Reducing the Greenhouse Gas Emissions from Beef and Dairy Production: A Canadian Perspective

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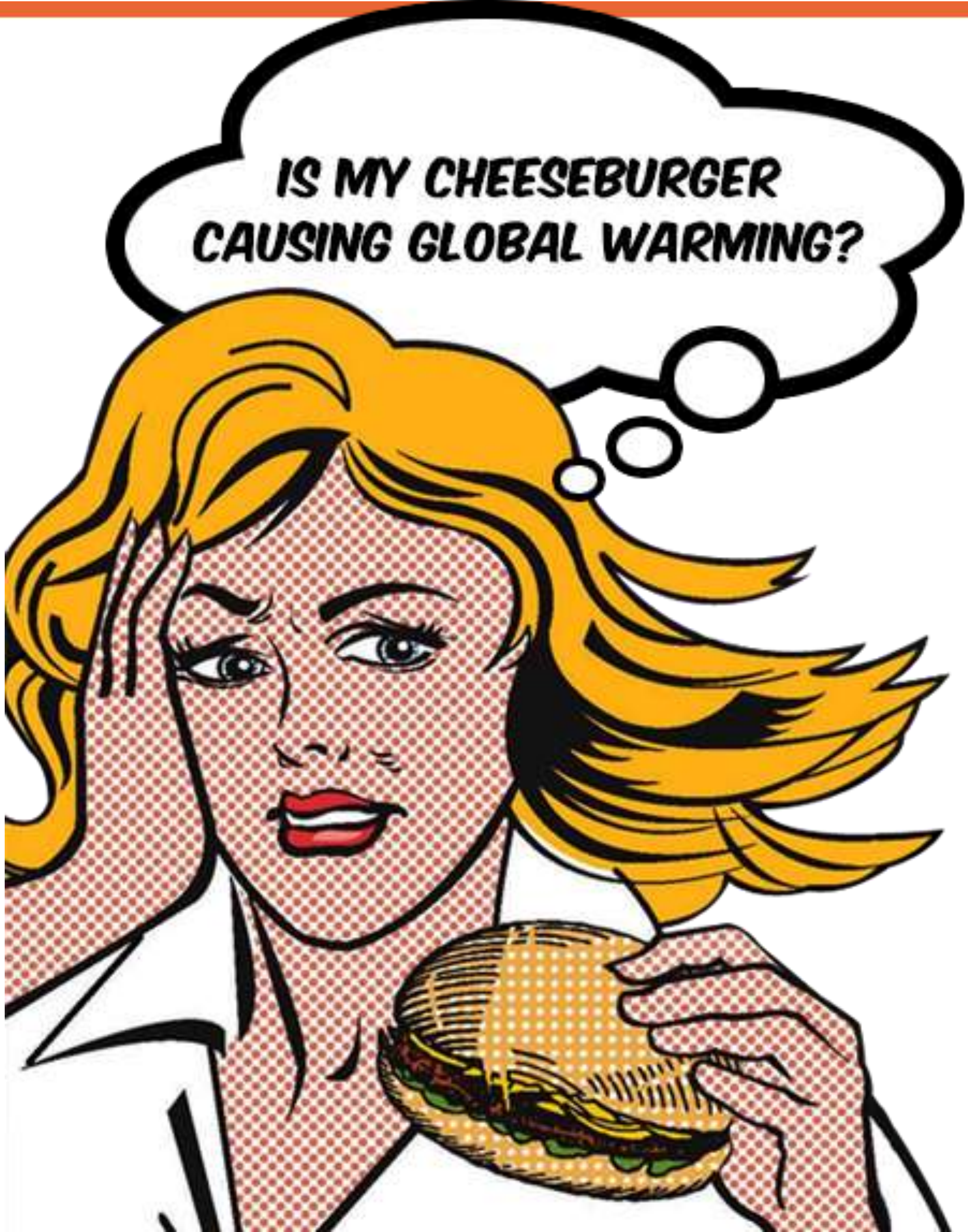
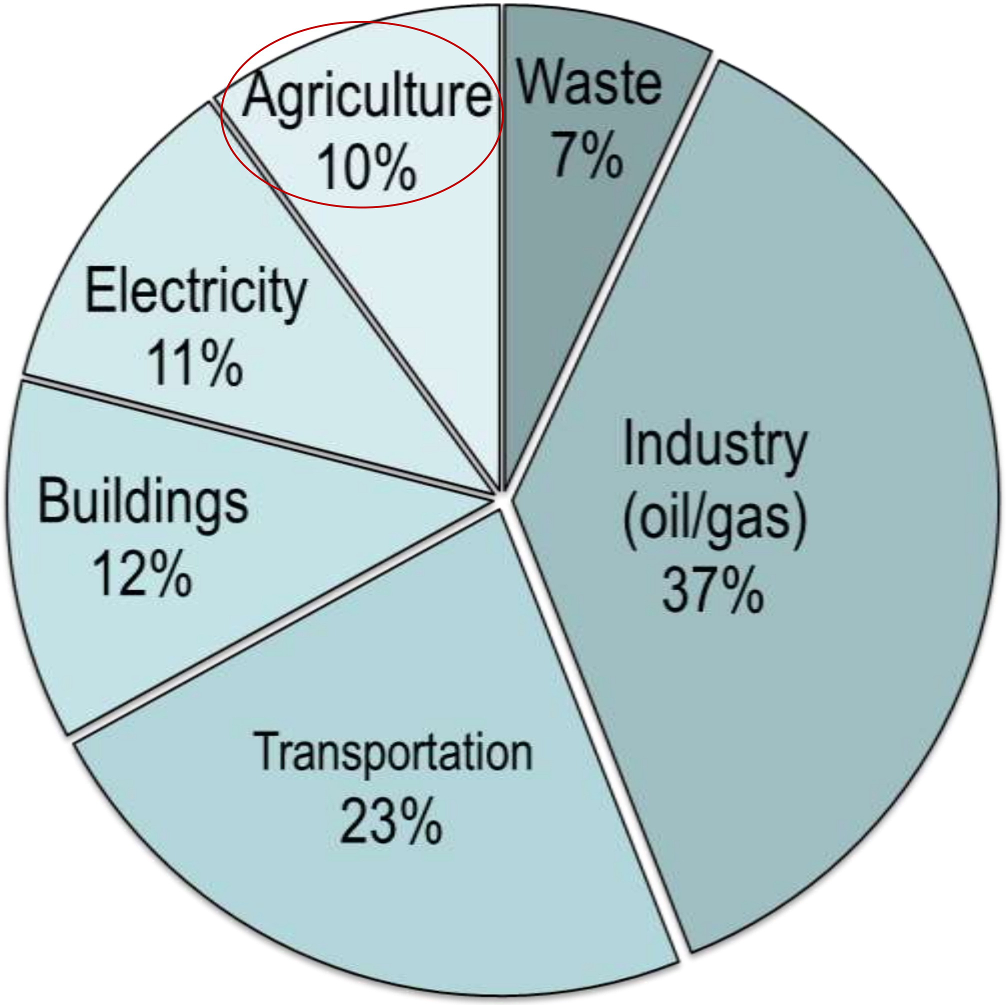

IS MY CHEESEBURGER CAUSING GLOBAL WARMING?

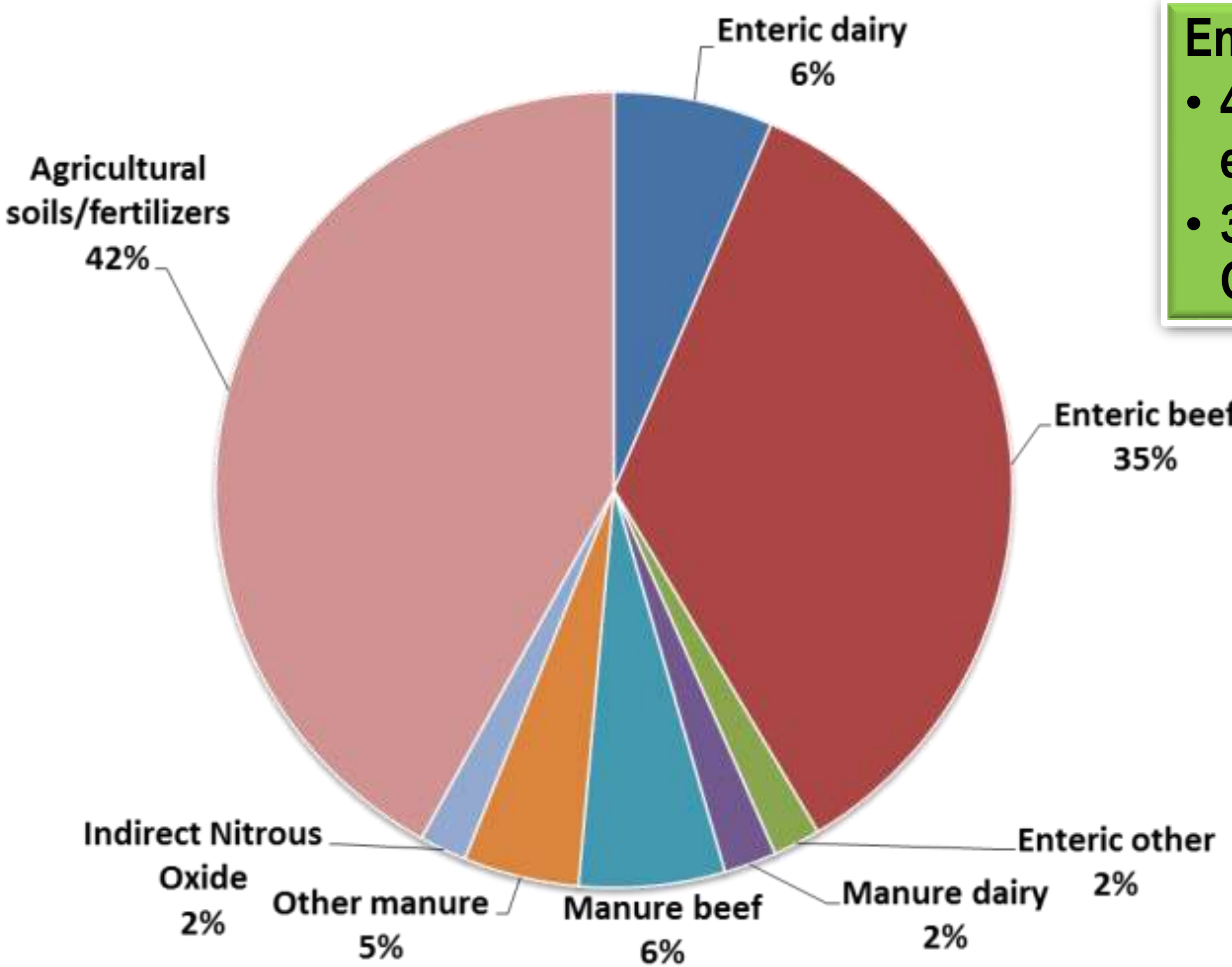
2014

- “51% of global GHGs are created by livestock”
  - Hollywood experts
- 14.5% (1/3 methane)
  - Scientific experts (FAO, 2013)

