Nutrient losses during digestion and metabolism

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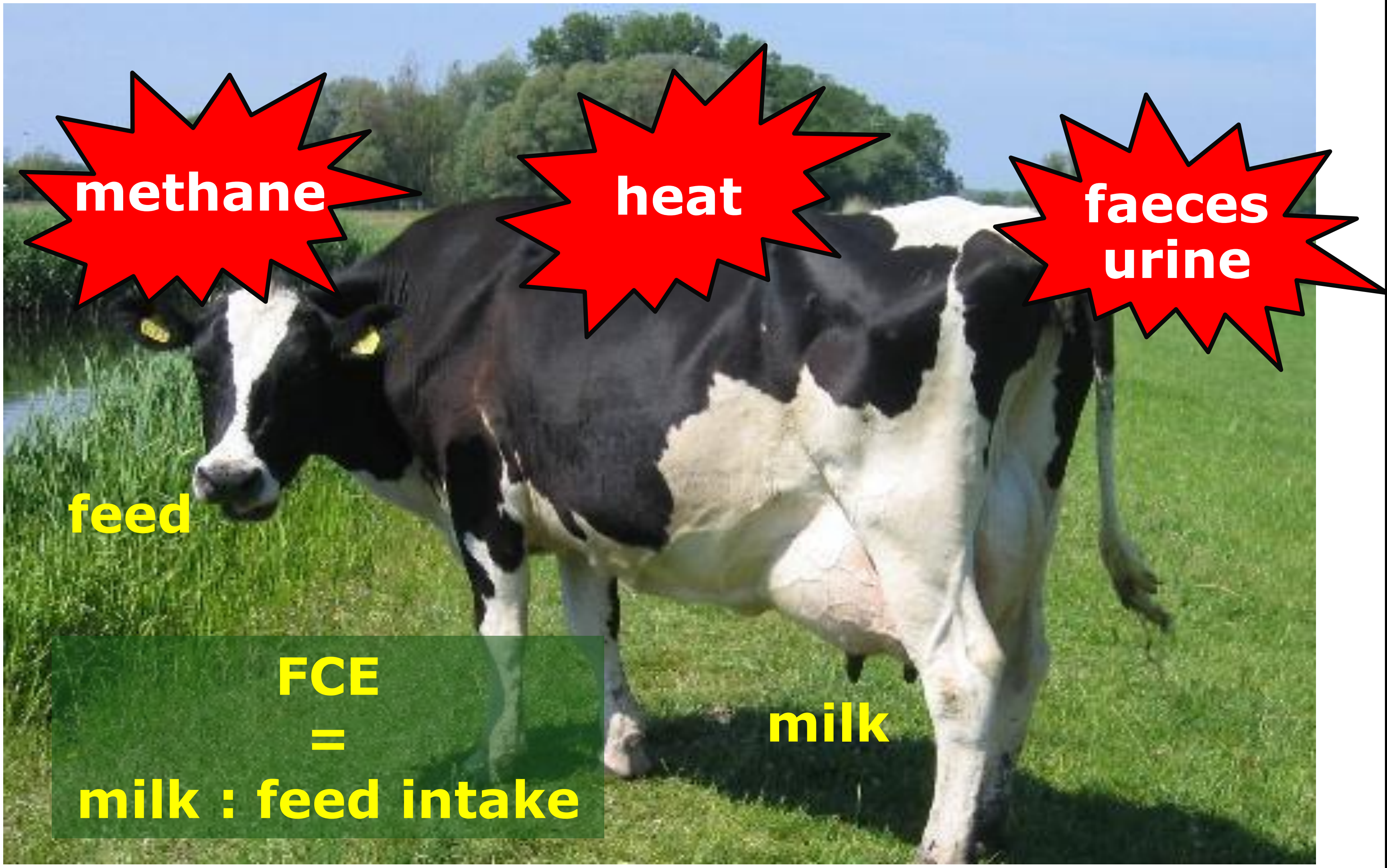
Conversion of feed into animal product



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Conversion of feed into animal product

- Feed conversion efficiency (FCE) of ruminants
  - large economic impact
  - resource efficiency
- Efficiency gain with intensive management, but potential environmental impacts and trade-offs
- Interest to improve FCE by
  - feed intake / productivity
  - feed digestion
  - post-absorptive metabolism

