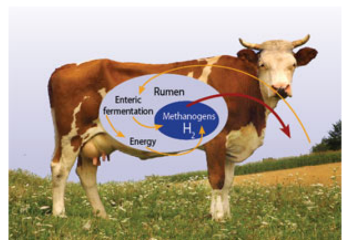
Environmental Constraints to Milk Production and Regulation

CA Perspective

Ermias Kebreab
University of California, Davis

San Diego, May 3, 2017



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Outline

- Air related constraints
  - Greenhouse gas emissions
  - Enteric methane emissions
  - Mitigation options for enteric
  - Emissions from manure
  - Mitigation of options for manure emissions
- Nutrient and mineral related constraints
  - Risks in N loading in farms
  - Phosphorus loading
- Summary

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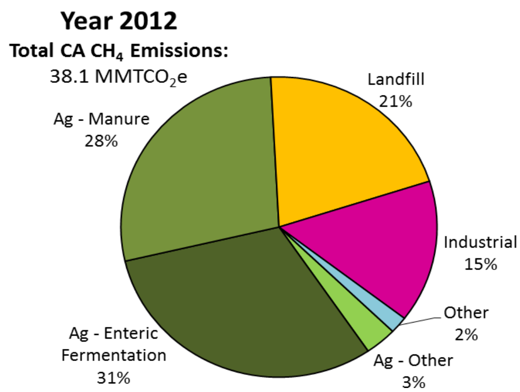
Methane Emissions in CA



CA Air Resources Board, 2014

- Methane makes up 60% of ag contribution
- About 77% from dairy cattle
- Do we have accurate data? What is the baseline?

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Current Regulations in CA

- Senate Bill 1383 Short lived climate pollutants
  - Black carbon, fluorinated gases, methane
  - Reduce methane by 40% below 2013 levels by 2030

- Air Resource Board to begin implementation by January 1, 2018

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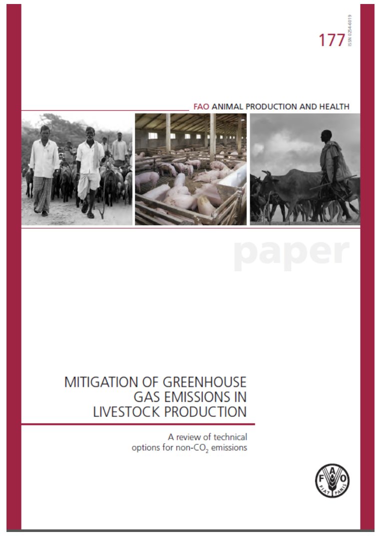
How can we reduce emissions?



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Mitigation Options

Enteric fermentation

Manure Management

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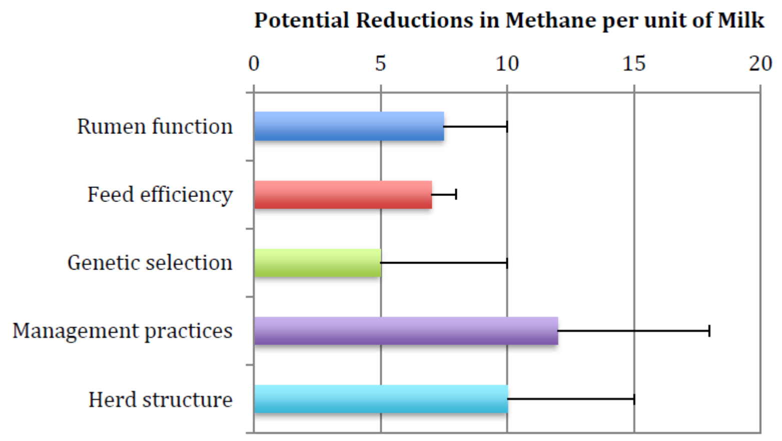
Mitigation Potential (Enteric)



Knapp et al. 2014, JDS

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Potential Mitigation Strategies

Table 1. Feed additives and feeding strategies targeting enteric methane (CH_4) emission mitigation