Canada's Emissions by Sector: 2014



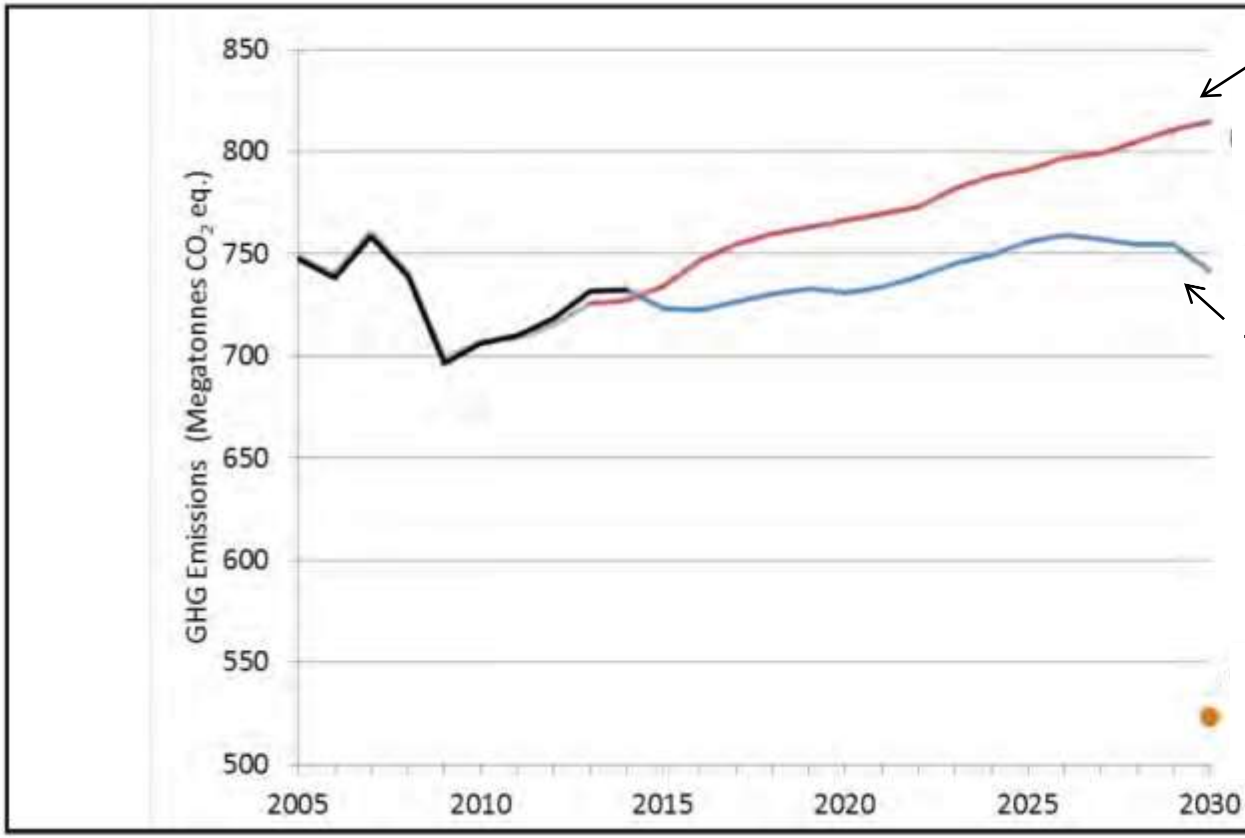
Canada's Agricultural Greenhouse Gas Emissions: 2013



Enteric methane =
- **43% of agricultural emissions**
- **3.5% of Canada's GHG emissions**

https://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=F60DB708-1

Canada's GHG Emissions Forecast to 2030



2015: Emissions forecast

Dec 2016: Revised forecast with lower oil and gas production due to lower price

Target of 30% below 2005 levels (523 Mt)

Pricing Carbon Pollution

Federal Policy: pricing carbon pollution by 2018

(Pan-Canadian Framework on Clean Growth and Climate Change)

Provincially implemented:

- British Columbia: carbon tax
- Ontario: cap and trade
- Quebec: cap and trade
- Alberta: hybrid system

2018 - $10/t
2019 - $20/t
2020 - $30/t
2021 - $40/t
2022 - $50/t

Approaches for the Agriculture Sector

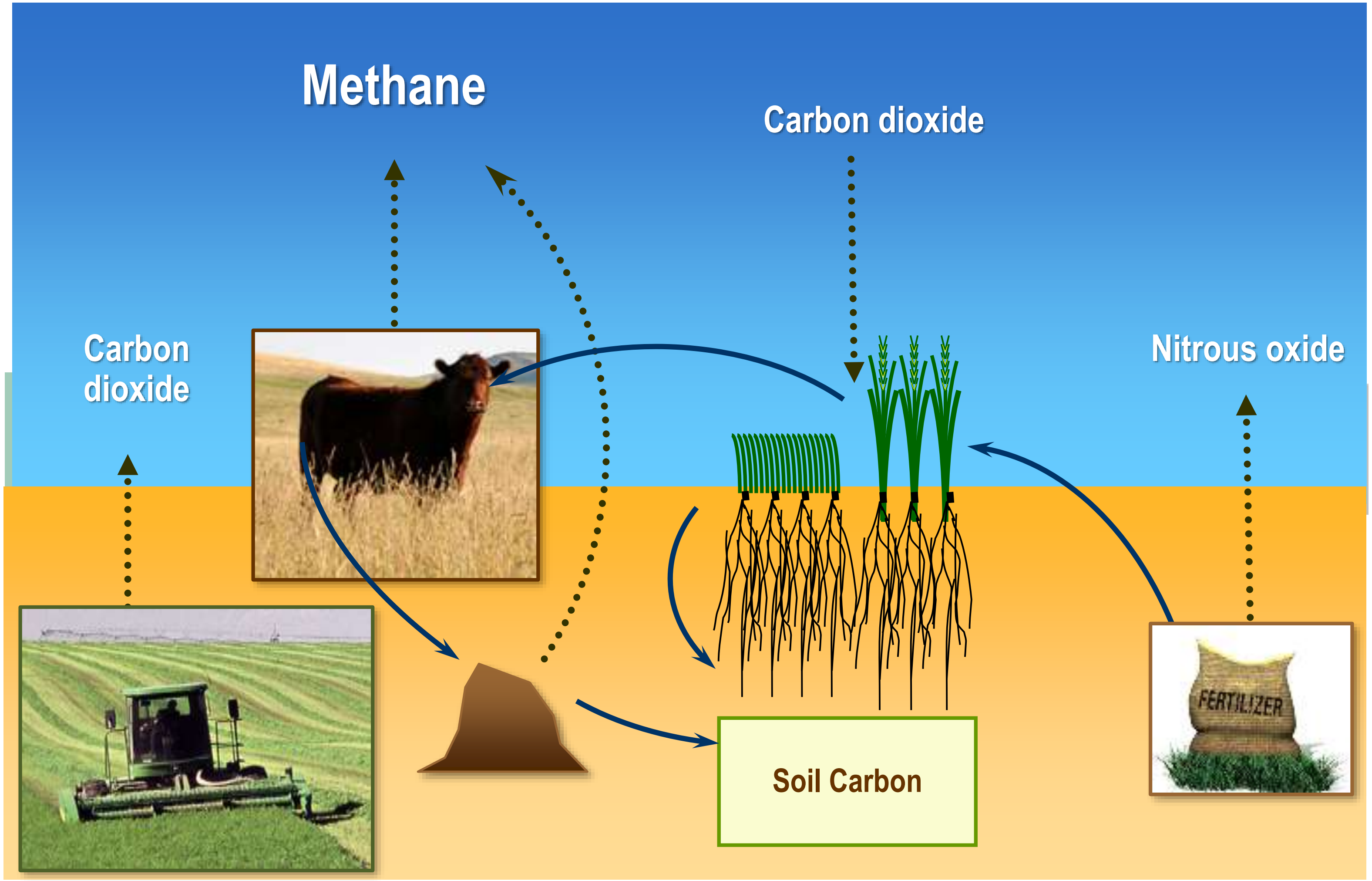
- Agricultural lands as "carbon sinks"
  - Promoting land management
  - Increasing perennial permanent cover
  - Zero-till farming
- No policy for enteric methane

