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Greenhouse gases emissions in high yielding cows

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1. The problem of greenhouse gases and ruminants

Mechanisms of methanogenesis

Contribution of livestock to global warming in France

(CITEPA, 2004)

	Million T CO_2-equivalent	
Transports	**149**	
Energy	**72**	
Industry	**111**	
Waste treatment	**14**	
Domestic use, services	**102**	
Agriculture	**108**	
Crops	**50**	
Livestock	**48**	**i.e. 9%**
Energy for agriculture	**10**	

Don't forget : pastures store CO_2

Why figures of the FAO report (global contribution of livestock = 18%) are so high?

→ **The proportion of livestock farming in total emissions is higher in southern countries**

and especially…

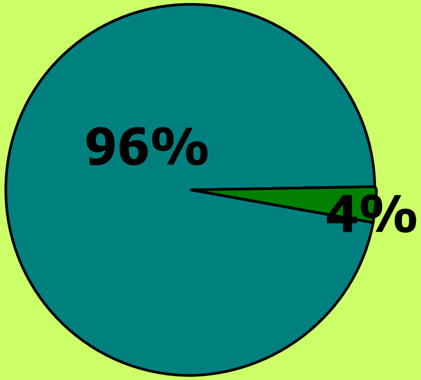
→ **The FAO report takes into account all emissions related to farming activities, i.e. those of crops for animal feeding, energy use in the farm, etc; it includes a part of emissions previously attributed to transport or industry sectors**

→ **The FAO report takes into account the change in land use and thus deforestation, including the difference in carbon sink between forest and pastures or crops**

How to decrease GHG emission by livestock ?

Decrease methane production

Is efficient because of its short life in the atmosphere
(10 y vs 100 y for carbon dioxide and 120 y for nitrous oxide)

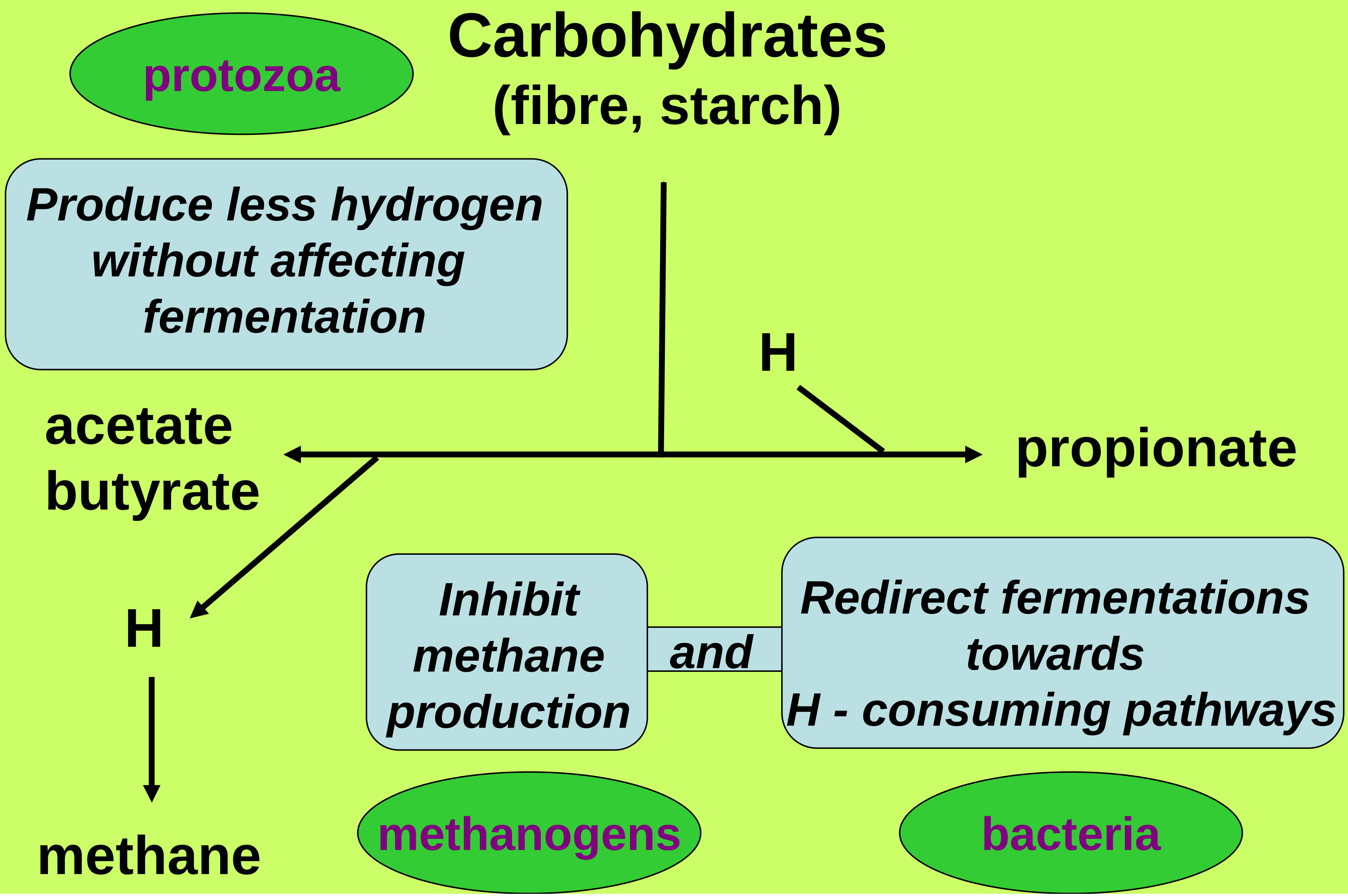


Methane emissions by ruminants
represent 3 to 5%
of total global warming

Decrease nitrous oxide production

Decrease carbon dioxide production

How to decrease methane emissions ?