Key role of ruminants in human food production

- Ruminants convert human inedible plant resources into high quality human edible food
- Return on human edible protein input > 1

Source	Country	Dairy
Baldwin (1984)	USA	1.8
CAST (1999)	Kenya	∞
	South Korea	14.3
Dijkstra et al. (2013)	Netherlands	3.4

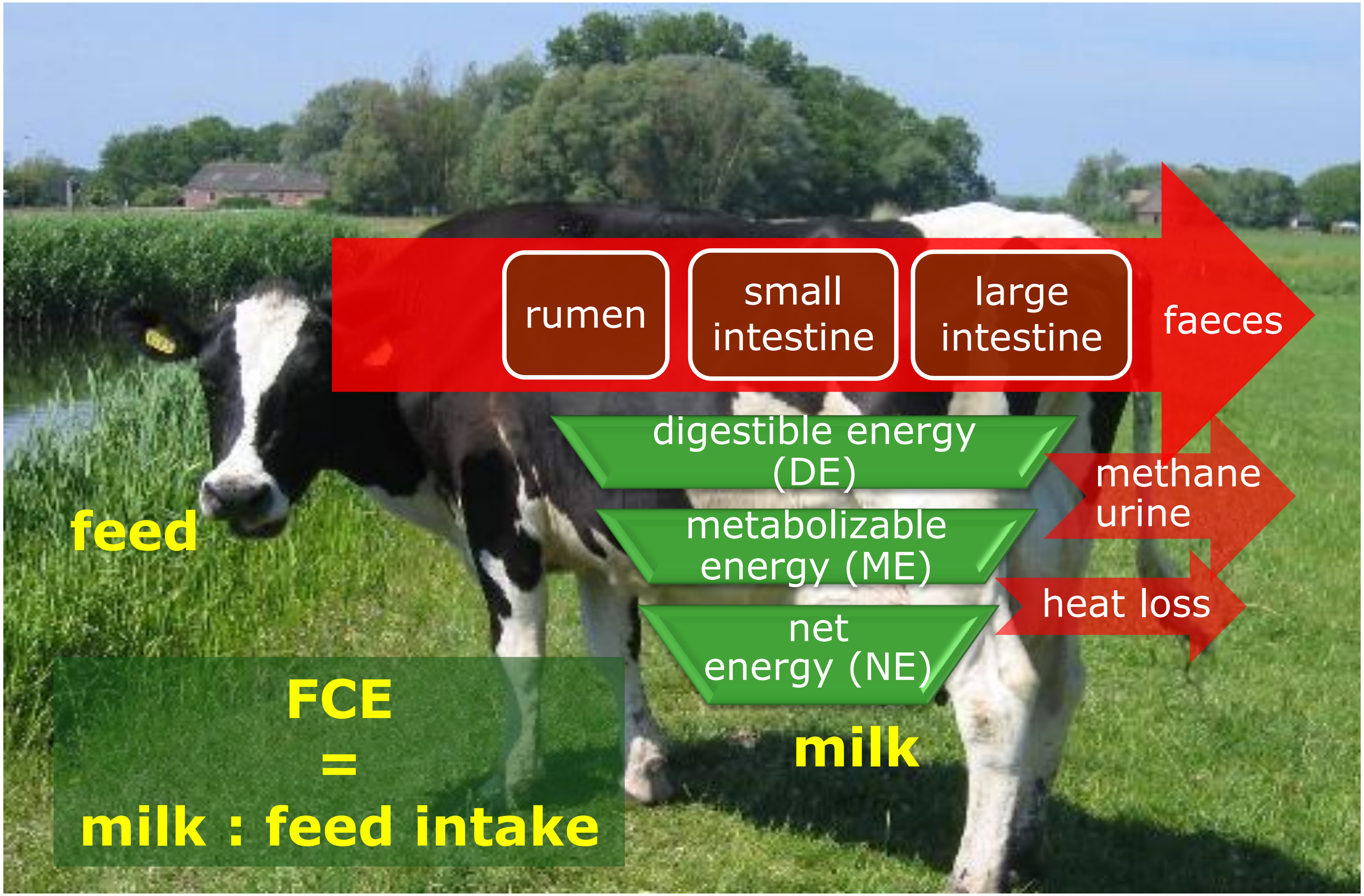
Return: output human edible products / human edible input feed