Category[1]	Potential CH_4 mitigating effect[2]	Long-term effect established	Effective[3]	Environmentally safe or safe to the animal[4]	Recommended[5]
Inhibitors					
BCM and BES[6]	High	?[7]	Yes	No[8]	No
Chloroform	High	No?	Yes	No	No
Cyclodextrin	Low	No	Yes	No	No
3-nitrooxypropanol	Medium	?	Yes	?	?
Electron receptors					
FMA[9]	No effect to High	?	?	Yes	No?
Nitroethane	Low	No	Yes?	No	No
Nitrate	High	No?	Yes	?	Yes?[10]
Ionophores[11]	Low[12]	No?	Yes?[12]	Yes?	Yes?
Plant bioactive compounds[13]					
Tannins[14] (condensed)	Low	No?	Yes	Yes	Yes?
Saponins	Low?	No	?	Yes	No?
Essential oils	Low?	No	?	Yes	No
Exogenous enzymes	No effect to Low	No	No?	Yes?	No?
Defaunation	Low	No	?	Yes	No
Manipulation of rumen archaea and bacteria	Low?	No	?	Yes?	Yes?[15]
Dietary lipids	Medium	No?	Yes	Yes	Yes?[16]
Inclusion of concentrate[17]	Low to Medium	Yes	Yes	Yes	Yes?[18]
Improving forage quality	Low to Medium	Yes	Yes	Yes	Yes
Grazing management	Low	Yes	Yes?	Yes	Yes?[19]
Feed processing	Low	Yes	Yes[20]	Yes[20]	Yes[20]
Mixed rations and feeding frequency[21]	?	?	?	Yes	?
Precision (balanced) feeding and feed analysis	Low to Medium	Yes	Yes?	Yes	Yes[22]

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Inhibitors - NOP

PNAS

An inhibitor persistently decreased enteric methane emission from dairy cows with no negative effect on milk production

Alexander N. Hristov[a,1], Joonpyo Oh[a], Fabio Giallongo[a], Tyler W. Frederick[a], Michael T. Harper[a], Holley L. Weeks[a], Antonio F. Branco[b], Peter J. Moate[c], Matthew H. Deighton[c], S. Richard O. Williams[c], Maik Kindermann[d], and Stephane Duval[e]

The Washington Post

Energy and Environment

Meet the "clean cow" technology that could help fight climate change

Cow dietary supplement may help in climate change fight

Jean-Louis Santini
AFP
August 5, 2015

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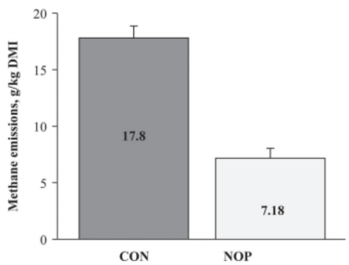
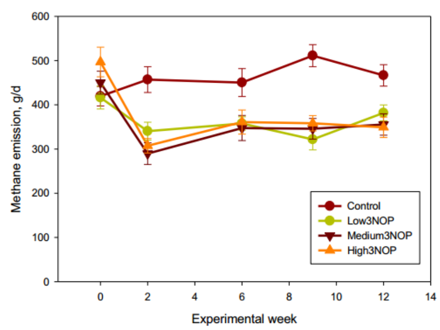
Inhibitors - NOP



Haisan et al. 2014



Hristov et al. 2015

3796 MARTÍNEZ-FERNÁNDEZ ET AL.

Table 5. Effect of the addition of 100 mg/d per animal of ethyl-3-nitrooxy propionate (E3NP) or 3-nitrooxypropanol (3NP) on BW, DMI, and methane emissions by sheep measured on d 14 and from d 29 to 30 of treatment (experiment 3)

	d 14			d 29–30				*P*-value		
Item	Control	E3NP	3NP	Control	E3NP	3NP	SEM	Additive (A)	Time (T)	A × T
BW, kg	44.6	44.1	43.9	44.3	44.0	43.6	1.7	0.28	0.72	0.70
DMI, kg	0.819	0.848	0.870	0.840	0.938	0.899	0.041	0.17	0.12	0.38
CH_4, L/d	24.3	21.8	19.7	22.3	20.6	18.8	1.7	0.14	0.32	0.88
CH_4, L/kg of DMI	30.0	25.6	22.3	27.4	21.5	20.9	1.8	0.003	0.04	0.62