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2. Mitigation through feeding

Additives and biotechnologies
Increasing feed intake and concentrates
Lipid supply

Additives

	Target	Efficiency and possible use
Antibiotics	Cellulolytic bacteria	Efficient but forbidden in the EU
Chemicals (chloroform,..)	Methanogens	In vitro effect, often toxic

Not applicable

Plant extracts	Methanogens Protozoa Bacteria	In vitro effect
Organic acids	Substrate effect Bacteria	High amount requested, acidity, cost

Further research needed.
Could be used in the short term

Biotechnology

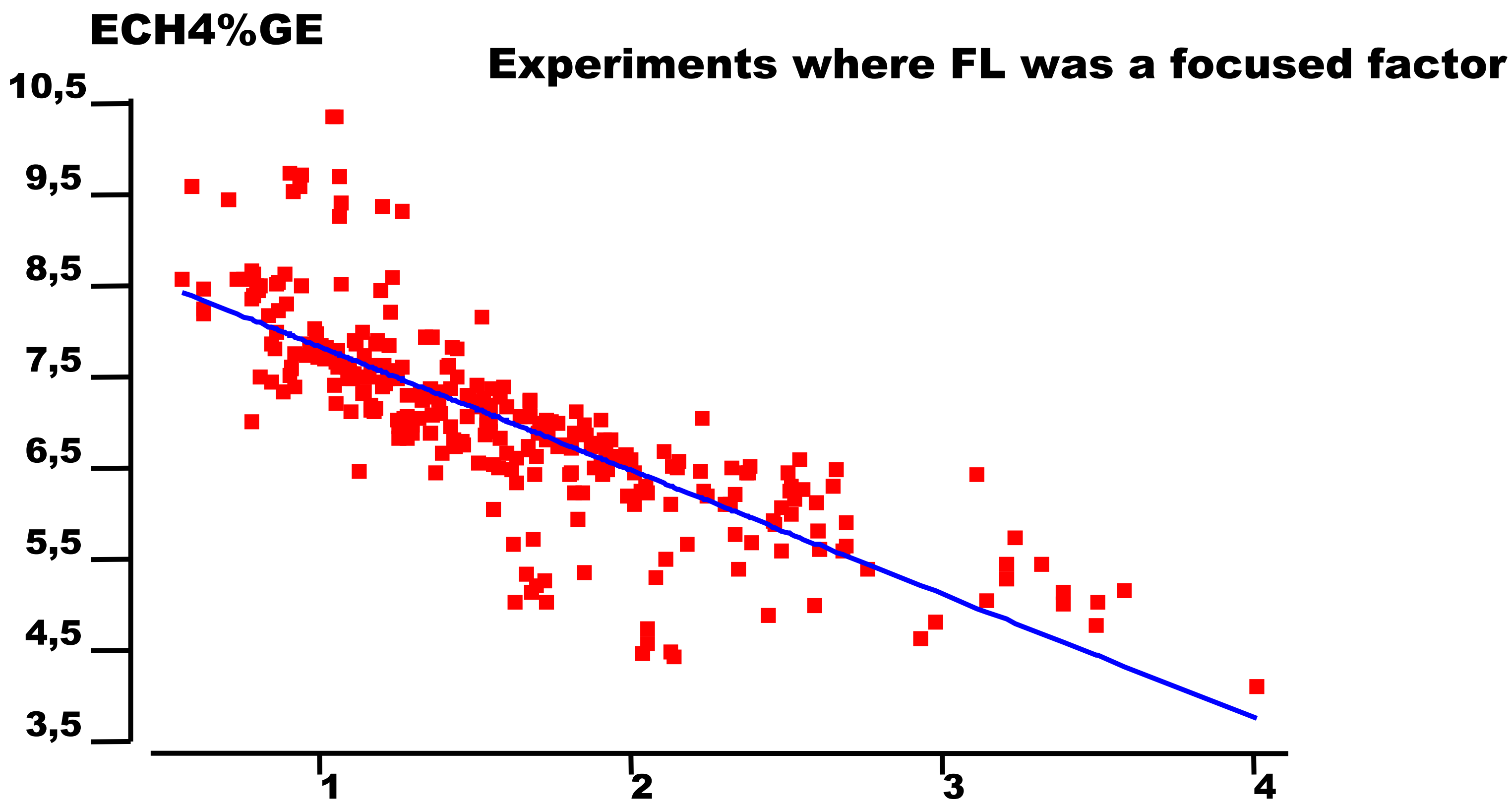
	Target	Efficiency and possible use
Removing protozoa	Protozoa	Efficient; mode of defaunation to be found
Adding yeast	?	In vitro effect

Additional research needed.
Could be used in the short term

Adding acetogens	Methanogens	In vitro effect of kangaroo bacteria
Vaccination	Methanogens	Effect to be confirmed
Antibodies	Methanogens	In vitro transient effect
Bacteriocins	Methanogens	In vitro effect

Long and complex research needed.
Might be used in the long term

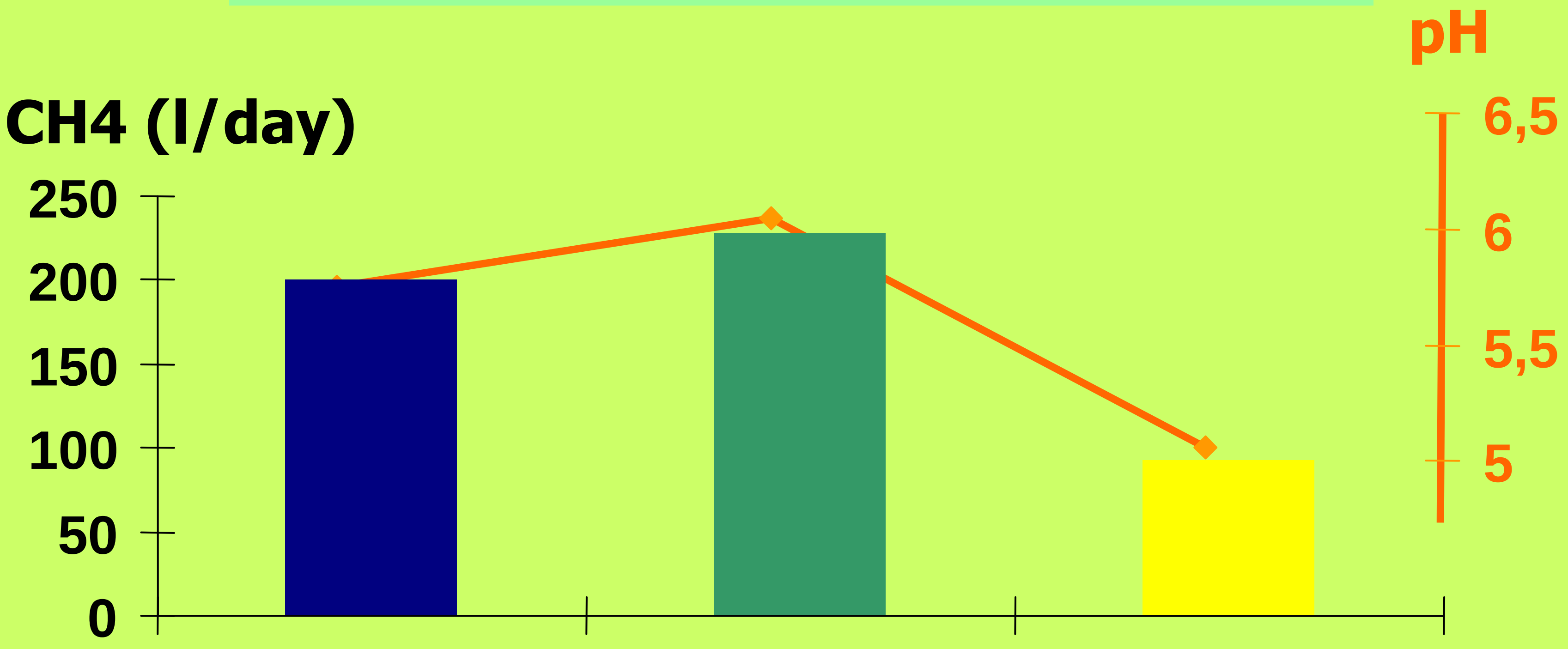
Feeding high- producing cows :
feeding level