This presentation

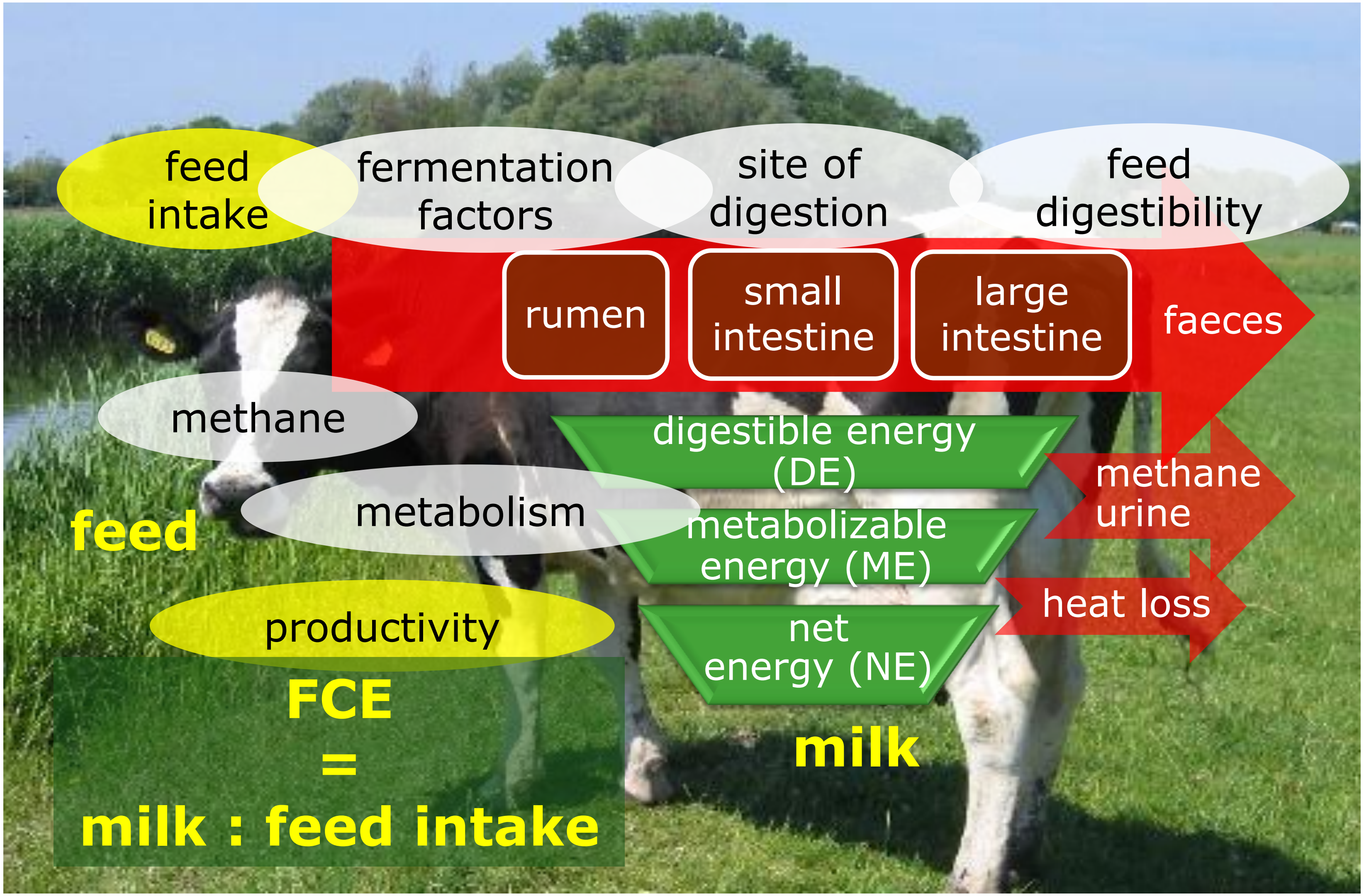
Focus on sources of variation in efficiency of feed utilisation by dairy cattle

- nutrient losses during digestion and metabolism
- pre-absorptive losses: methane
- post-absorptive losses: maintenance & lactation efficiency