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Inhibitors - Seaweed

CSIRO PUBLISHING
Animal Production Science, 2016, **56**, 282–289
http://dx.doi.org/10.1071/AN15576

The red macroalgae *Asparagopsis taxiformis* is a potent natural antimethanogenic that reduces methane production during *in vitro* fermentation with rumen fluid

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Canada › PEI

P.E.I. farmer assists in near-eradication of methane from cow farts

Scientist discovers particular seaweed reduces methane to nearly zero in cow burps, farts

By Shane Ross, CBC News Posted: Nov 17, 2016 8:26 PM AT | Last Updated: Nov 18, 2016 11:41 AM AT

Rob Kinley with cattle in Australia. Methane from cows' farts and burps is a major source of greenhouse gas emissions, he says. (CSIRO Agriculture)

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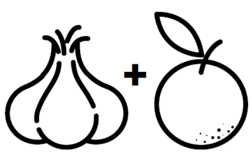
Inhibitors - Mootral



MOOTRAL™

A NATURAL HOLISTIC SOLUTION

Our proprietary feed supplement is made from natural ingredients. Allicin, obtained from Garlic, and Citric extract, which originates as a by-product from the processing of Oranges. There are opportunities to locally source the ingredients and make the whole Mootral™ production carbon-friendly.
The Mootral™ product is easy to produce, and market access should not encounter any significant regulatory hurdles as it is made from natural feed components.

stopcowsfarting!

Dear Humans,

Each day, we, cows, produce more than 500 billion litres of methane. This means that we are responsible for more than 20% of all greenhouse gas emissions worldwide… More than all transportation globally!

A small company called mootral has developed a product that will reduce our emissions by 90%. mootral is so revolutionary that it was featured and shortlisted by the *Financial Times* on March 20th as one of 5 solutions to solve climate change.

We understand our responsibility towards climate change and thus need you to vote for mootral to STOPUSFARTING!

So please CLICK HERE (*Financial Times*) and vote for mootral!

moorely yours,
Cows United

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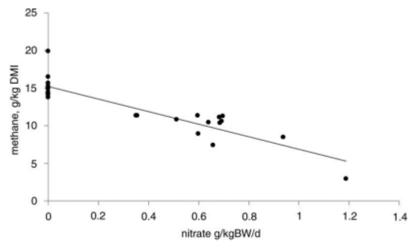
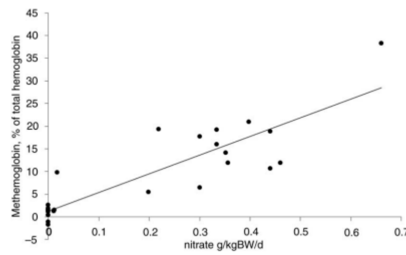
Electron Receptors

- Nitrates in the feed can reduce methane by up to 50%



Beauchemin et al. 2014



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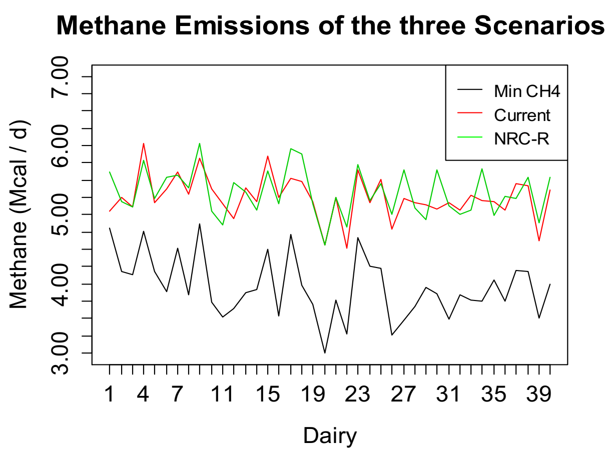
Dietary Manipulation



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Possible but costly!