Sauvant and Giger-Reverdin, 2007

The decrease in energy of methane (% gross energy) when feeding level increases is due to the decrease in retention time in the rumen

Feeding high- producing cows :
proportion of concentrates (1)

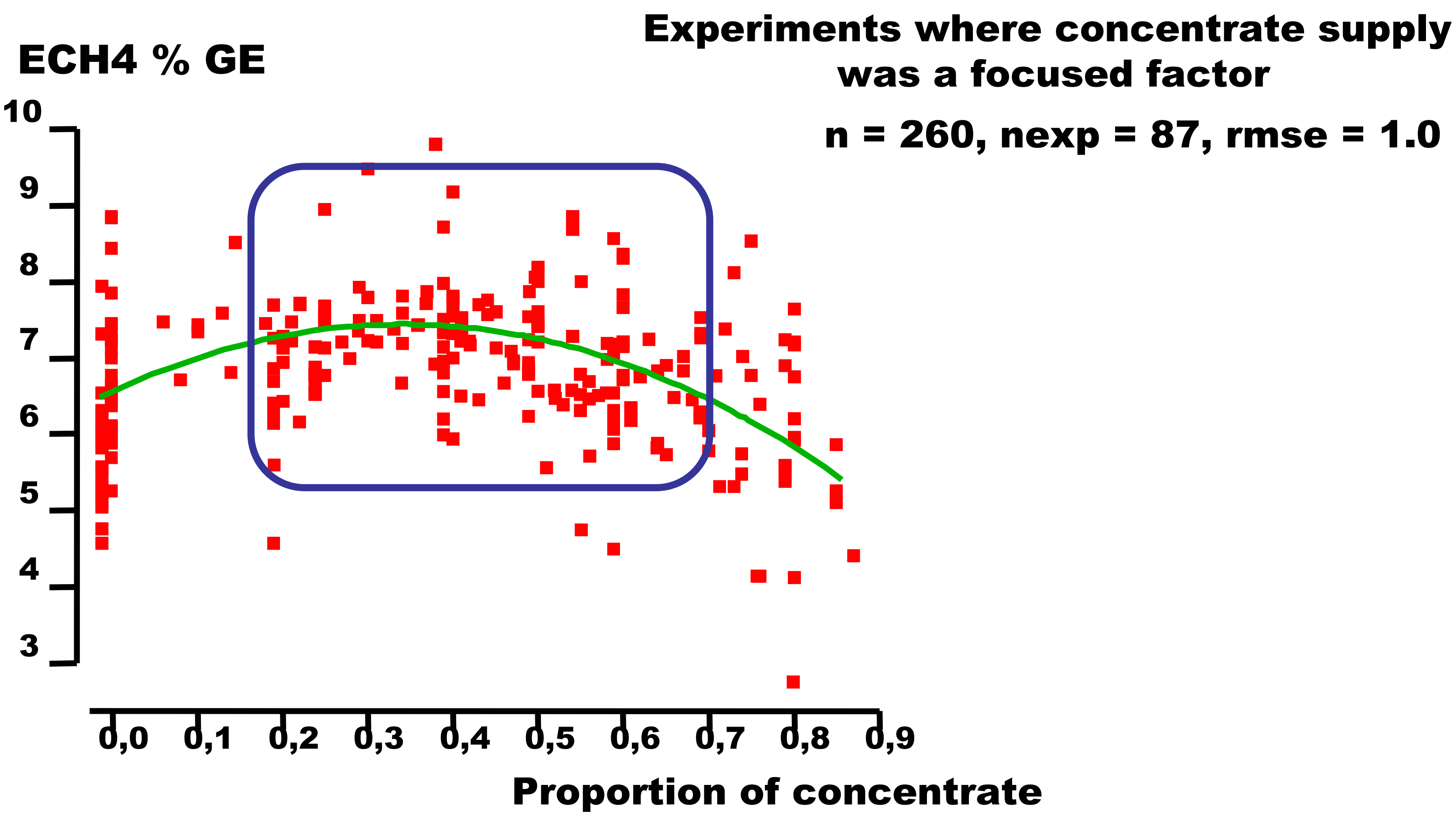


	50% hay 50% conc.	62% maize silage	90% concentrate
CH4 (% E intake)	7.2	6.6	2.5

Martin et al, 2007

<u>High-concentrate diets</u> decrease methanogenesis : increase in propionate, decrease in protozoa and methanogens, related to low pH

Feeding high- producing cows :
proportion of concentrates (2)