Conversion of feed into animal product

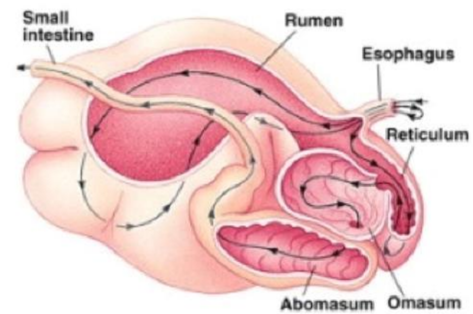


Conversion of feed into animal product



Faecal losses nutrients highly variable

- Digestible energy (DE) accounted for > 80% of variation in net energy (NE) Moe et al. (1972)
- Rumen main contributor to absorbed nutrients
  - volatile fatty acids and microbial mass
- Variation in feed digestibility: main role rumen
  - passage rate/retention time
  - feed degradability
  - rumen conditions (pH, [ammonia], structural mat)



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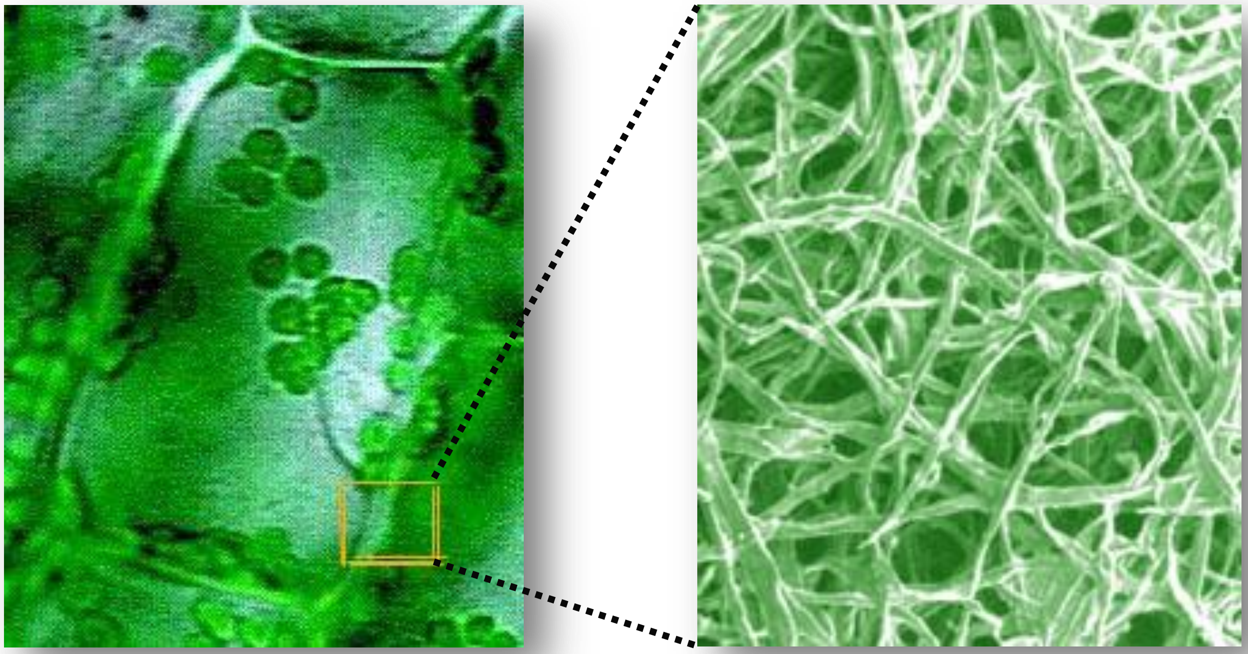
High fibre diets

- Plant structural factors
- Forage management and processing
- Silage and feed additives



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Variation post-absorptive losses

- Ratio metabolizable energy (ME) to DE relatively constant (~0.90)
  - methane
  - N-containing compounds in urine (primarily urea)
- Moderate variation in ratio net energy (NE) to ME
  - heat