- Diets formulated to minimize methane emissions increased costs substantially

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Modeling the trade-off between diet costs and methane emissions: A goal programming approach

L. E. Moraes,* J. G. Fadel,* A. R. Castillo,† D. P. Casper,‡ J. M. Tricarico,§ and E. Kebreab*[1]
*Department of Animal Science, University of California, Davis 95616
†Cooperative Extension, University of California, Merced 95341
‡Dairy Science Department, South Dakota State University, Brookings 57007
§Innovation Center for US Dairy, Rosemont, IL 60018

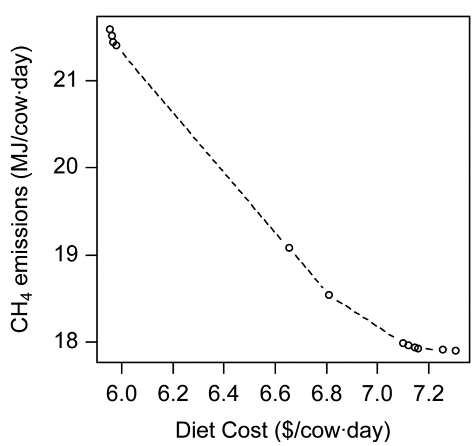

Figure 2. Methane emissions versus diet costs from the solutions of the weighted goal programming model on a per cow daily basis.

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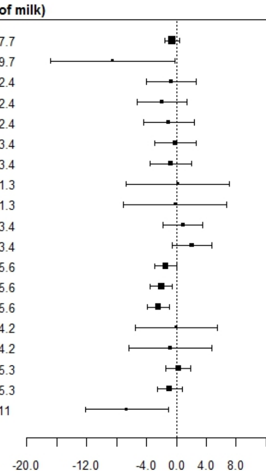
Lipid Supplementation

Study and Treatments		CH4 in Control (g/kg of milk)	Mean Difference [95% CI]
Odongo et al., 2007a	- Feeding monenesin (24 mg/kg of DM)	17.7	-0.5 [-1.5 , 0.4]
Odongo et al., 2007b	- Supplementing Myristic acid (5% DM)	29.7	-8.5 [-16.8 , -0.2]
Beauchemin et al., 2009	- Crushed Sunflower seeds (10.6% DM)	12.4	-0.7 [-4.1 , 2.7]
	- Crushed Flax seeds (9.3% DM)	12.4	-1.9 [-5.3 , 1.5]
	- Crushed Canola seeds (9.3% DM)	12.4	-1.0 [-4.4 , 2.4]
Holtshausen et al., 2009	- Feeding saponin (Yucca schidigera); chamber method	13.4	-0.1 [-2.9 , 2.7]
	- Feeding saponin (Quillaja saponaria); chamber method	13.4	-0.8 [-3.5 , 2.0]
	- Feeding saponin (Yucca schidigera); SF6 method	11.3	0.2 [-6.7 , 7.1]
	- Feeding saponin (Quillaja saponaria); SF6 method	11.3	-0.2 [-7.1 , 6.8]
Chung et al., 2012	- Fibrolytic enzyme additive (low dose)	13.4	0.9 [-1.8 , 3.6]
	- Fibrolytic enzyme additive (high dose)	13.4	2.1 [-0.6 , 4.8]
Benchaar et al., 2013	- Dry distiller grain solubles (10% DM)	15.6	-1.4 [-2.9 , 0.1]
	- Dry distiller grain solubles (20% DM)	15.6	-2.0 [-3.5 , -0.5]
	- Dry distiller grain solubles (30% DM)	15.6	-2.4 [-3.9 , -0.9]
Hassanat et al., 2013	- Replacing forage (alfalfa silage) with corn silage (50%)	14.2	0.0 [-5.5 , 5.5]
	- Replacing forage (alfalfa silage) with corn silage (100%)	14.2	-0.8 [-6.3 , 4.7]
Benchaar et al., 2014	- Replacing forage (barley silage) with corn silage (0% DM)	15.3	0.3 [-1.4 , 2.0]
	- Replacing forage (barley silage) with corn silage (100% DM)	15.3	-0.9 [-2.6 , 0.8]
Haisan et al., 2014	- Feeding 3-nitrooxypropanol (25 g/d)	11	-6.7 [-12.2 , -1.1]



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Ionophores

- Used extensively in N. America
- Do not target methanogens directly
- Effectiveness dose dependent
  - At 20 mg/kg no effect on methane production
  - At 25-35 mg/kg reduced by 4-13%
  - At 33 mg/kg short-term reduction of up to 30%
- Inhibitory effect not persistent over time
- Some future potential