Sauvant and Giger-Reverdin, 2007

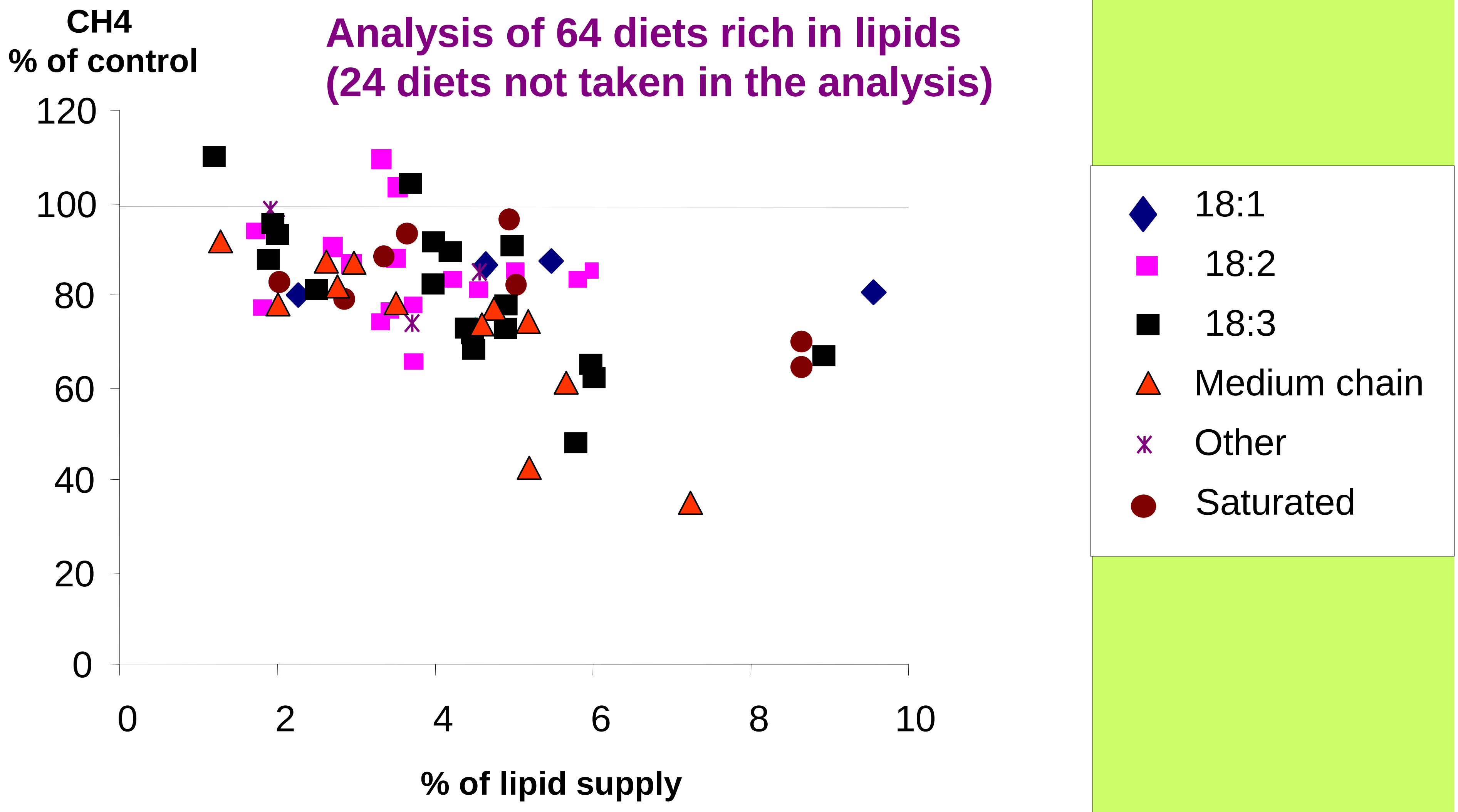
Feeding high- producing cows :
Nature of concentrates

Many experiments, few differences

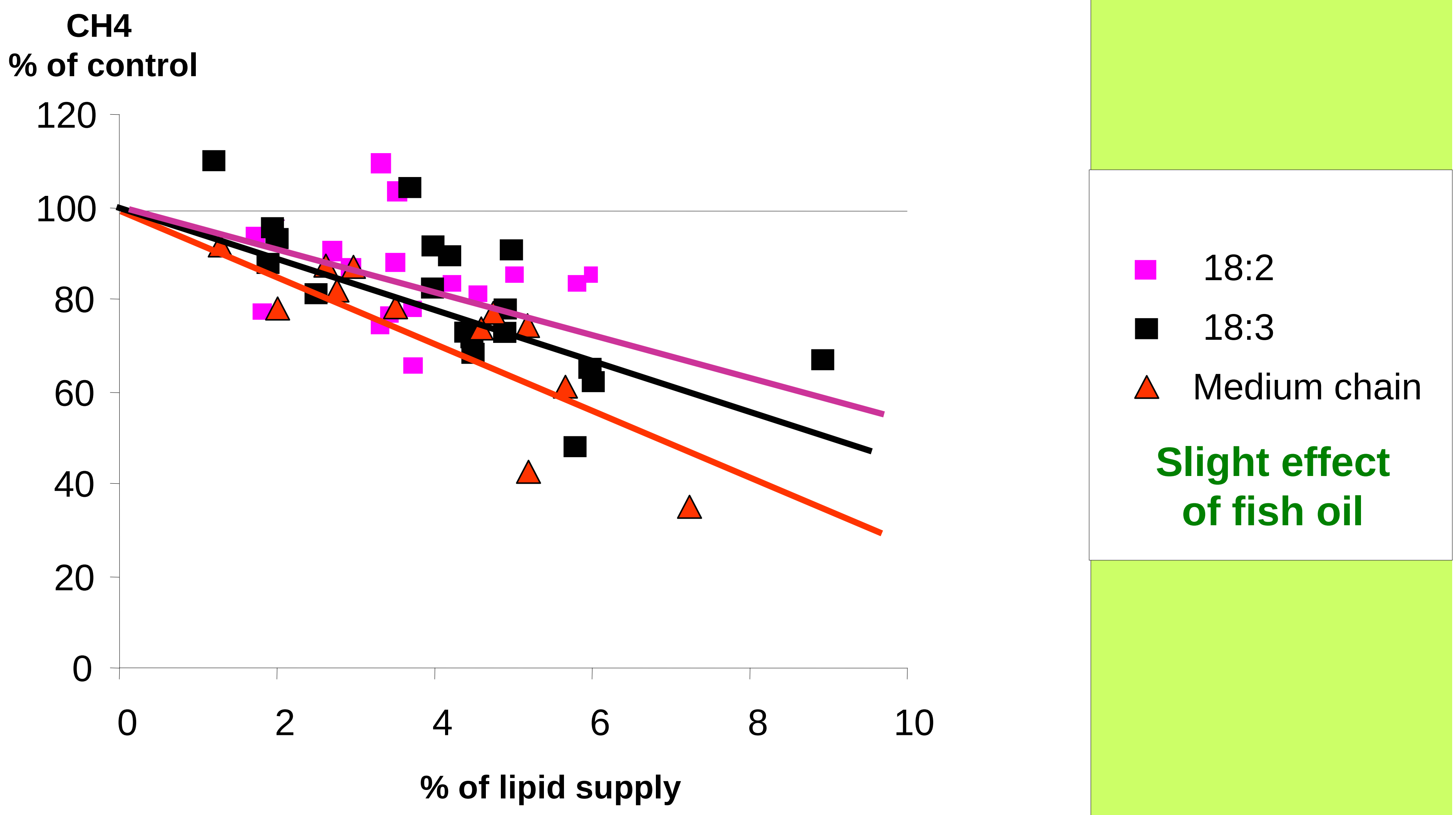
Lower for cereals than for by-products rich in fiber (orientation towards propionate, effect of pH) especially at high intake ***(Moe and Tyrrell, 1979, Boadi et al., 2004)***