Ruminants and Forage-based Diets

Beef: 80% forage diet

http://www.juliaepalmer.com/portfol

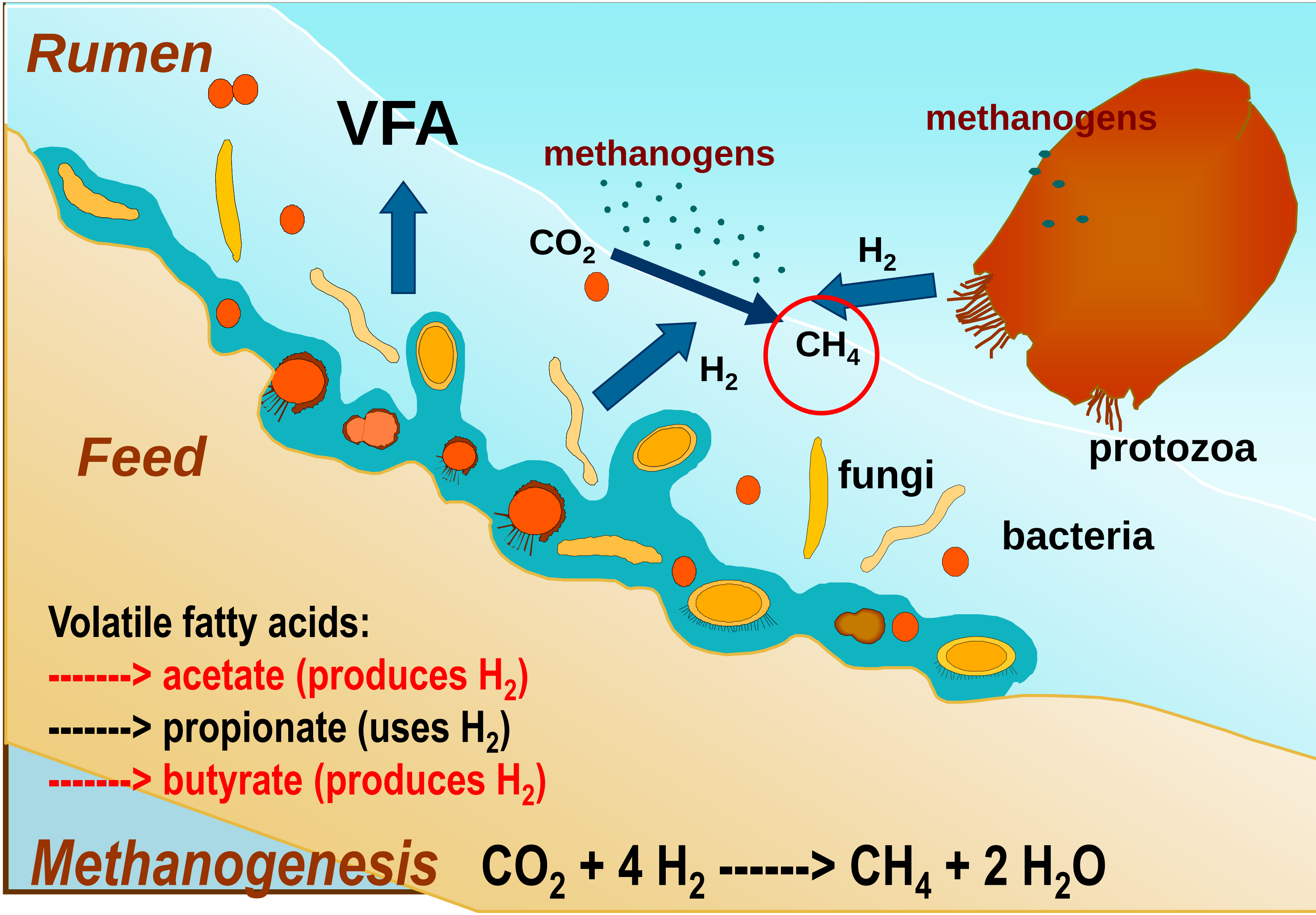
Dairy: 70% forage diet



Enteric methane

- 28-times more potent than CO_2
- 2 to 12% of energy intake

Methanogenesis in the Rumen



Volatile fatty acids:

-------> acetate (produces H_2)

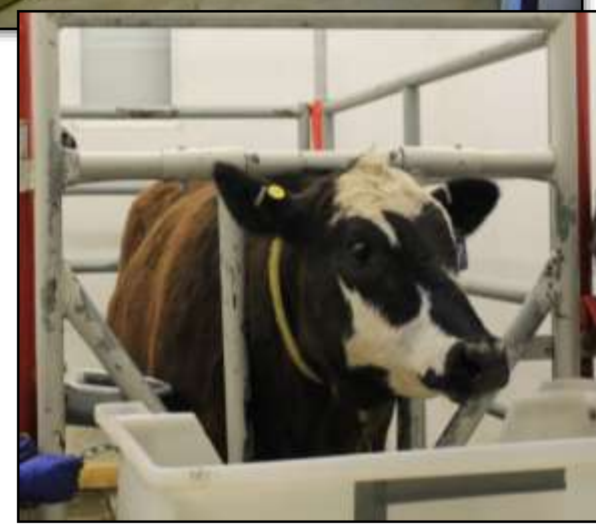
-------> propionate (uses H_2)

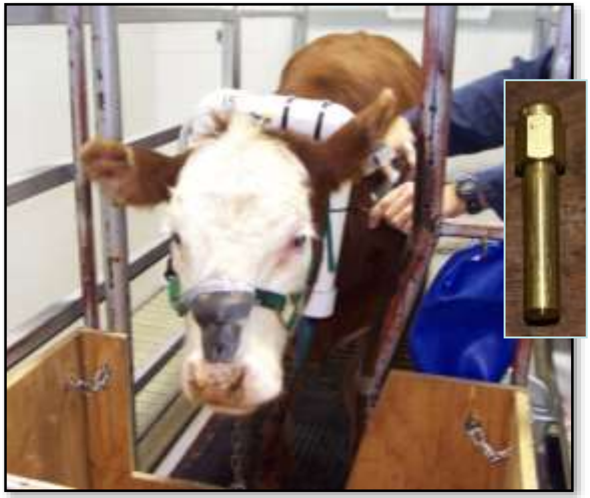
-------> butyrate (produces H_2)

Methanogenesis $CO_2 + 4\ H_2 \text{ ------> } CH_4 + 2\ H_2O$

Measuring Methane Emissions

Respiration Chambers





Controlled release of trace gas in the rumen

Tracer Gas Technique

GreenFeed System

Is there a way to decrease enteric methane production without decreasing productivity?

↓ Methane production

↑

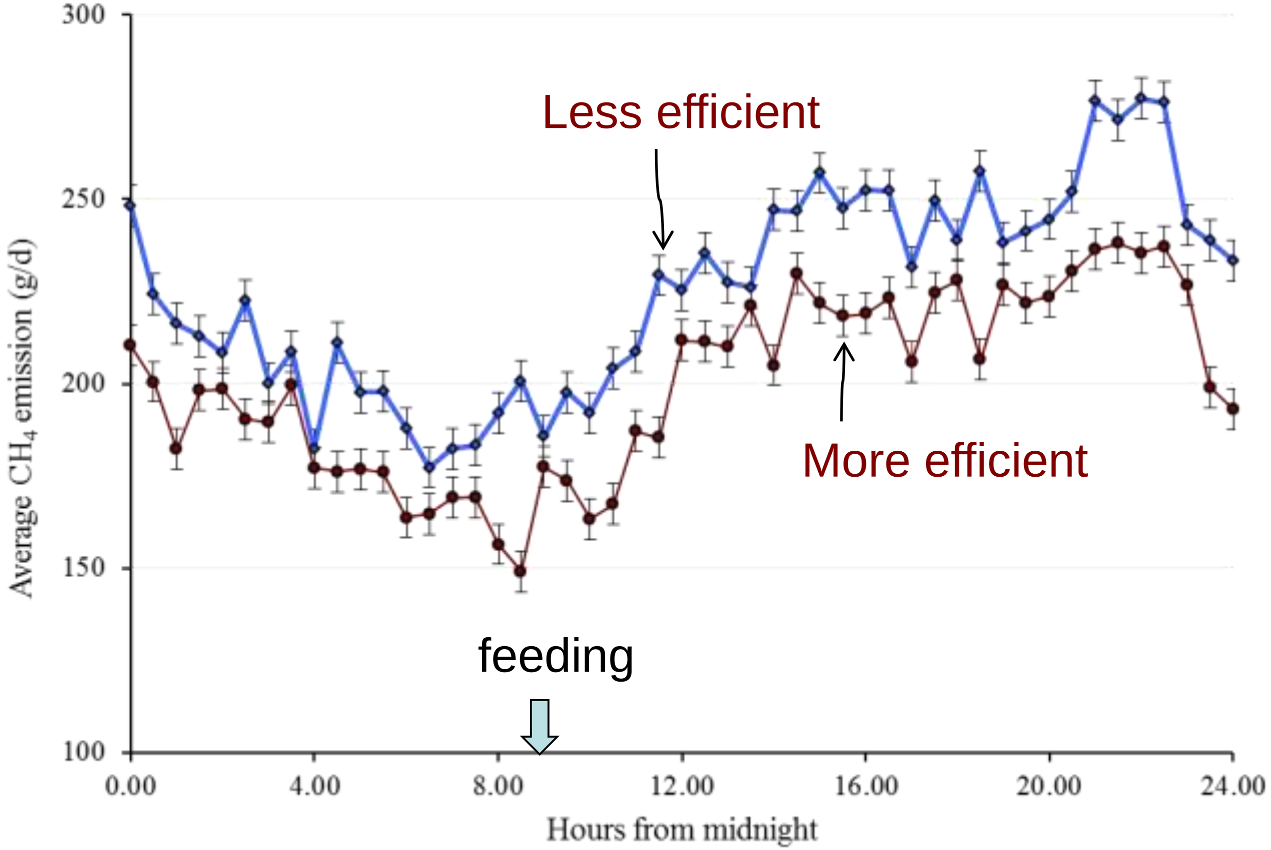
Animal genetics and management

- Animal efficiency
- Fewer days on feed
- Gain to feed ratio

Enteric methane emissions from high and low efficiency beef replacement heifers (GreenFeed system)

9% less CH_4 (g/d)

0 difference (g/kg DMI)



Alemu et al. 2017 J. Anim. Sci. 95:3727-3737

Is there a way to decrease enteric methane production without decreasing productivity?