J. Dairy Sci. 96:5161–5173
http://dx.doi.org/10.3168/jds.2012-5923

Anti-methanogenic effects of monensin in dairy and beef cattle: A meta-analysis

J. A. D. Ranga Niroshan Appuhamy,*[1] A. B. Strathe,* S. Jayasundara,† C. Wagner-Riddle,† J. Dijkstra,‡ J. France,§ and E. Kebreab*

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Mitigation from Manure Storage

- Anaerobic digestion
- Alternative manure management practices
  - Reduce manure storage time
  - Manure liquid-solid separation
  - Composting
  - Manure stacking
  - New Technologies?

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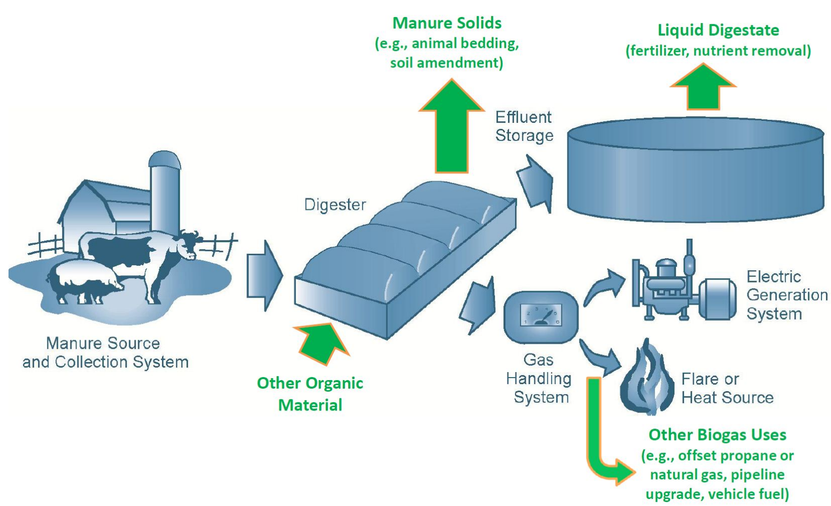
Anaerobic Digestion



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Anaerobic Digestion (DK)

Advantages:

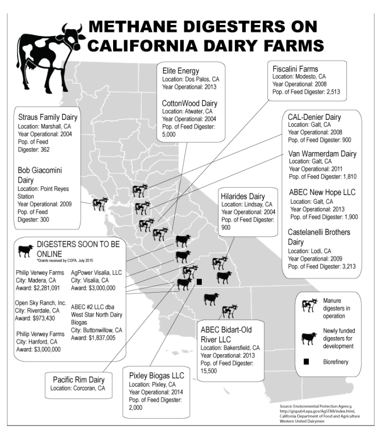
- Reduce methane/produce biogas
- Pathogen kill, nutrient preserved

Disadvantages:

- High initial capital investment
- High standards maintenance

Anaerobic Digestion (CA)

Is there any incentive for producers to either decrease emissions or being more sustainable?



Source: EPA; CDFA; Western United Dairymen

Anaerobic Digestion

Table 9. Cost of Mitigation Options and Policy Instruments and Corresponding Mitigation Potentials

Mitigation Option or Policy Instrument (tax or credit)	Agricultural Sector	Marginal Cost of Mitigation or Incentive Price ($/MTCO2e)	GHG Mitigation Potential (MTCO2e)	% of Total Ag GHG Emissions (2009)[a]	% of GHG Emissions from Appropriate Agricultural Sector (2009)[a]	Source
C-emission tax or credit	Crops - California (Central Valley)	$ 5	1,400,000	4.4%	15.5%	Garnache et al. (2013)
C-emission tax or credit	Crops - California (Central Valley)	$ 10	1,900,000	5.9%	21.1%	Garnache et al. (2013)
C-emission tax or credit	Crops - California (Central Valley)	$ 20	2,600,000	8.1%	28.8%	Garnache et al. (2013)
C-emission tax or credit	Crops - California (Central Valley)	$ 30	3,100,000	9.7%	34.4%	Garnache et al. (2013)
Anaerobic digestion - dairy	Manure management - US National	$ 0	770,000	0.2%	2.4%	Gloy (2011)
Anaerobic digestion - dairy	Manure management - US National	$ 5	2,590,000	0.6%	8.2%	Gloy (2011)