Lower for maize than for barley (higher intestinal digestion ?)

Effect of lipids : available literature



Effect of lipids : available literature



Slight effect of fish oil

Mode of action of lipids

Substitution of cereals degraded in VFA
by lipids undegraded in the rumen

Action

on methanogens	**Medium-chain FA**	***Machmuller et al 2003*** ***review by Machmuller 2006***
on protozoa	**Medium-chain FA** **18:3**	***Review by*** ***Doreau and Ferlay, 1995***
on cellulolytic bacteria	**18:2** **18:3** **Medium-chain FA ?**	***Nagaraja et al., 1997*** ***Maia et al., 2007***

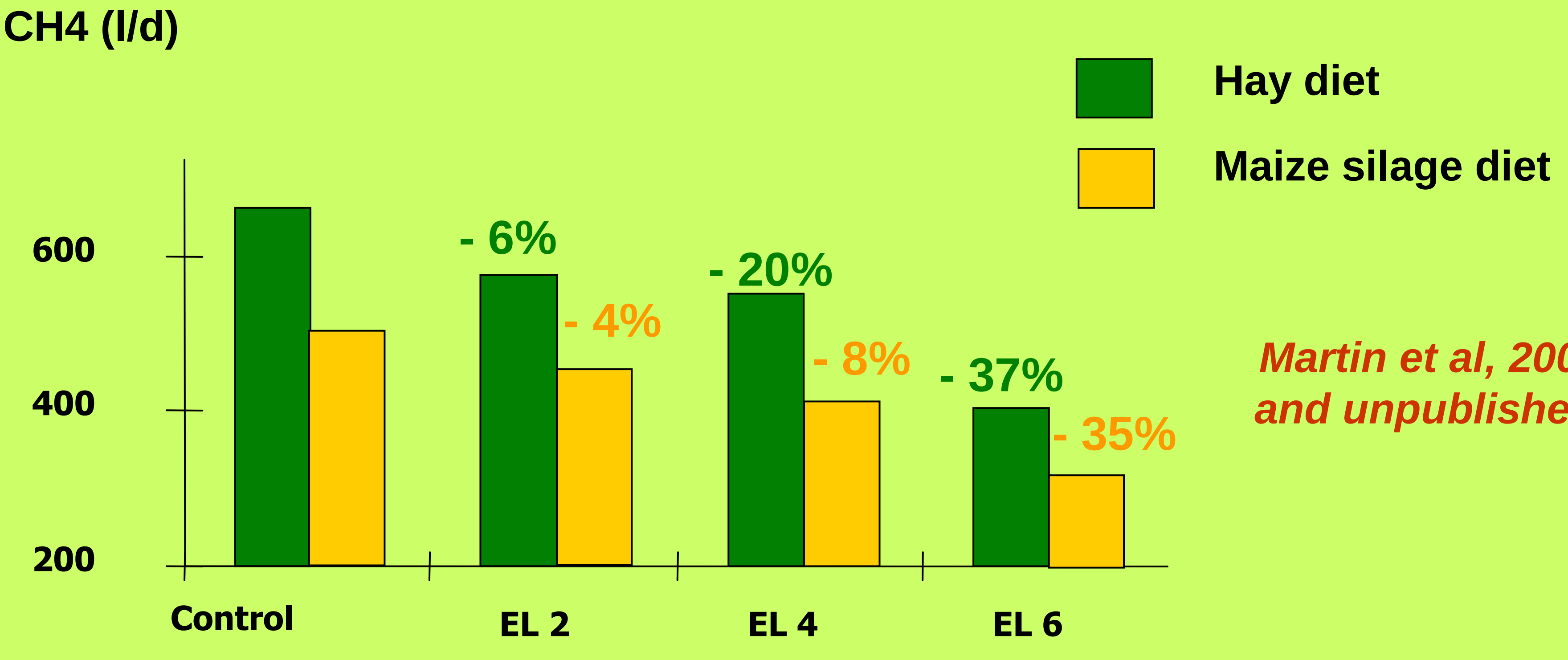
~~Competition for H use between FA hydrogenation and methanogenesis~~

Effect of lipids : some questions

Is the effect permanent ?