↓ Methane production

Diet composition

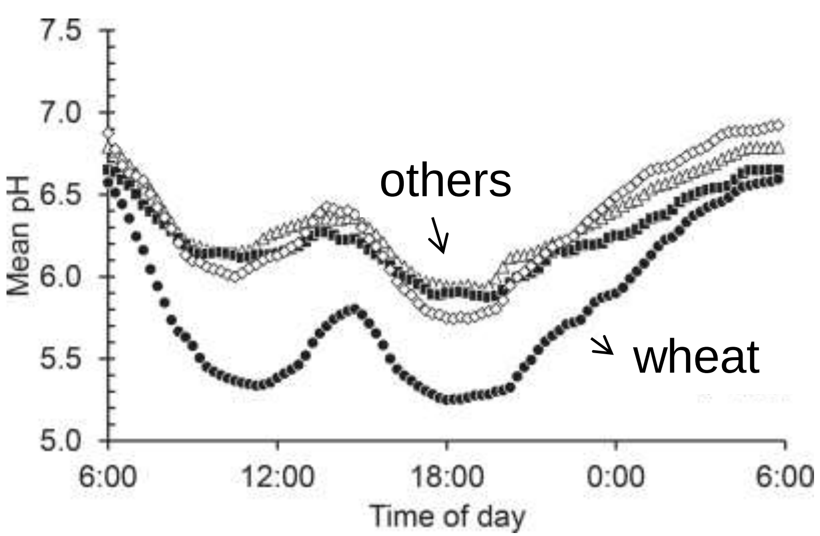
- Grain
- Lipids
- Forage quality
- Legumes
- Pasture management

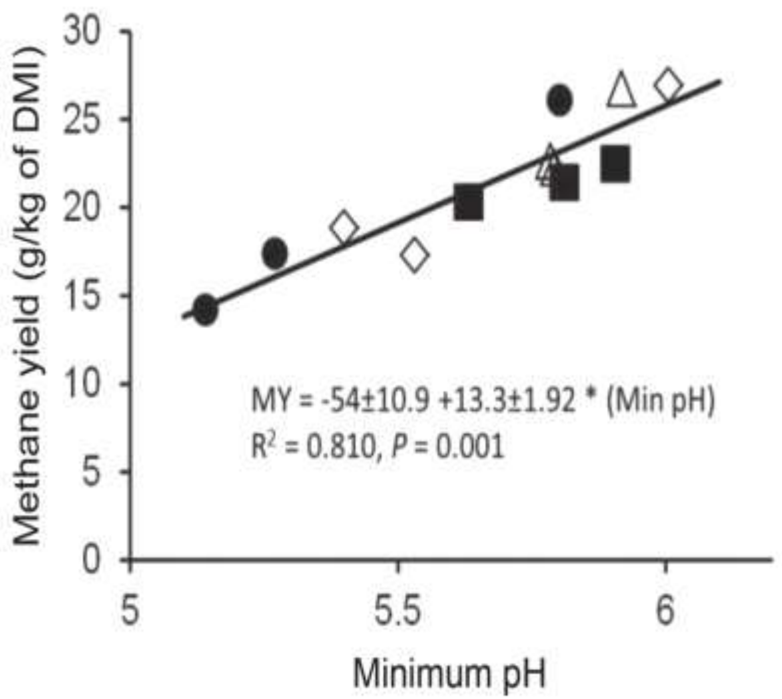
Animal genetics and management

- Efficiency
- Fewer days on feed
- Gain to feed ratio

Feeding wheat to dairy cows lowered methane emissions in a short term study

- Moate et al. 2017
  - 35-d study, 32 cows (8/trt)
  - Dry rolled corn, wheat, barley, and double rolled barley
  - Cows fed wheat had 30% lower methane (g/kg DMI)





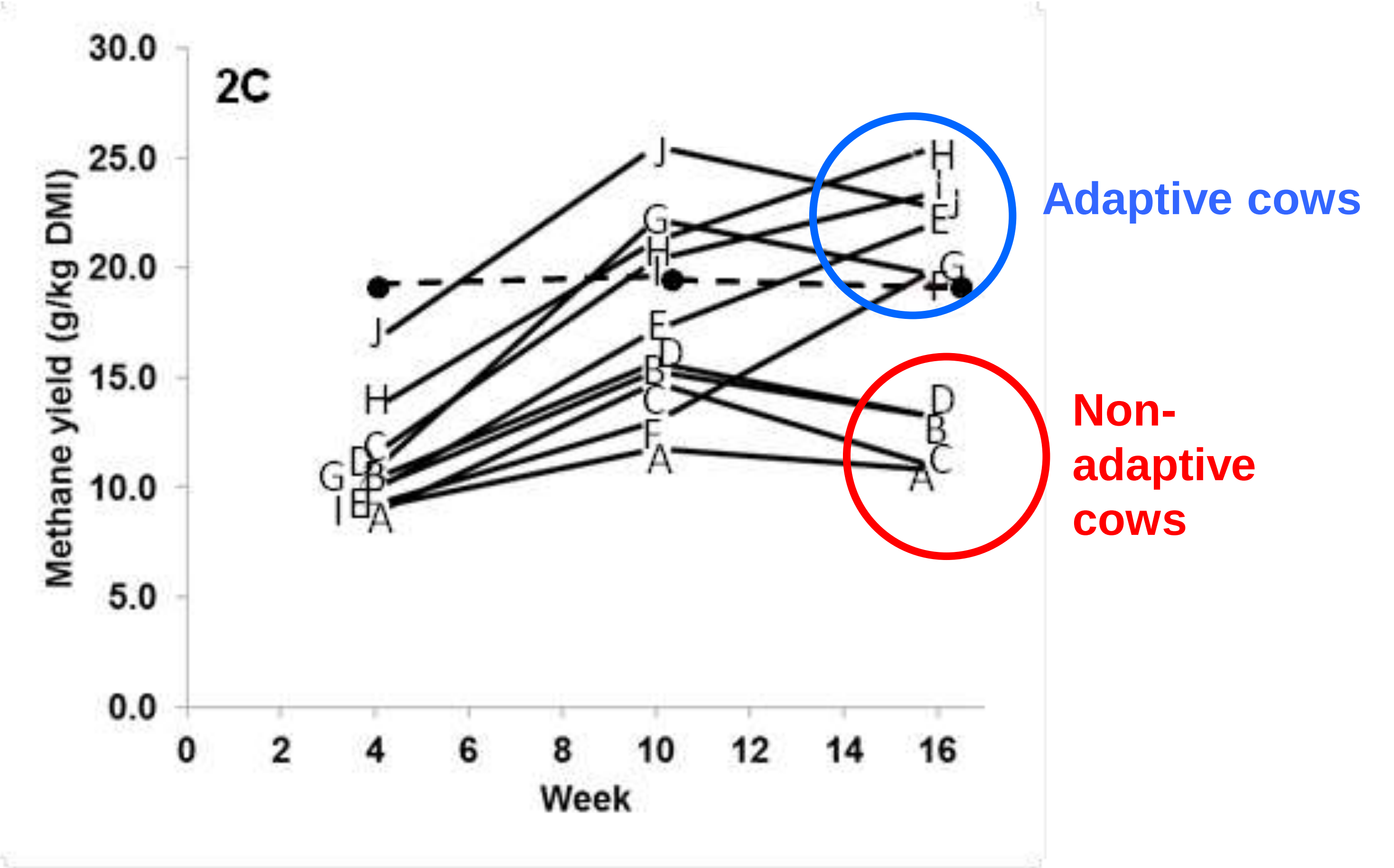
Longer term study: Persistency of Methane Reduction with Wheat

Parameter	Week 4		Week 10		Week 16		*P*-value		
	CRN	WHT	CRN	WHT	CRN	WHT	TRT	Week	TRT × Week
CH_4, g/d	404^{b}	233^{a}	433^{b}	375^{b}	410^{b}	409^{b}	0.025	0.001	0.001
CH_4, g/kg DMI	18.4^{b}	11.2^{a}	19.3^{b}	17.9^{b}	18.3^{b}	18.3^{b}	0.040	0.001	0.001
CH_4, % GE intake	5.68^{b}	3.28^{a}	5.97^{b}	5.24^{b}	5.49^{b}	5.64^{b}	0.033	0.001	0.001

a b ($P < 0.05$)

Moate et al. 2018 (unpublished data)

Persistency of Methane Reduction with Wheat



Moate et al. 2018 (unpublished data)

Methane Mitigation for Grazing Beef Cattle: Legumes vs Grasses

Irrigated pastures in Utah (n=5/trt; SF6 technique)

	Meadow bromegrass	Birdsfoot trefoil *	Cicer milkvetch
Body weight, kg			
Cows, 2014	681 a	634 a	676 a
Heifers, 2015	448 a	432 a	438 a
Forage DM disappearance, kg/d			
Cows, 2014	11.2 c	12.1 b	15.4 a
Heifers, 2015	7.2 b	8.6 b	11.7 a
Enteric methane, g/d			
Cows, 2014	322 a	169 b	146 b
Heifers, 2015	201 a	128 b	135 b

Within row: a,b ($P < 0.05$)

* Contained 2 to 3% CT

J. MacAdam, University of Utah (unpublished data)

Effects of Condensed Tannin Containing Fresh-cut Legumes in Growing Cattle

(cut and carry, chambers)

	Early		Late	
	Alfalfa	CT-Sainfoin	Alfalfa	CT-Sainfoin
CT content, % DM	0 b	2.45 a	0 b	0.66 b
Methane, g/kg DMI	26.6	28.2	24.8	24.0
Methane, % GE intake	8.6	9.1	8.2	8.0

a,b (P < 0.05)

No stage x forage interaction

Chung et al. (2013) J. Anim. Sci. 91:4861-4874

Is there a way to decrease enteric methane production without decreasing productivity?