Sumner et al. 2013

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Anaerobic Digestion

CDFA received $50 million from the Greenhouse Gas Reduction Fund

- ~29 to 36 million for digester installation assistance

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Alternative Methods

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Alternative Methods

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Alternative Methods

~9 to 16 million for project development to support AMMP

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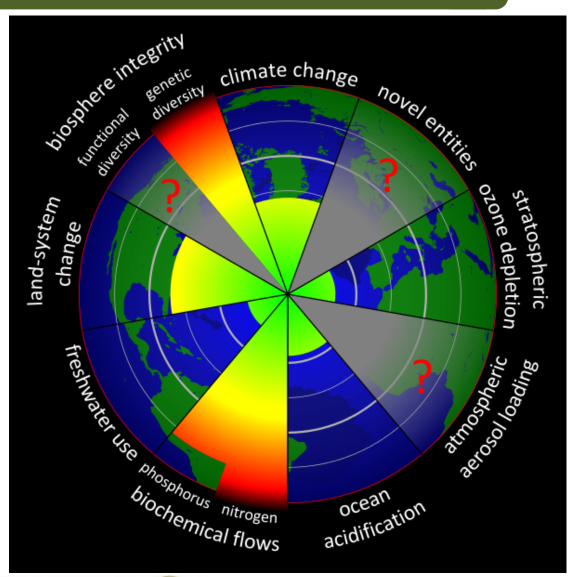
Nutrient/Mineral Loading



Rockström *et al.* 2009

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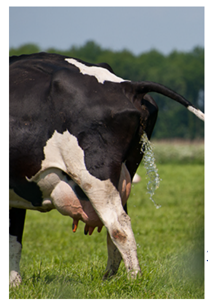
Risks of Surplus N in Farms

- Ammonia
  - small particles ($PM_{2.5}$) → lung problems
  - acidification → soil fertility and tree vitality problems
- Nitrate
  - pollution of drinking water → health risk
  - eutrophication → algae growth, toxins
- Nitrous oxide
  - greenhouse gas → climate change
- Urinary N far more vulnerable to evaporative/leaching losses than fecal N



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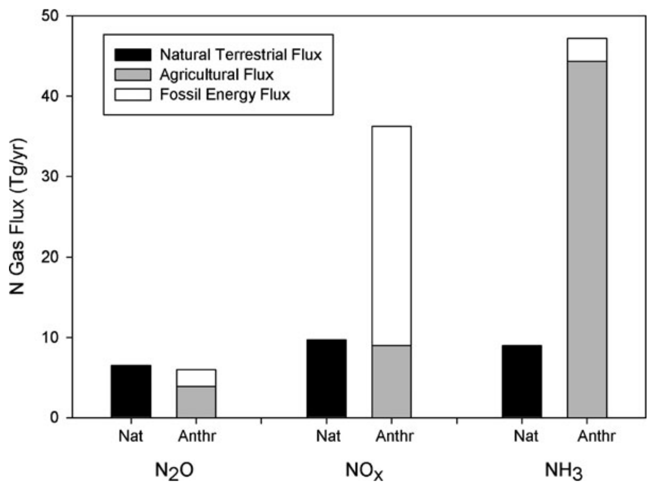
Reactive N Sources



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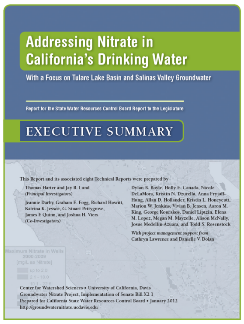
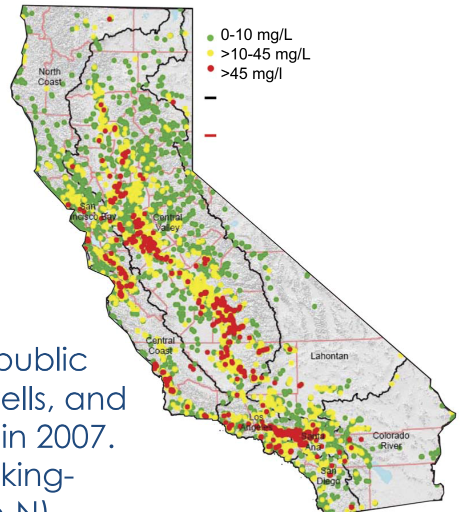
Nitrate Concentrations