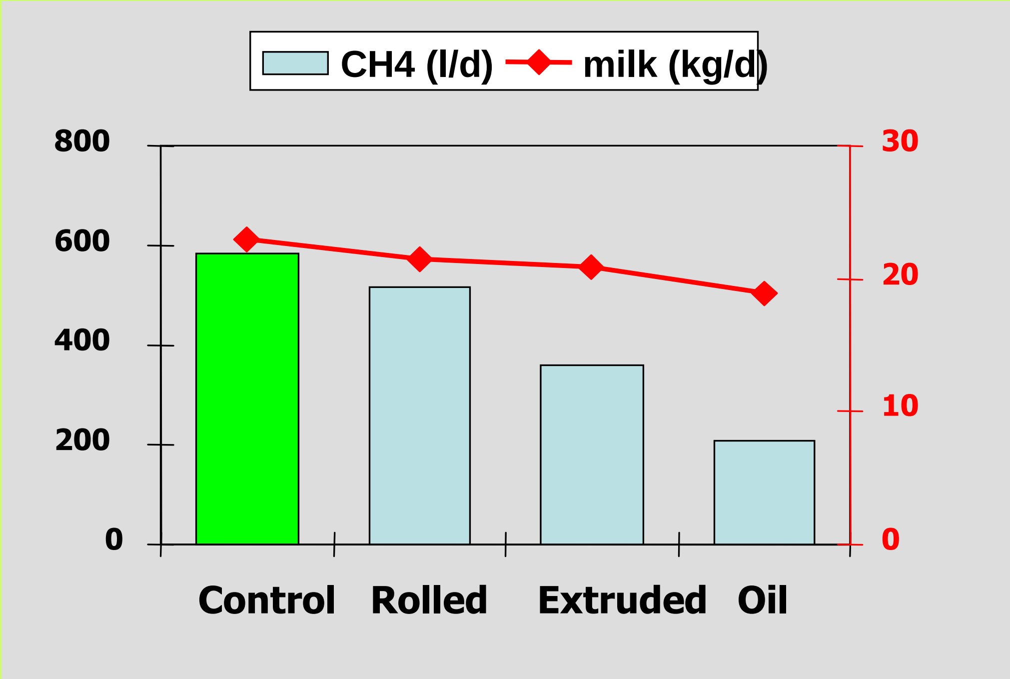
One experiment suggests that the effect of lipids is transient ***(Woodward et al., 2006)***

Does it work with any basal diet ?



Martin et al, 2007 and unpublished

Lipids – form of supply



Martin et al, 2008

CH4 (l/kg milk)	-12%	-38%	-64%

The reverse has been observed with sunflower seed or oil
(Beauchemin et al., 2007)

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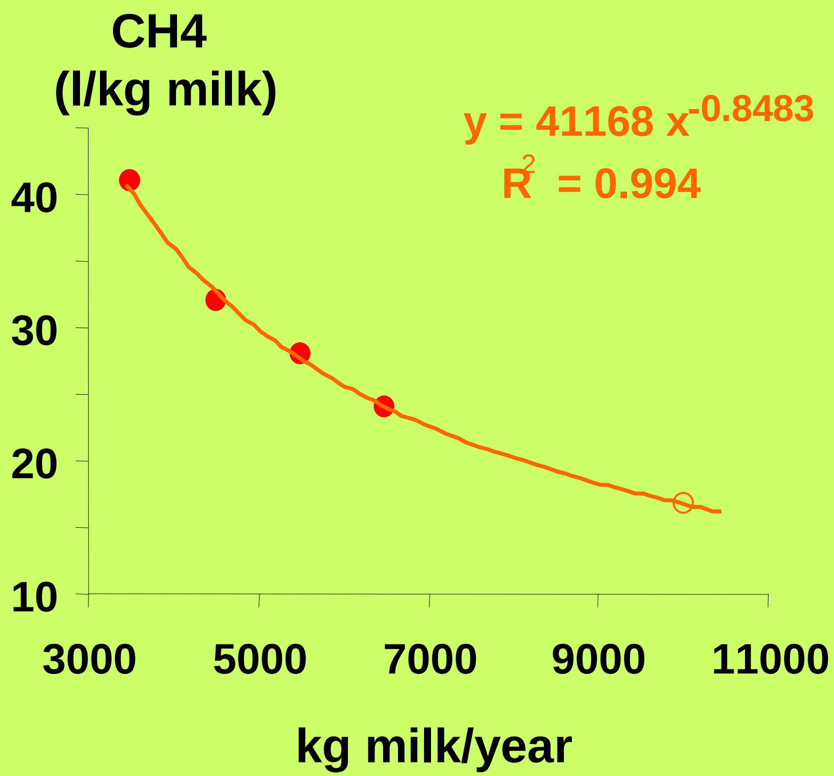
3. Individual variations and genetic factors

General relationship between CH4 and milk yield



adapted from Vermorel (1995) and Kirchgessner et al (1994)

High-producing cows eat:

- **more**
- **a diet higher in concentrates**

- **and the part of maintenance is lower**

Importance of non-productive periods

Calculations according to INRA Tables, 2007

	% of non-productive requirements	
	Year scale	**Career scale**
Temperate countries		
700-kg cow, 50 kg milk/d 1st calving 2 yr, 2.5 lactations calving interval 410 d	**33**	**47**
700-kg cow, 25 kg milk/d 1st calving 2.5 yr, 4 lactations calving interval 380 d	**47**	**59**

The difference in % of months in milk may be lower ***(Garnsworthy, 2004)***

	% of non-productive requirements	
	Year scale	**Career scale**
Tropical countries Extreme case of the lowest producing cows		
400-kg cow, 2 kg milk/d 1st calving 3.5 yr, 8 lactations calving interval 500 d	**87**	**90**

Genetics (1)

→ **No effect of milk potential independently of the diet**

Methane emission does not vary with cow milk index
(Lovett et al. 2006)

→ **No persistency of individual variations**

Trials are not consistent but generally show the absence of repeatability of methane production with time for a same diet
(Goopy and Hegarty, 2004, Vlaming et al., 2008 for 2 diets, Munger and Kreuzer 2008 for 3 breeds)

→ **Relation with digestive processes**

Differences in feed retention time in the rumen for a same intake may explain 30% of individual variations
(Pinares-Patino et al., 2003)

Differences in microbial ecosystem ?

Genetics (2)

→ **Selection based on global feed efficiency**

Animals which eat less for a same production
(low residual feed intake)

Example with steers ***(Hegarty et al., 2007)***

	Low RFI	High RFI
ADG, kg/d	1.1	1.3
DMI, kg/d	8.4	14.1
Methane, g/kg ADG	132	173

A low RFI is related to:

- **a high digestibility**
- **a low heat production**

(Nkrumah et al., 2006)

Selection for high efficiency is a promising way for a sustainable production

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4. Total emission of greenhouse gases