↓ Methane production

Feed additives

- Probiotics
- Inhibitors
- Nitrate
- Tannin extracts
- Essential oils

Diet composition

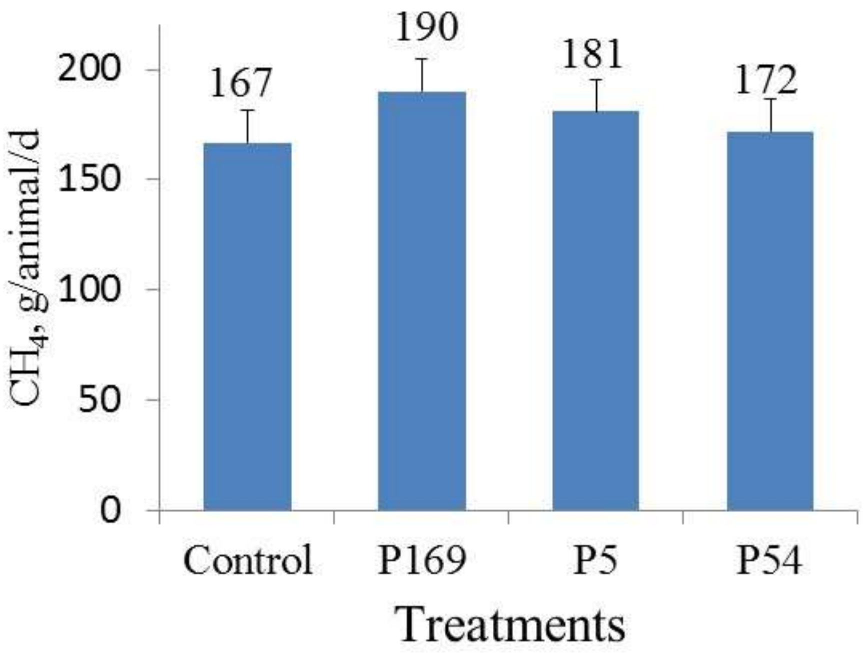
- Grain
- Lipids
- Forage quality
- Legumes
- Pasture management

Animal genetics and management

- Efficiency
- Fewer days on feed
- Gain to feed ratio

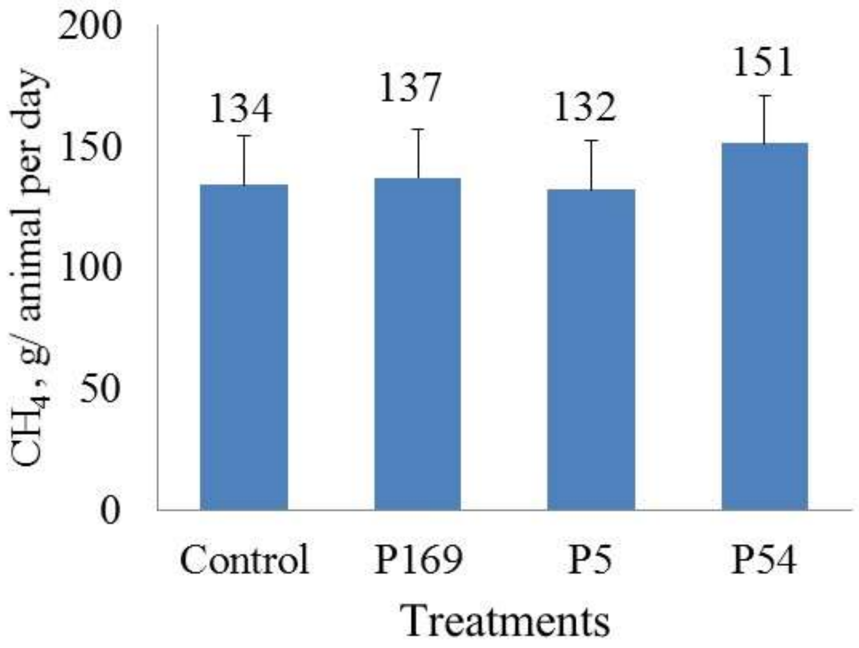
Direct-fed Microbial Containing the Lactate Utilizer *Propionibacterium* fed to Beef Cattle

Backgrounding



(Vyas et al., 2014; JAS 92: 2192-2201)

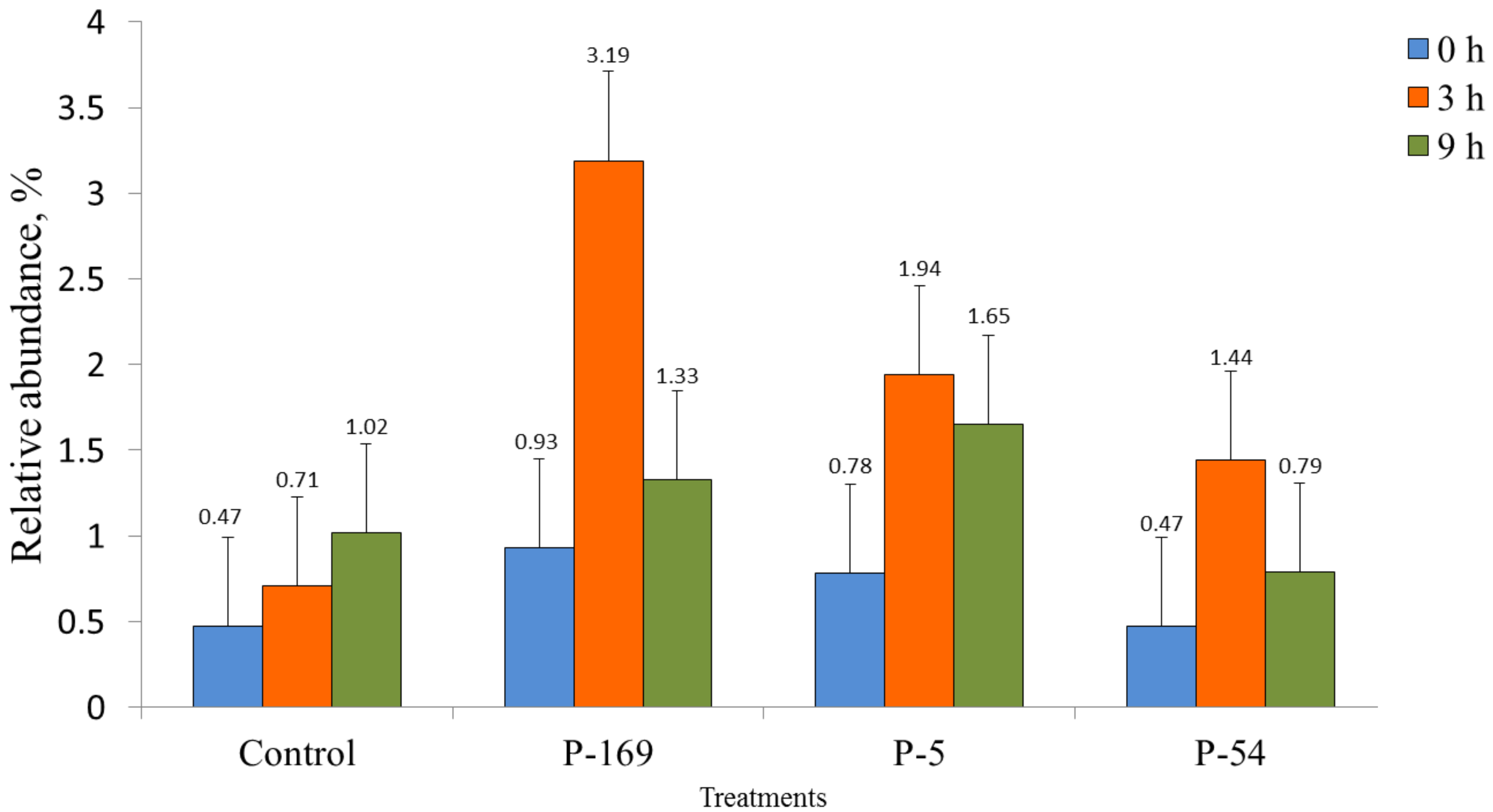
Finishing



(Vyas et al., 2014; Animal 8: 1807-1815)

Propionibacterium acidipropionici strain P169, P. acidipropionici strain P5, and P. jensenii strain P54; each at 5 × 10^9 CFU

Bacterial Probiotics: Reduced Persistency of Inoculated Strains

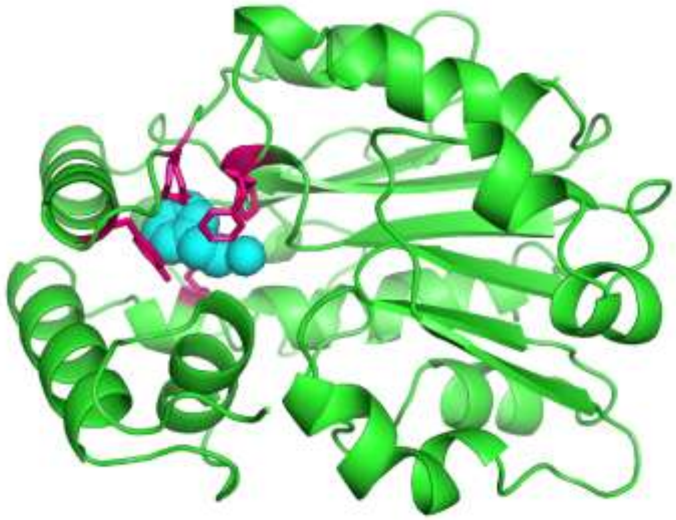


Relative abundance of *Propionibacterium* at 0, 3, 9h post-feeding in beef cattle fed a **high forage** diet

Vyas et al., 2014; JAS 92: 2192-2201

Methane Inhibitor: 3-Nitrooxypropanol (NOP)

