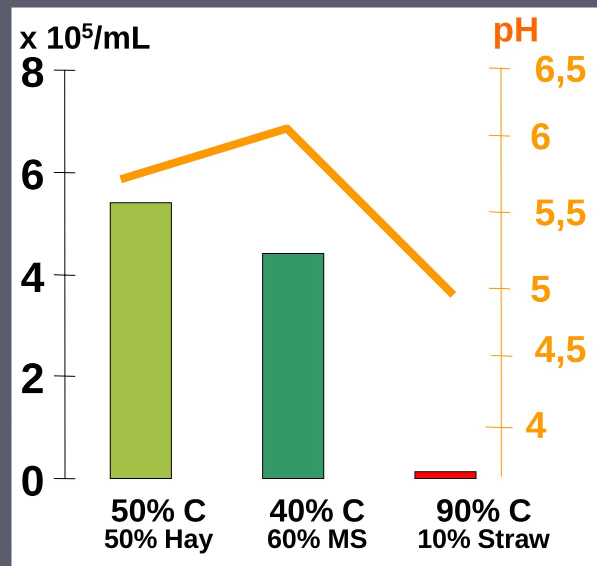
Martin et al 2007

Methane



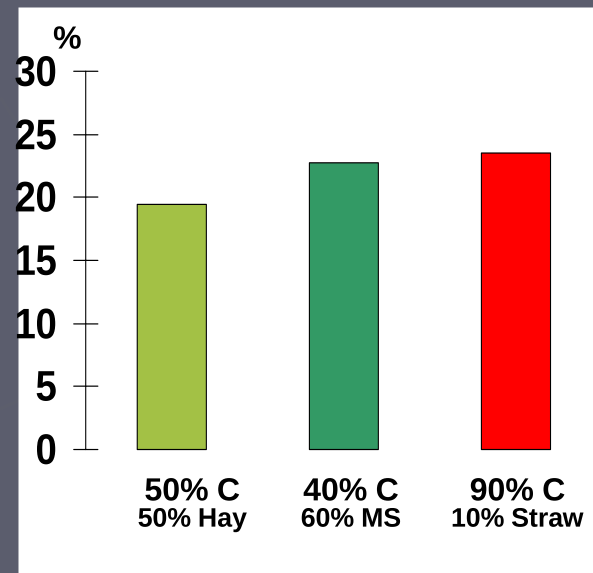
Methane 2 times lower with the diet containing 90% C

Protozoa and ruminal pH



Decrease in protozoa and ruminal pH

Propionate



No change in C3

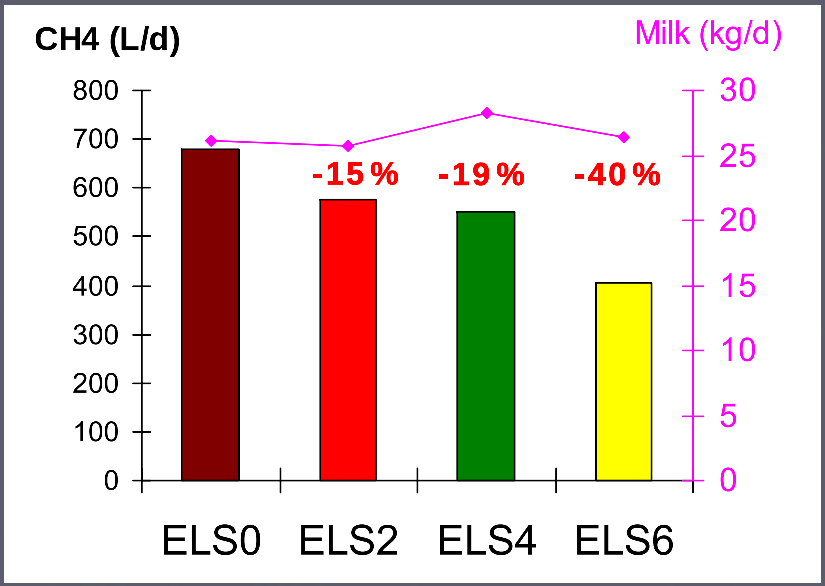
• decrease in H_2 production and methanogenesis

• increase digestive perturbation and health problems
• increase other GHG emissions at farm scale

3. Feeding: lipids

CH_4 and milk

Martin et al 2007



Linear decrease of methanogenesis

Microbes numbers and VFA

Mosoni et al 2008

	H2-producers		H2-utilizers	VFA
	Protozoa	Cellulolytic bacteria	Archaea methanogens	C3
1h pre feeding	→	→	→	→
3h post feeding	↘	Not determined	Not determined	→

Before feeding : no modification

After feeding : protozoa decrease and ??

- decrease H_2 production and methanogenesis
- post-prandial changes in hydrolytic and methanogenic microorganisms

- dose > 6% : negative effect on DMI and digestion process
- nature : PUFA = MCFA Machmüller et al 2003
- long term effect ??

Methane mitigation is possible

Feeding: most developed

Biotechnologies and additives: promising

RESEARCH

- Combination between strategies

APPLICATION

- Safety for the animal and the consumer
- Long term sustainability
- Cost
- Total net emissions of GHG at animal and farm scale

Thank you for your attention