High *vs* low productivity

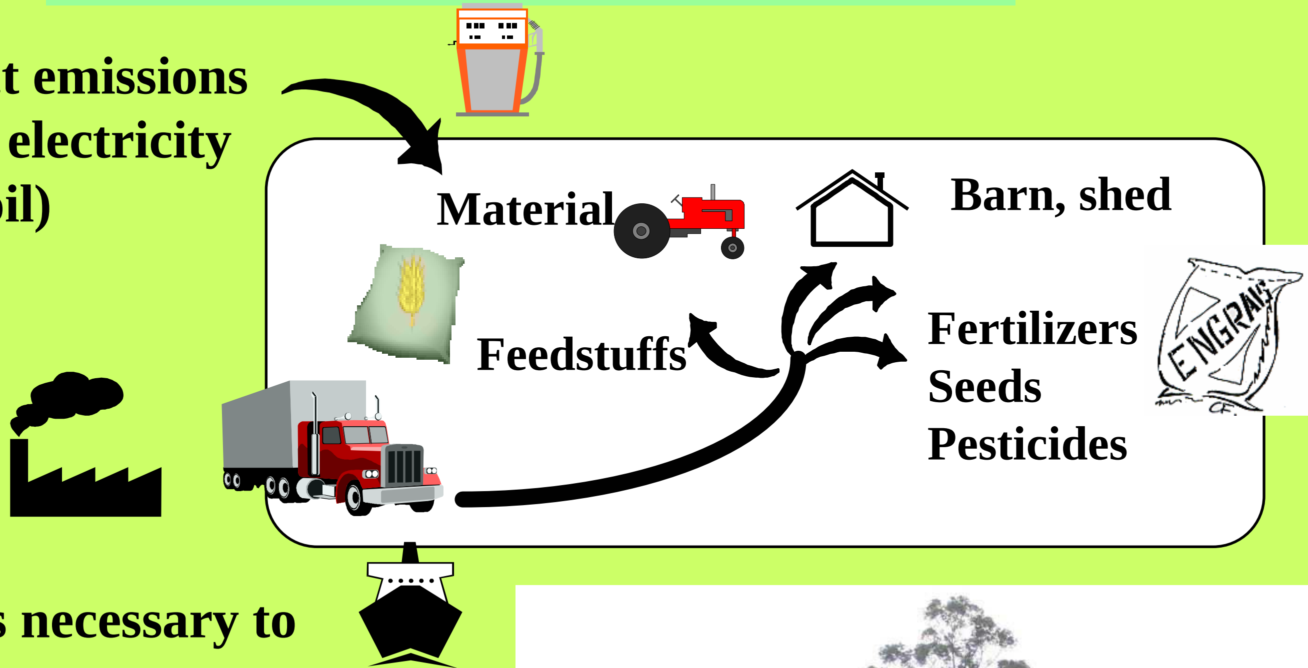
Emission of greenhouse gases
due to ruminants at farm level (in eq. CO_2)

Warming power on a 100-yr basis: CO_2 = 1 CH_4 = 21 N_2O = 310

Methane	**45 – 60%**
Enteric Excreta (mainly manure)	
Nitrous oxide	**25 – 35%**
Excreta (mainly on pasture) N fertilisers Indirect emissions due to input	
Carbon dioxide	**10 – 25%**
Fuel Indirect emissions due to input	

Carbon dioxide emissions

Direct emissions (fuel, electricity gas, oil)



Indirect emissions necessary to obtain inputs (extraction or harvesting, processing, transport)

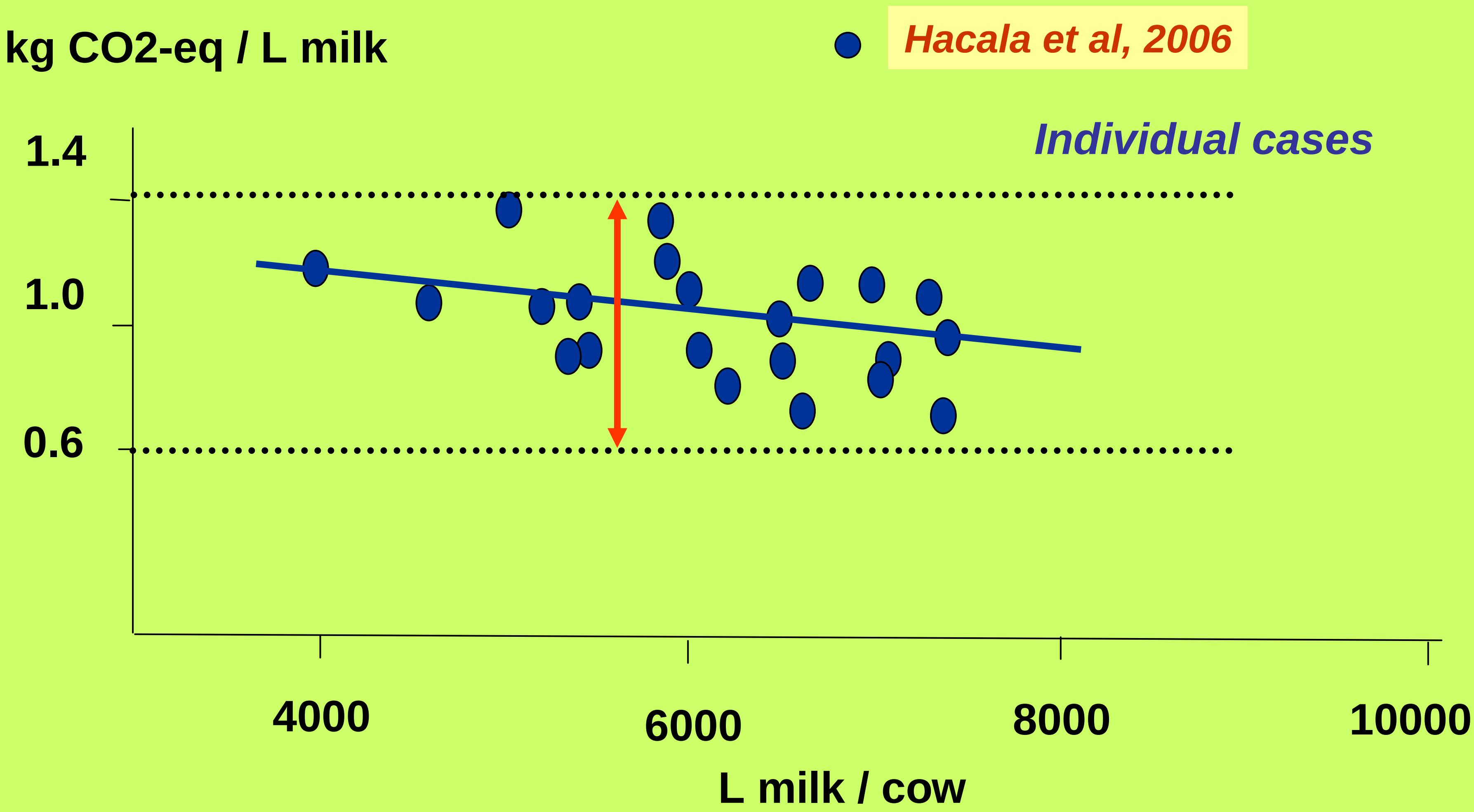
CH_4 balance at farm level

2 extreme systems	New Zealand	California	
	Pasture only	50% forage 50% concentrate	
Milk (kg / cow / yr)	3400	9000	
CH4 enteric (g / kg milk)	27	17	- 37%
CH4 excreta / manure (g / kg milk)	3	18	
CH4 total (g / kg milk)	30	35	