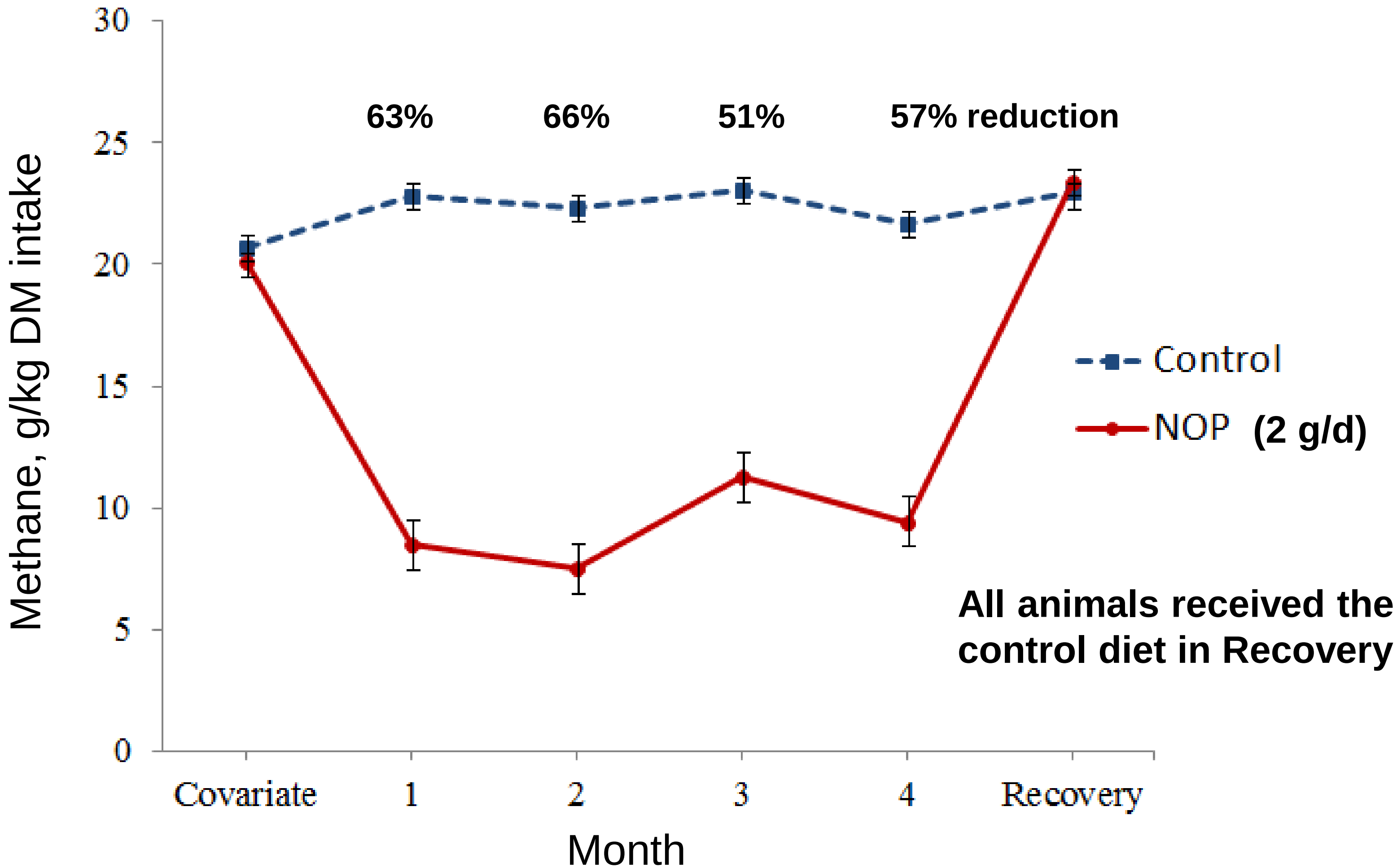
- Experimental compound (DSM Nutritional Products, Switzerland)
- Inhibits the last step of methanogenesis in the rumen
- Degraded in the GIT to propanediol, (propylene glycol), nitrate, nitrite
- Low safety risk (not carcinogenic or mutagenic)



Mode of Action:

- Structural analog of Methyl-coenzyme M
- Binds to the active site of the enzyme (methyl-coenzyme M reductase) involved in the last step of methane synthesis and oxidizes its active site Ni(I) (Duin et al. 2016. PNAS.1600298113)

NOP Mixed into High Forage Diet and Fed to Beef Cattle for 5 Months



Romero-Perez et al. 2015

Effects of Feeding 3-Nitrooxypropanol (NOP) and Monensin (33 ppm) to Feedlot Cattle

Backgrounding phase – 105 days

	No MON		With MON		Significance	
	No NOP	Plus NOP	No NOP	Plus NOP	MON	NOP
Initial BW, kg	308	308	308	310	0.86	0.69
Final BW, kg	462	459	464	464	0.31	0.71
DM intake, kg/day	8.41	7.64	8.08	7.64	0.12	<0.01
Gain:feed	0.172	0.184	0.183	0.189	<0.01 +4%	<0.01 +5%
ADG, kg/d	1.45	1.43	1.47	1.46	0.21	0.41
CH_4, g/kg DM intake	28.2	15.7	28.1	17.1	0.65	<0.01 -42%

No significant interactions between MON and NOP

240 steers, 6 pens/trt

Vyas et al., submitted

Effects of Feeding 3-Nitrooxypropanol (NOP) and Monensin (33 ppm) to Feedlot Cattle

Finishing phase – 105 days

	No MON		With MON		Significance	
	No NOP	Plus NOP	No NOP	Plus NOP	MON	NOP
Initial BW, kg	507	504	512	513	0.06	0.81
Final BW, kg	698	692	694	697	0.97	0.82
DM intake, kg/day	12.1	11.4	11.4	11.0	0.06	0.06
Gain:feed	0.150	0.152	0.152	0.159	0.58	<0.01 +3%
ADG, kg/d	1.80	1.79	1.73	1.74	0.08	0.98
CH_4, g/kg DM intake	15.9	8.32	19.1	13.8	0.06	<0.01 -37%

No significant interactions between MON and NOP

240 steers, 6 pens/trt

Vyas et al., submitted

Evaluation of an Experimental Methane Inhibitor at a Commercial Feedlot (2017-2018)

Research Studies: 30-60% reduction in methane from beef and dairy cattle; no negative effects for animals; low safety hazard for humans

Evaluation of an Experimental Methane Inhibitor at a Commercial Feedlot (2017-2018)

Sean McGinn: open path lasers

GreenFeed System to measure methane production per animal

GrowSafe system to measure feed intake per animal

Nitrate as an Alternative Hydrogen Sink in the Rumen

- Nitrate is reduced to nitrite and then ammonia
- Nitrate acts as an alternative H sink, competes with methanogenesis and lowers methane emissions
- Source of dietary non-protein nitrogen
- Potential for nitrite toxicity
  - Animal adaptation needed
  - Encapsulation slows release of nitrate

Lee and Beauchemin (2014) Can J Anim Sci 94:557-570 (review)

Evaluation of Nitrate for Methane Reduction

Beef Cattle Studies	Diet (DM basis)	Methane yield (g/kg DMI) reduction
Short-term (28 d periods)		
Lee et al. 2015 JAS	55% barley silage	-18% ($P < 0.05$)
Long-term studies		
Lee et al. 2017 JAS	65% corn silage	-6 to -10% NS
	10% corn silage	0% NS
Aklilu et al. 2018 (unpublished)	65% barley silage	-12% ($P < 0.05$)
	8% barley silage	-10% ($P < 0.05$)

Reducing GHG Emissions from Ruminants

Nitrous oxide (GWP=298)
Methane (GWP=25)
Carbon dioxide (GWP=1)

GHG emissions (kg CO_2 eq)

kg product

Functional unit

- kg fat-protein corrected milk
- kg carcass
- kg protein, MJ energy

"Carbon footprint" or "GHG Intensity"

Holos

A tool to estimate and reduce GHGs from farms

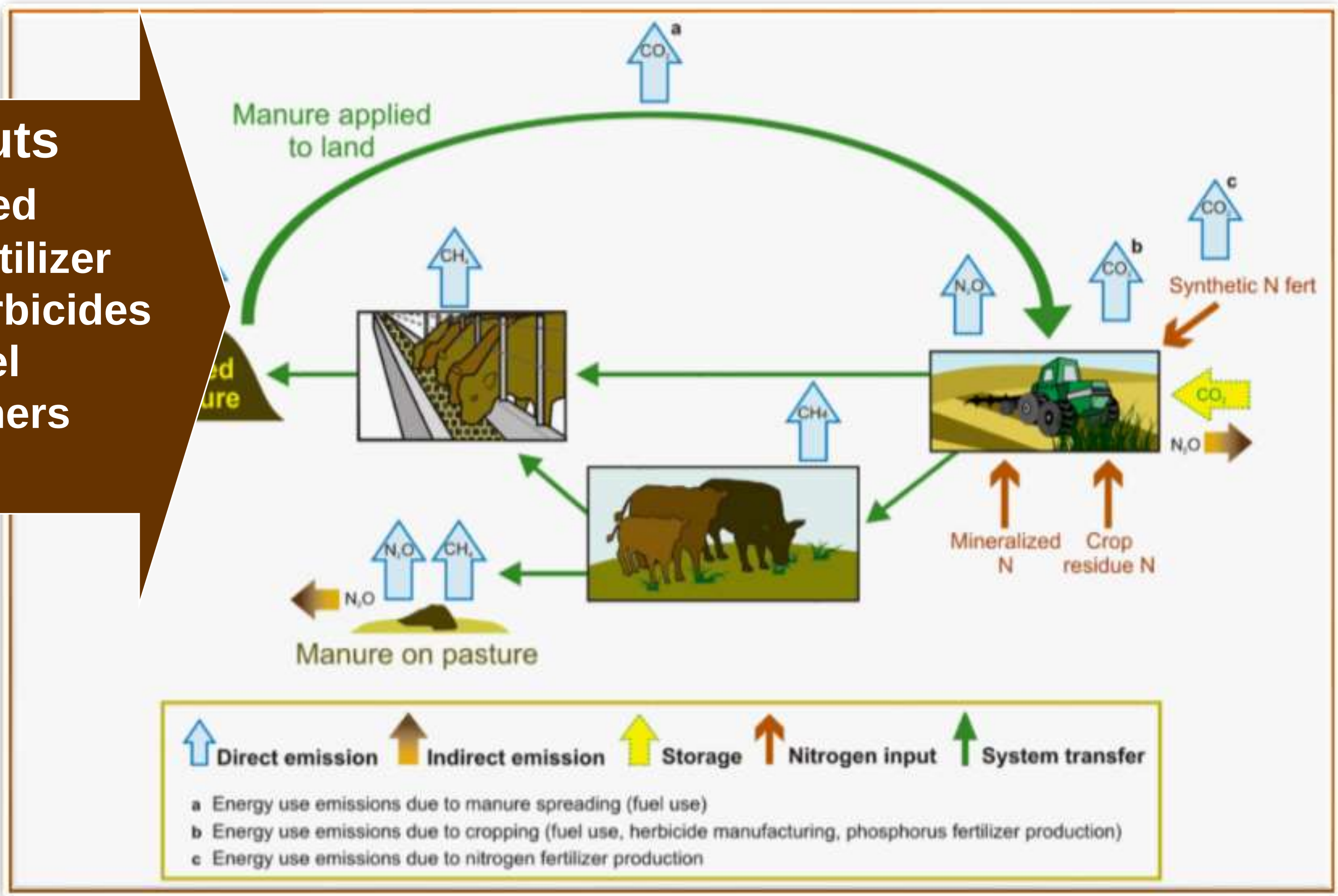
Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Canada