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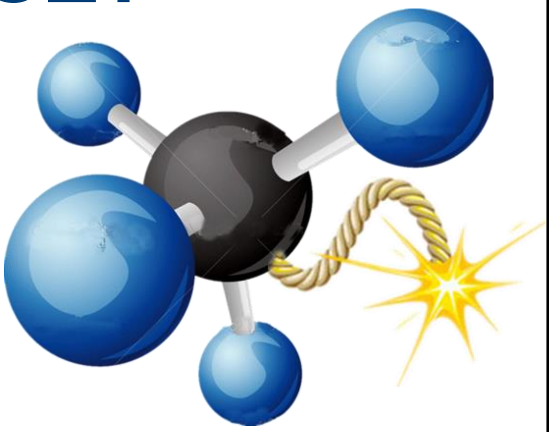
- pre-absorptive losses: methane
- post-absorptive losses: maintenance & lactation efficiency

Reduced methane: benefit to FCE?

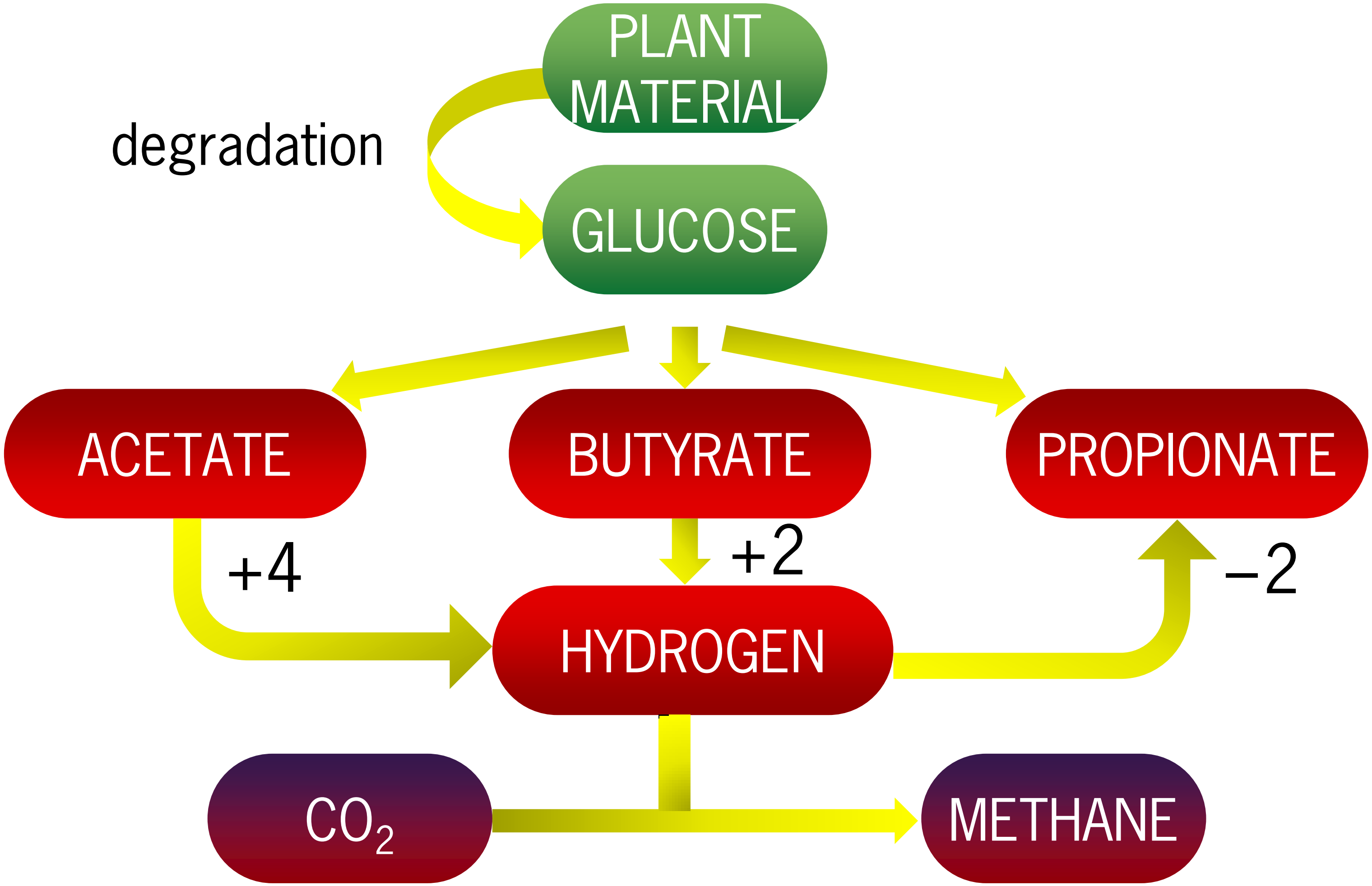


Hypothesis: reduced methane production will increase feed efficiency

Example

- dairy cow, 650 kg LW, 25 kg FPCM/d:
  FCE 1.34 kg FPCM/kg feed DM
- methane 6.5% of gross energy
- ↓ methane to ↑ metabolizable energy (ME):
  - ↓ 100% methane: ↑ 4.0 kg FPCM/d; FCE 1.55
  - ↓ 20% methane: ↑ 0.8 kg FPCM/d; FCE 1.38