Johnson et al (2000)

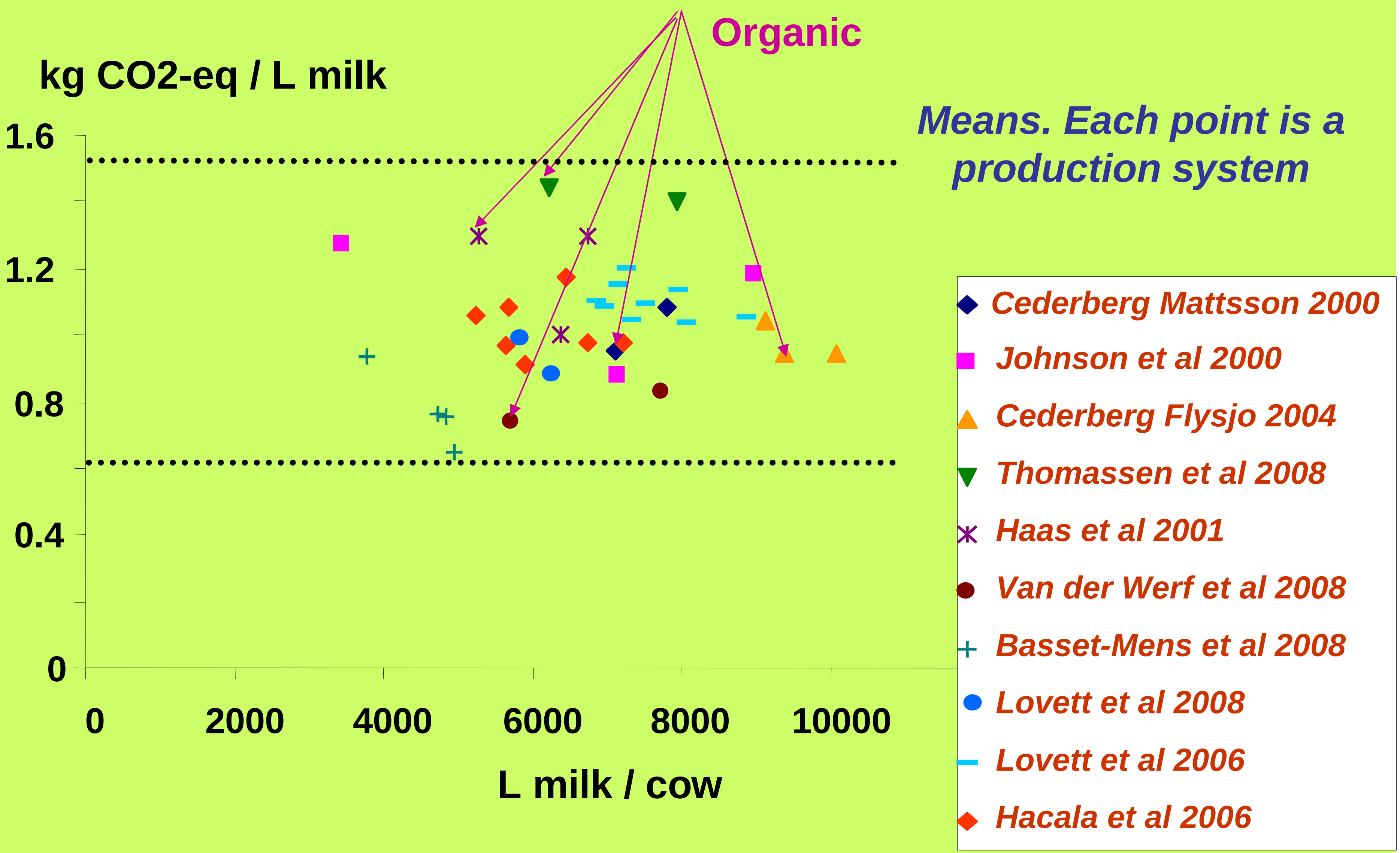
Few differences between these two systems

GHG balance at farm level



No clear effect of cow productivity
Large variation for a same productivity

GHG balance at farm level



The use of BST

Johnson et al. (1992)

BST → **- 11% cows**
- 9% feed
→ **- 9% CH_4**
- 9% fossil fuel
- 8% manure N

Capper et al. (2008)

BST → **-11% cows**
- 9% feed
→ **- 7% CH_4**
- 9% CO_2
- 10% N_2O

BST use leads to an increase in milk yield
BST effects on methane are due to dilution of maintenance requirement

The decrease in N_2O and in CO_2 when intensification increases is not consistent with the literature

GHG emissions figures are difficult to interpret

→ **Emissions are calculated from general equations which are not always relevant, and from national statistics which are difficult to check**

→ **Differences between systems depend on the hypotheses on feeding systems taken by the author**
- **see BST example**
- **Concentrates produced on farm or coming from Brasil**

→ **Differences between systems depend on the reference: emissions per kg milk or emissions per ha**

Literature data show that within-system differences are higher than between-system differences

Global warming is only one component of the environmental evaluation of livestock

Global warming
Fossil energy consumption

Water consumption and quality (nitrates, pesticides)
Soil quality (heavy metals, pesticides, erosion, etc)
Air quality (acid deposition)

Land use
Livestock density at regional scale

Animal and vegetal biodiversity
Landscape preservation

… and environmental evaluation of livestock is only one of the components of sustainability

Economical results

Acceptance by the citizen

Social and cultural role of livestock

Society survival (tropics)


Thank you
Lorraine, France, August 2003