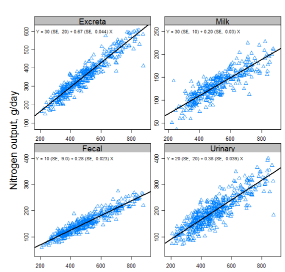




Nitrate concentrations in public supply wells, monitoring wells, and domestic wells measured in 2007. Red wells exceed the drinking-water limit (10 mg/l nitrate-N).

Strategies to Reduce N

- Limiting access
- Total Maximum Daily Load (TMDL)
- Improving efficiency of utilization



Large Variation in N Efficiency

	Milk N efficiency			
	USA (*n* = 167)		EU (*n* = 287)	
	Low	High	Low	High
Milk N efficiency	0.22	0.33	0.21	0.32
DM intake (kg/d)	23.2	23.8	17.9	18.9
3.5% FCM (l/d)	31.8	38.2	26.8	31.2
Forage (g/kg DM)	534	526	665	569
Forage CP (g/kg DM)	179	154	200	148

Lower (low) and upper (high) quartile for N efficiency

Calsamiglia et al. (2010)

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Inherent Limitations to N Efficiency in Cattle?

- Maximal N efficiency: 0.40 – 0.45
  - 600-kg dairy cow, 25 kg milk/d, 33 g protein/kg milk
  - inevitable losses: 115 g fecal N/d, 55 g urine N/d
  - optimal diet CP content ~105 g/kg DM

Van Vuuren and Meijs (1987)

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Inevitable N Losses and Milk N Output (g/d)

Source	N feces	N urine	N milk
Fermentation		35	
Microbial nucleic acids	[illegible]	71	
Ur[illegible]	[illegible]	[illegible]	[illegible]
En[illegible]	[illegible]	19	
M[illegible]	[illegible]	13	
M[illegible]	[illegible]	36	198
Total	89	174	198
Maximum N efficiency			***0.43***

- little scope to improve N recycling to rumen
- optimal rumen fermentable energy to RDN supply

Reference cow: 40 kg milk/d, milk true protein content 31.5 g/kg

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Inevitable N Losses and Milk N Output (g/d)

Source	N faeces	N urine	N milk
Fermentation		35	
Microbial nucleic acids	13	71	
Undigested protein	[illegible]		
[illegible]	[illegible]9	19	
[illegible]	[illegible]	13	
[illegible]	[illegible]	36	198
[illegible]	[illegible]9	174	198
[illegible]			***0.43***

- always nucleic acid N loss with microbial fermentation
- shift from rumen fermentation (*fibre)* to intestinal digestion (*starch, fat)*

Reference cow: 40 kg milk/d, milk true protein content 31.5 g/kg

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Inevitable N Losses and Milk N Output (g/d)

Source	N faeces	N urine	N milk
Fermentation		35	
Microbial nucleic acids	13	71	
Undigested protein	37		
Endogenous protein	39	19	
Maintenance		13	
		36	198
	89	174	198
			0.43

- little variation in microbial protein digestion
- use high digestible feed resources (*starch vs fibre*)

Reference cow: 40 kg milk/d, milk true protein content 31.5 g/kg

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Inevitable N Losses and Milk N Output (g/d)

Source	N faeces	N urine	N milk
Fermentation		35	
Microbial nucleic acids	13	71	
Undigested protein	37		
Endogenous protein	39	19	
Maintenance		13	
Milk production		36	198
	89	174	198
Maximum N efficiency			***0.43***

- little scope to reduce loss

Reference cow: 40 kg milk/d, milk true protein content 31.5 g/kg

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Inevitable N Losses and Milk N Output (g/d)