Production of methane



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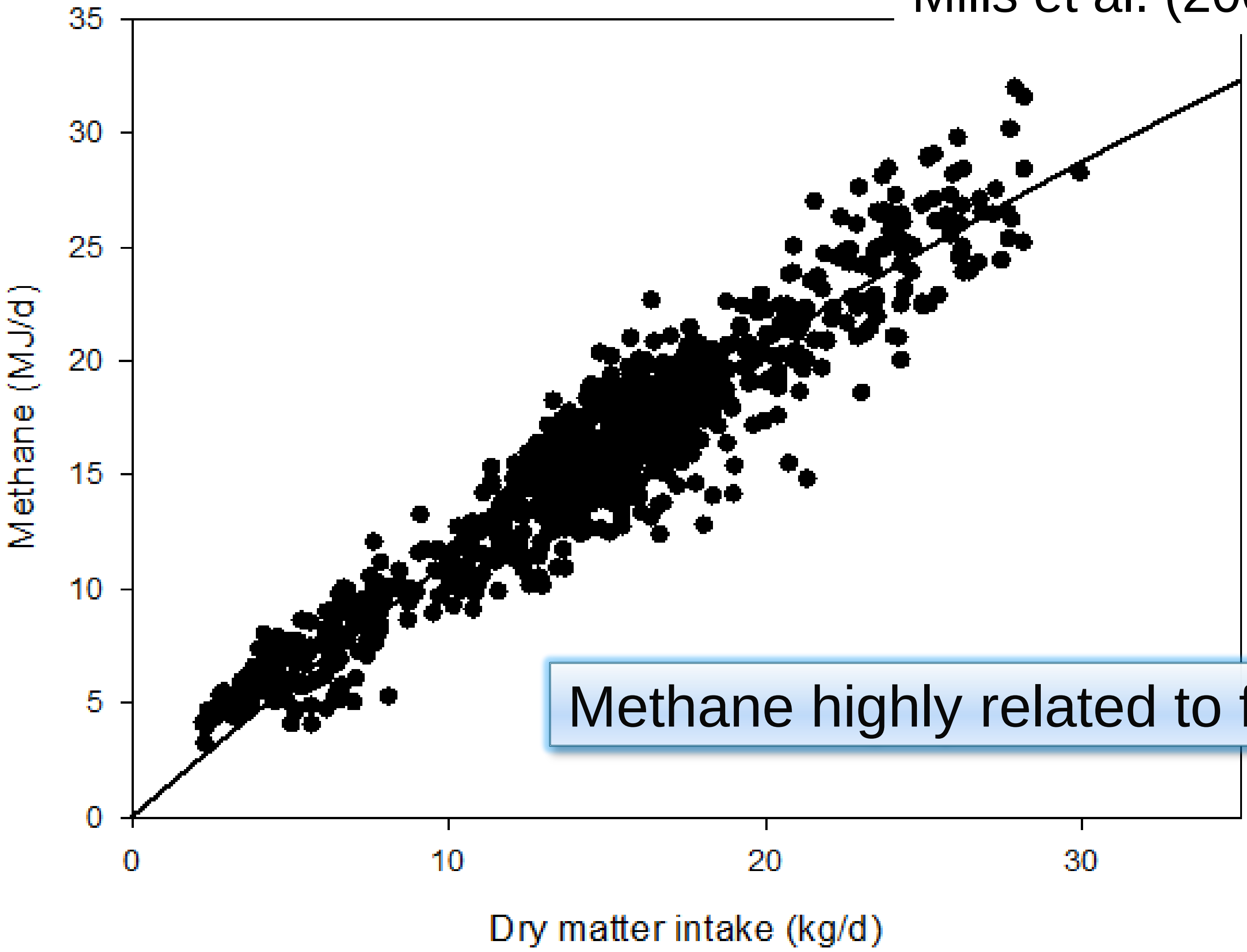