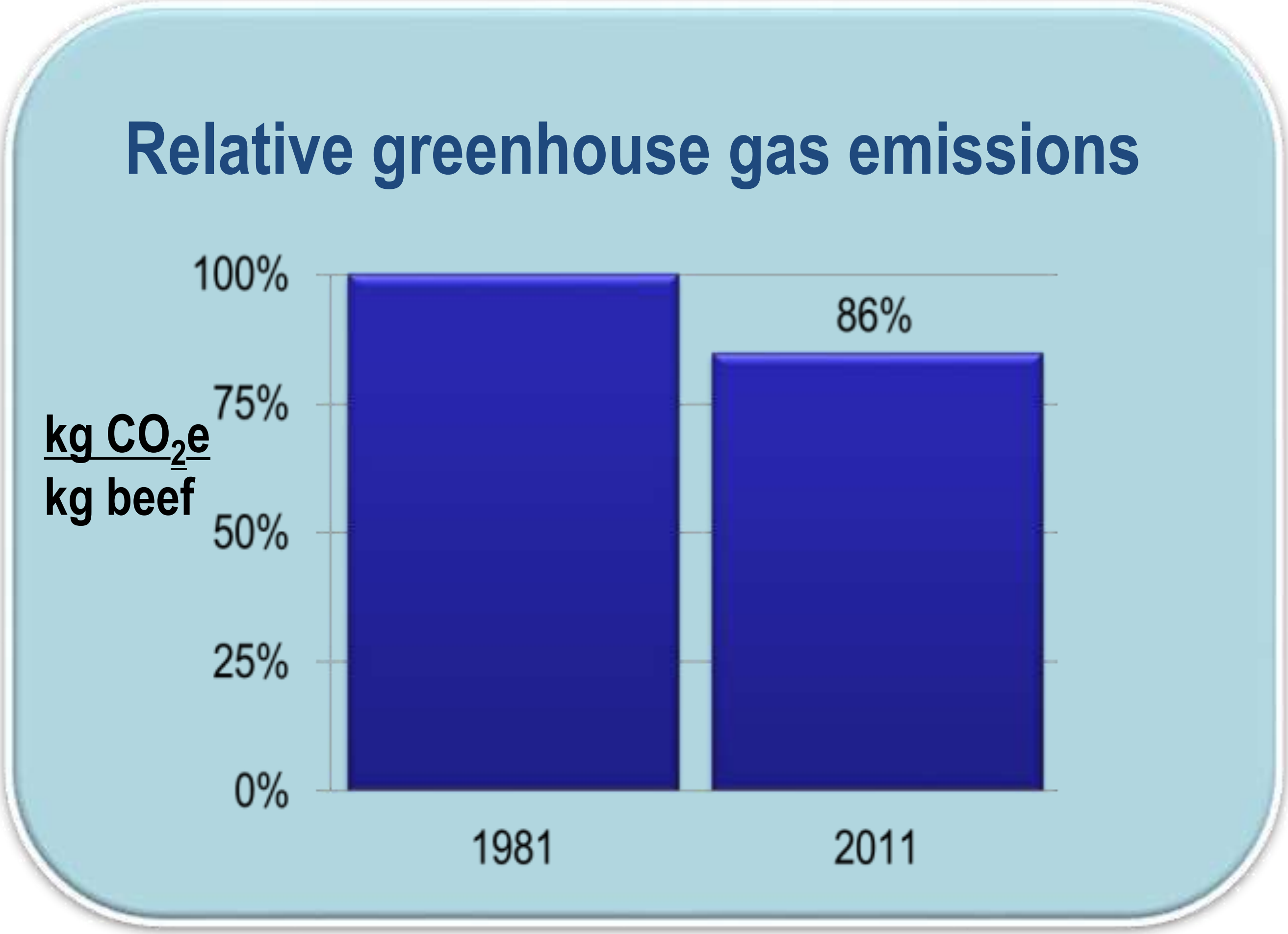
Holos – Systems Approach of Estimating GHG Emissions from Farms

Inputs

- Feed
- Fertilizer
- Herbicides
- Fuel
- Others

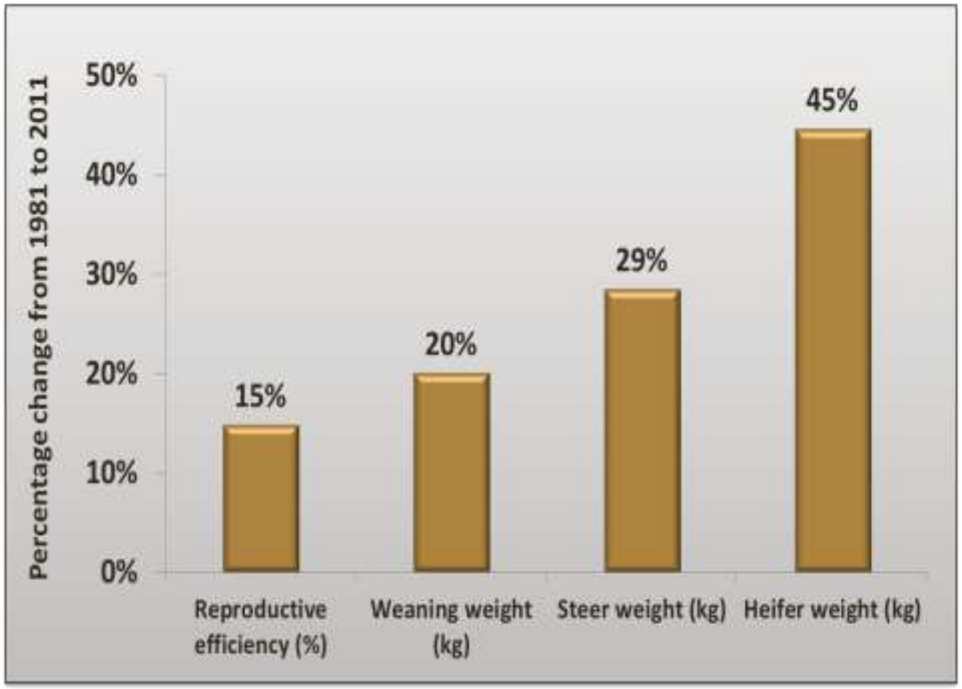


In Canada, Beef Production in 2011 Resulted in 14% Less Greenhouse Gas Emissions than in 1981



Legesse et al. 2016. Anim. Prod. Sci. 56:153-168

GHG Emissions of Canadian Beef Production in 1981 as Compared with 2011



To produce the same quantity now:

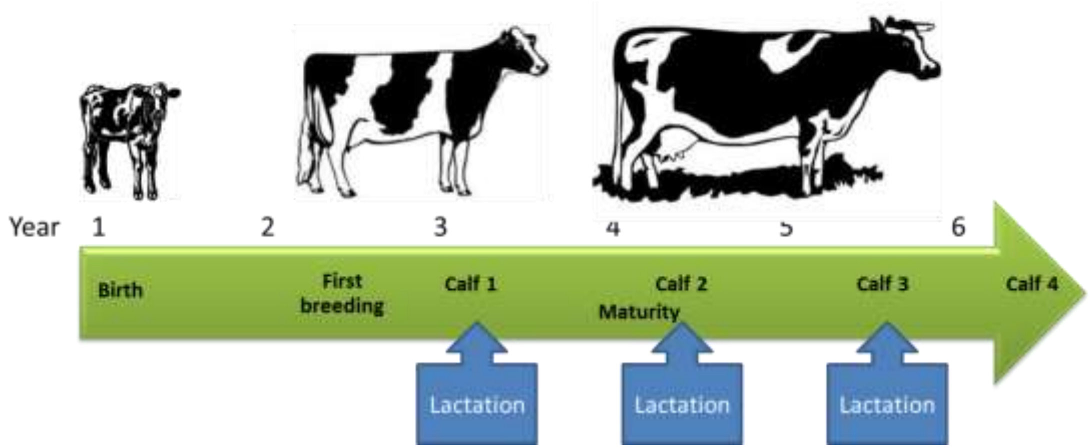
- **29% fewer cattle required for breeding**
- **27% fewer slaughter cattle required**
- **24% less land required**

Legesse et al. 2016. Animal Prod Sci. 56: 153 - 168

The Effect of Corn vs. Alfalfa Silage on the Carbon Footprint of Milk (Little et al. 2017)

Included:

- Lactating, dry cows, replacements and veal offspring
- 6 -year cycle
- Cropping/feed system
- Manure management



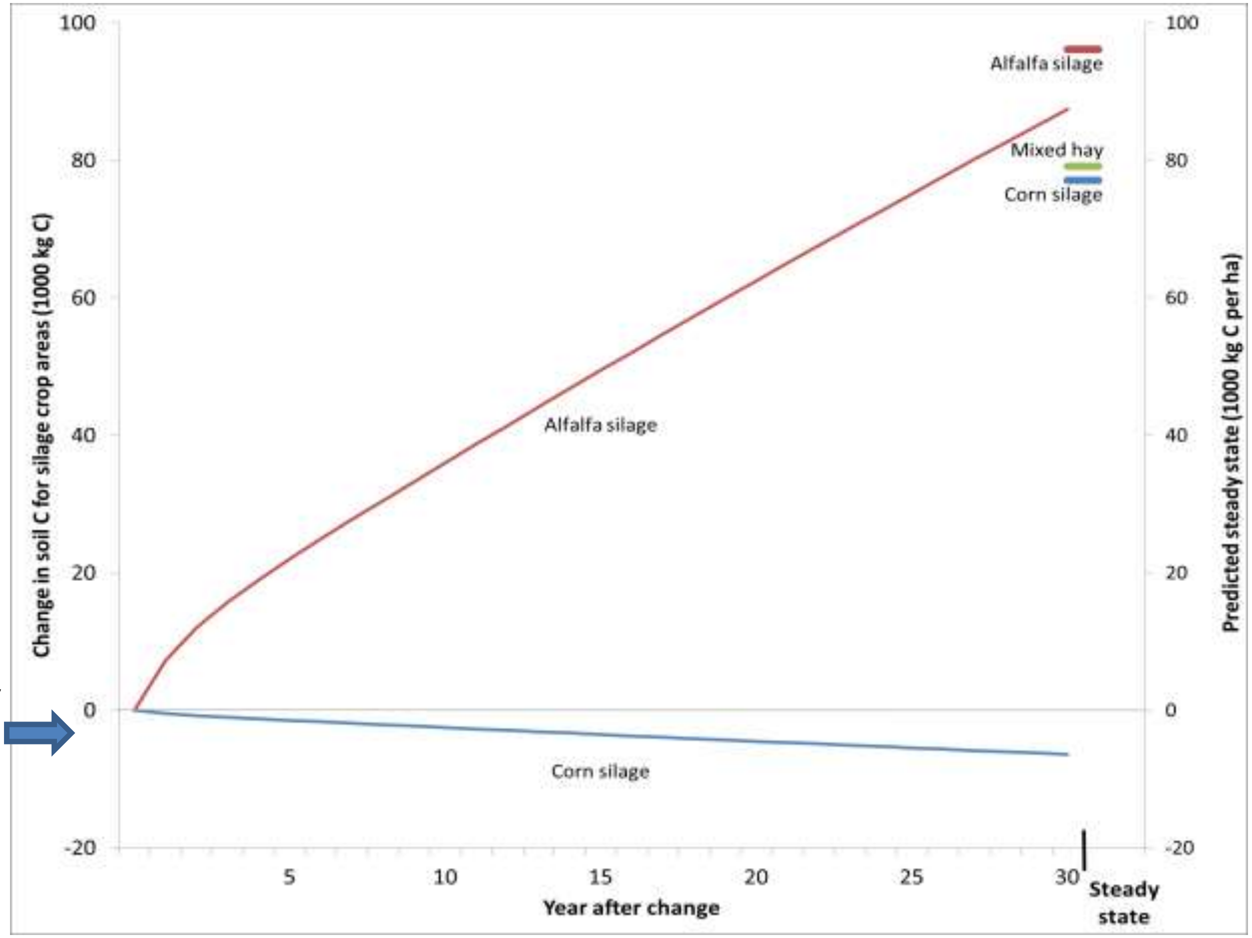
Animal products
GHG emissions
Land area use
Soil carbon