- efficiency of absorbed protein to milk protein often lower than maximum
- feed high energy, low protein diets
- avoid imbalance of amino acids

	ces	N urine	N milk
		35	
		71	
		19	
		13	
Milk production		36	198
Total	89	174	198
Maximum N efficiency			***0.43***

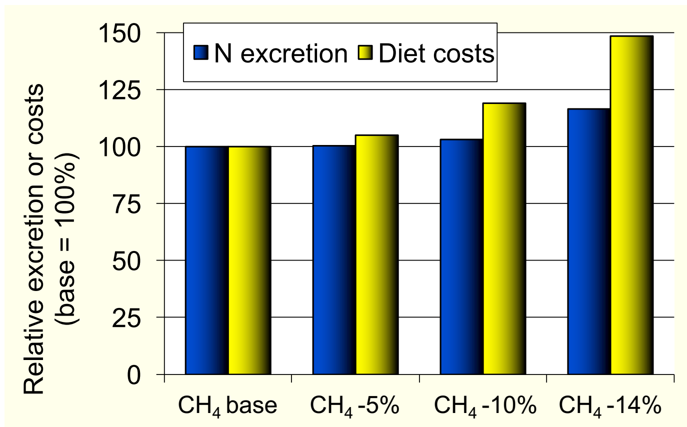
Reference cow: 40 kg milk/d, milk true protein content 31.5 g/kg

Hypothetical Diet

Source	N feces	N urine	N milk
Fermentation		35	
Microbial nucleic acids	13	71	
Undigested protein	37		
Endogenous protein	39	19	
Maintenance		13	
Milk production		36	198
Total	89	174	198
Maximum N efficiency			***0.43***

Reference cow: 40 kg milk/d, milk true protein content 31.5 g/kg

CH_4/N Excretion/diet Costs Tradeoff

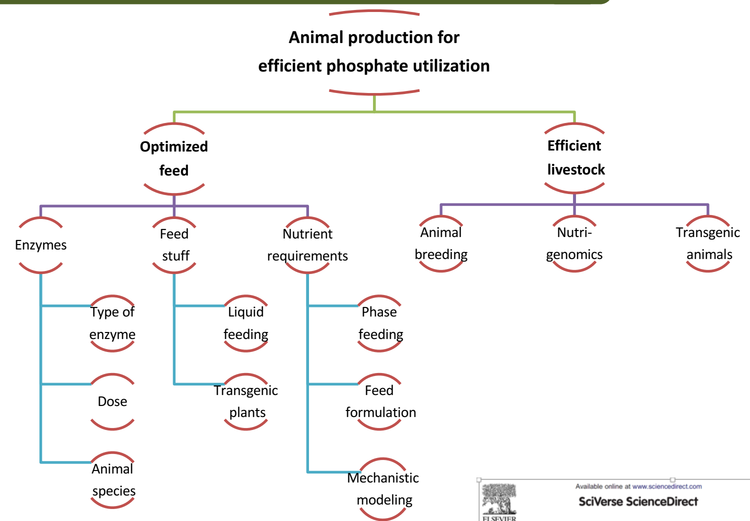


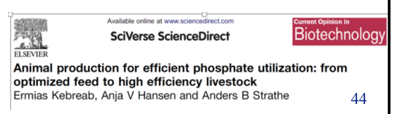
Linear programming minimum cost diet model (Moraes et al. 2012)

Phosphorus in the Environment

- Why livestock systems are sources of P?
  - Supplementation with inorganic P to feed
  - Less than 40% is utilized
  - Excess P is excreted
- P causes eutrophication
  - Excessive growth of algae and aquatic plants
  - consumes dissolved O_2 in water for aquatic animal life, drinking, recreation, etc.

Strategies to reduce P

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Current Opinion in Biotechnology

ELSEVIER

Animal production for efficient phosphate utilization: from optimized feed to high efficiency livestock

Ermias Kebreab, Anja V Hansen and Anders B Strathe

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Summary

- Air related constraints include methane emissions
  - Enteric fermentation – Few opportunities
  - Manure management - Possibilities
- Nutrient/mineral related emissions
  - N loading a concern but some options to reduce N are available
  - Phosphorus also a concern with less opportunities to mitigate

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Acknowledgments

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Thank You!

Questions?

ekebreab@ucdavis.edu

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