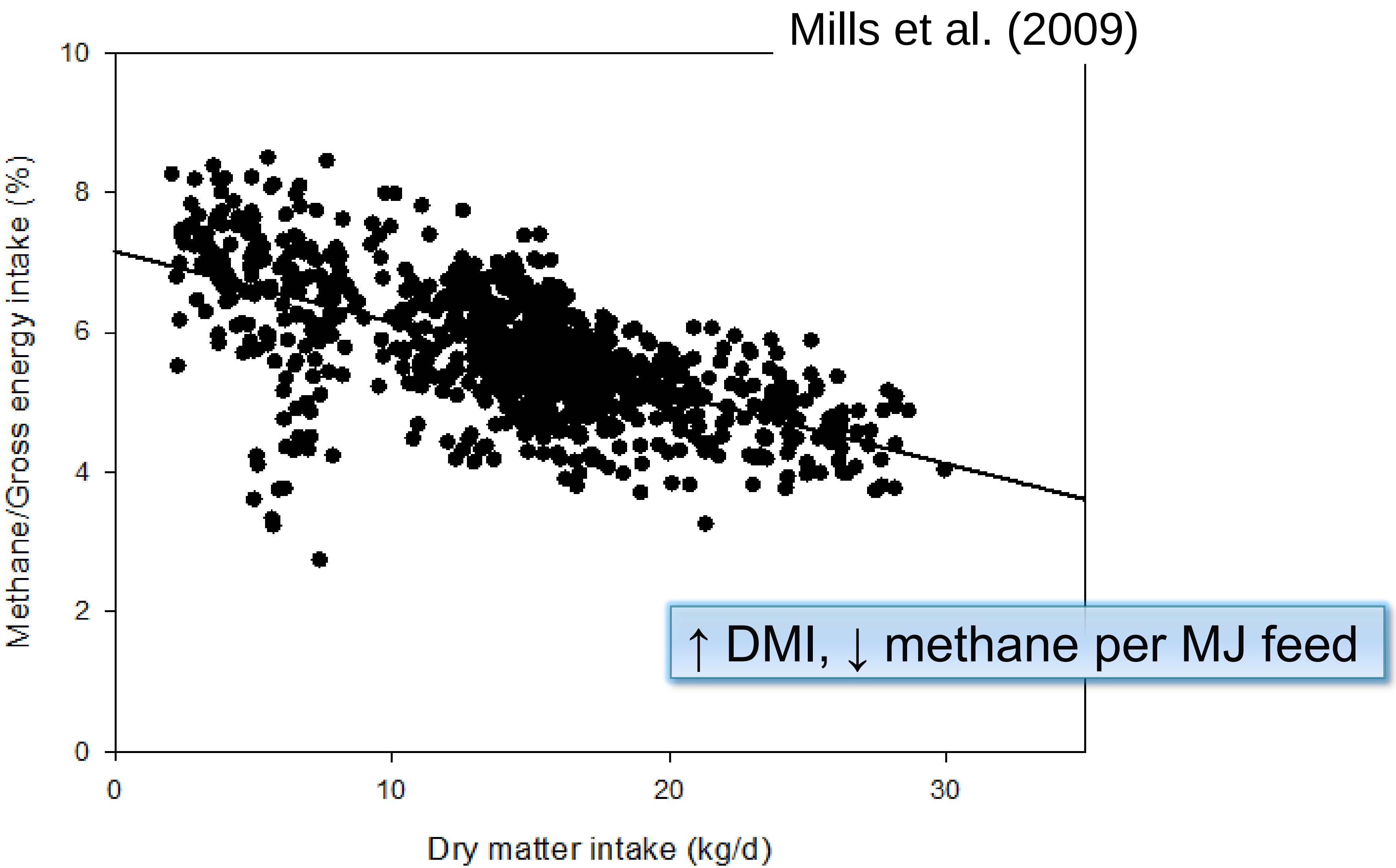
Meta-analysis: feed intake and methane