	Kg FPCM /ha/year
Corn silage	5208
Alfalfa silage	4853

	Enteric Methane (Y_M, % GEI)	Milk (kg FPCM) per day)	kg CO_2e / per kg FPCM
Corn silage	5.27	30.5	1.24
Alfalfa silage	5.85	30.7	1.25

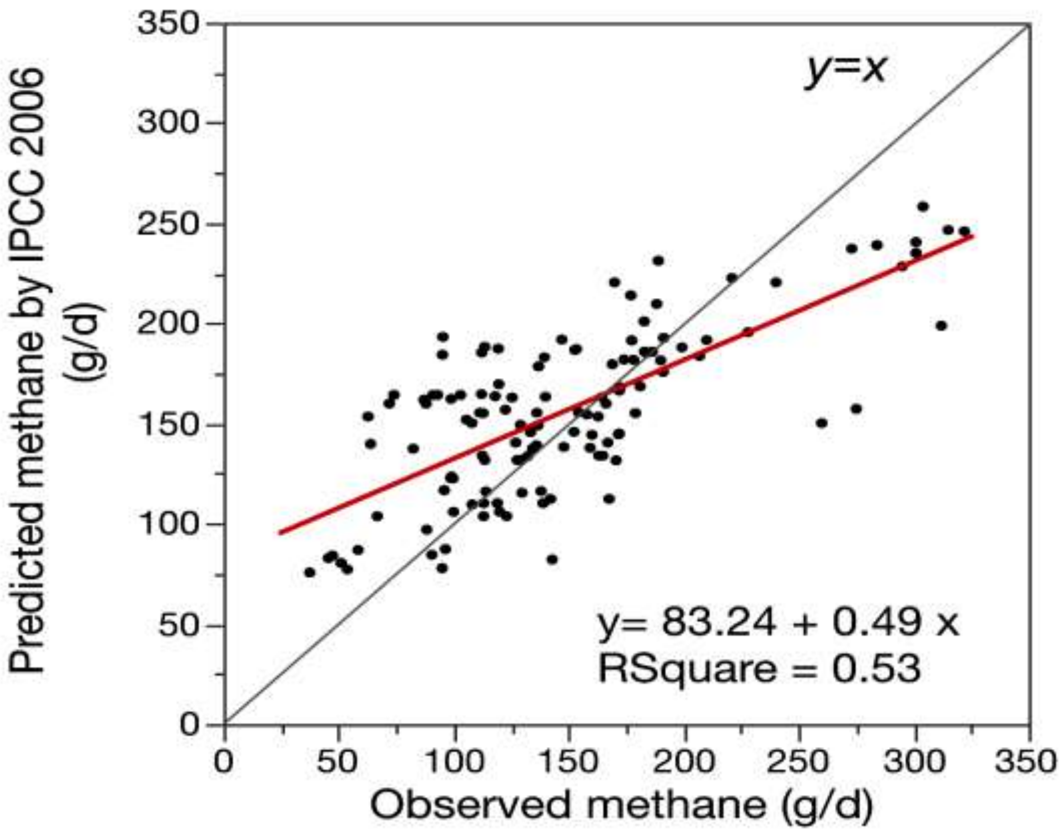
100% allocation of GHG to milk

mixed hay steady state



Predicted gain or loss of soil carbon due to rotation change from a mixed hay steady state to alfalfa silage or corn silage for the entire forage cropland over 30 years since change (**left side**); and predicted steady state per hectare for each forage rotation (**right side**).

Predicted (IPCC 2006, Ym = 6.5% of GE intake) vs. Observed Methane Emissions for Beef Cattle fed ≥ 40% Forage (Ym value)



Escobar-Bahamondes et al. 2017. Can. J. Anim. Sci. 97:83–94

HOLOS Development

- Feed database
- Ym predictions from feed composition
- Monthly time step expanded to yearly time step (crop rotations, soil carbon)
- Water budget
- Other ecosystem services (wildlife habitat)

The Way Forward

Low methane diets
Additives

Animal genetics
Management

Methane (kg)

Meat (kg) & Milk (kg)

Other benefits from forage based systems

Measuring Emissions on Pasture and Farms (S. McGinn)

- Carbon dioxide exchange (land)
- Enteric methane (cattle)

Open path laser

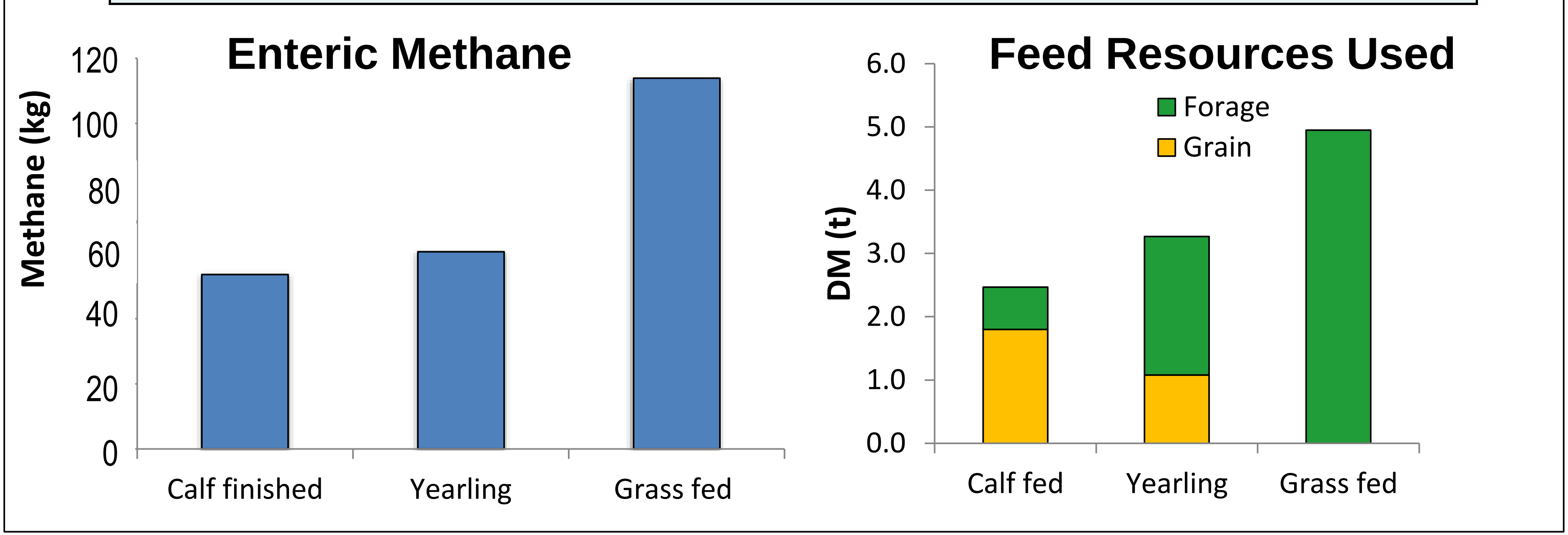
Feeding Lipids

- Lowers CH_4 by 3 - 5% per 1% added fat
- Effectiveness depends on:
  - Source (medium > long chain FA)
  - Form (refined oil > full-fat oilseeds)
- Max. total fat content of diet 6% DM
- Mode of action
  - Inhibits growth of rumen protozoa
  - Replaces some of the carbohydrates, which would be digested and produce CH_4 in the rumen
  - Biohydrogenation of fatty acids competes with hydrogen
  - Medium chain fatty acids have toxic effects on rumen methanogens
  - Reduces fiber digestion (esp. high fiber diets)

Beef calf finishing systems

System	Phase 1	Phase 2	Phase 3	Age at market (months)
Calf finished	110 d (1 kg/d) Forage	170 d (1.5 kg/d) Grain-finished		**16**
Yearling (Stocker)	150 d (0.7 kg/d) Forage	120 d (0.7 kg/d) Pasture	120 d (1.6 kg/d) Grain-finished	**20**
Grass-fed	150 d (0.7 kg/d) Forage	120 d (0.7 kg/d) Pasture	240 d (0.8 kg/d) Forage-finished	**24**

	Calf-fed system	Grass-fed System
Enteric CH_4 emissions	low	high
N_2O emissions	high	low ???
Soil carbon	loss	preserves
Fossil fuel energy use	more	less
Wildlife habitat	low	high
Land use	less	more
Competition for human for grain	high	low



Beauchemin, 2015