Mills et al. (2009)

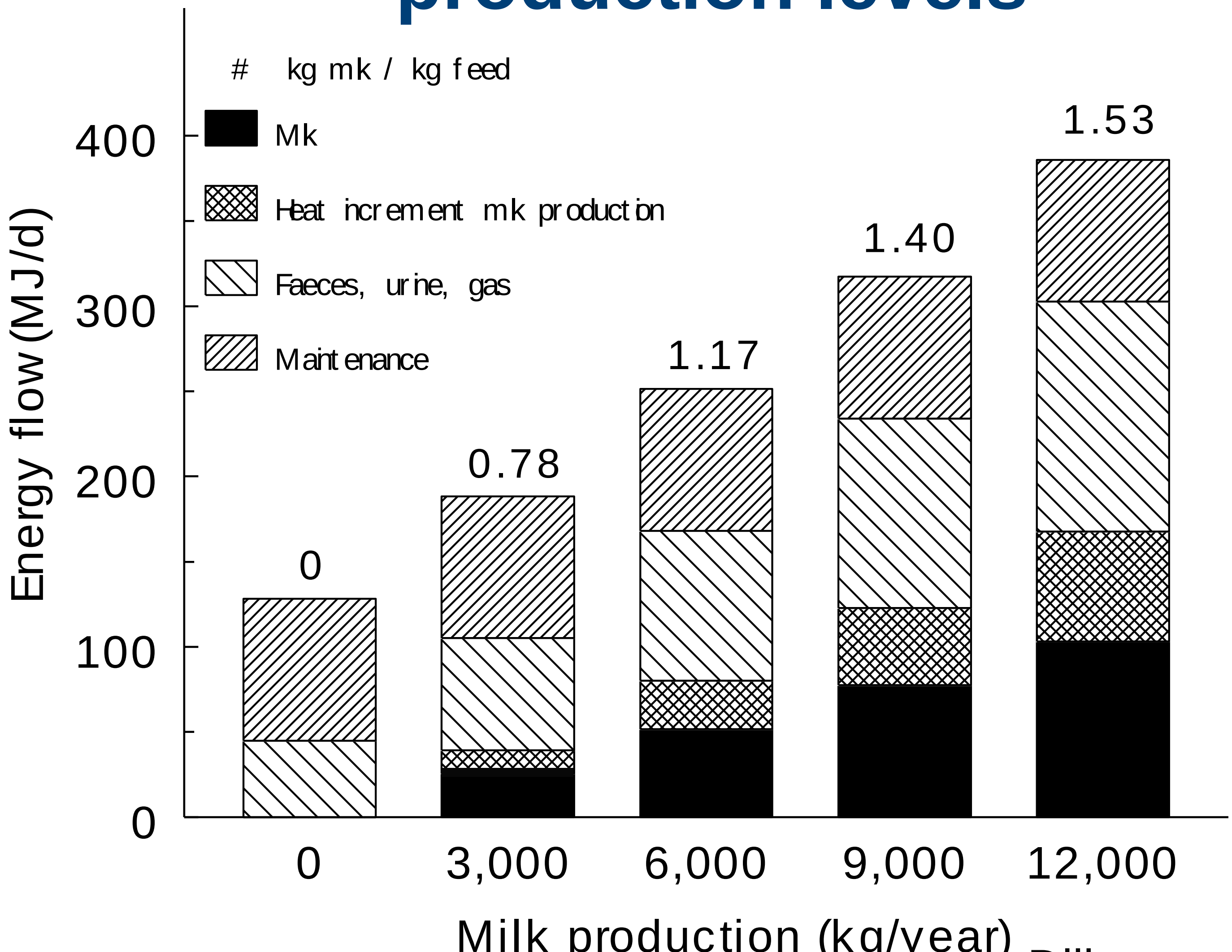


Methane highly related to feed intake

Meta-analysis: methane per MJ feed



Improved feed efficiency at high production levels



Dijkstra et al. (2013)

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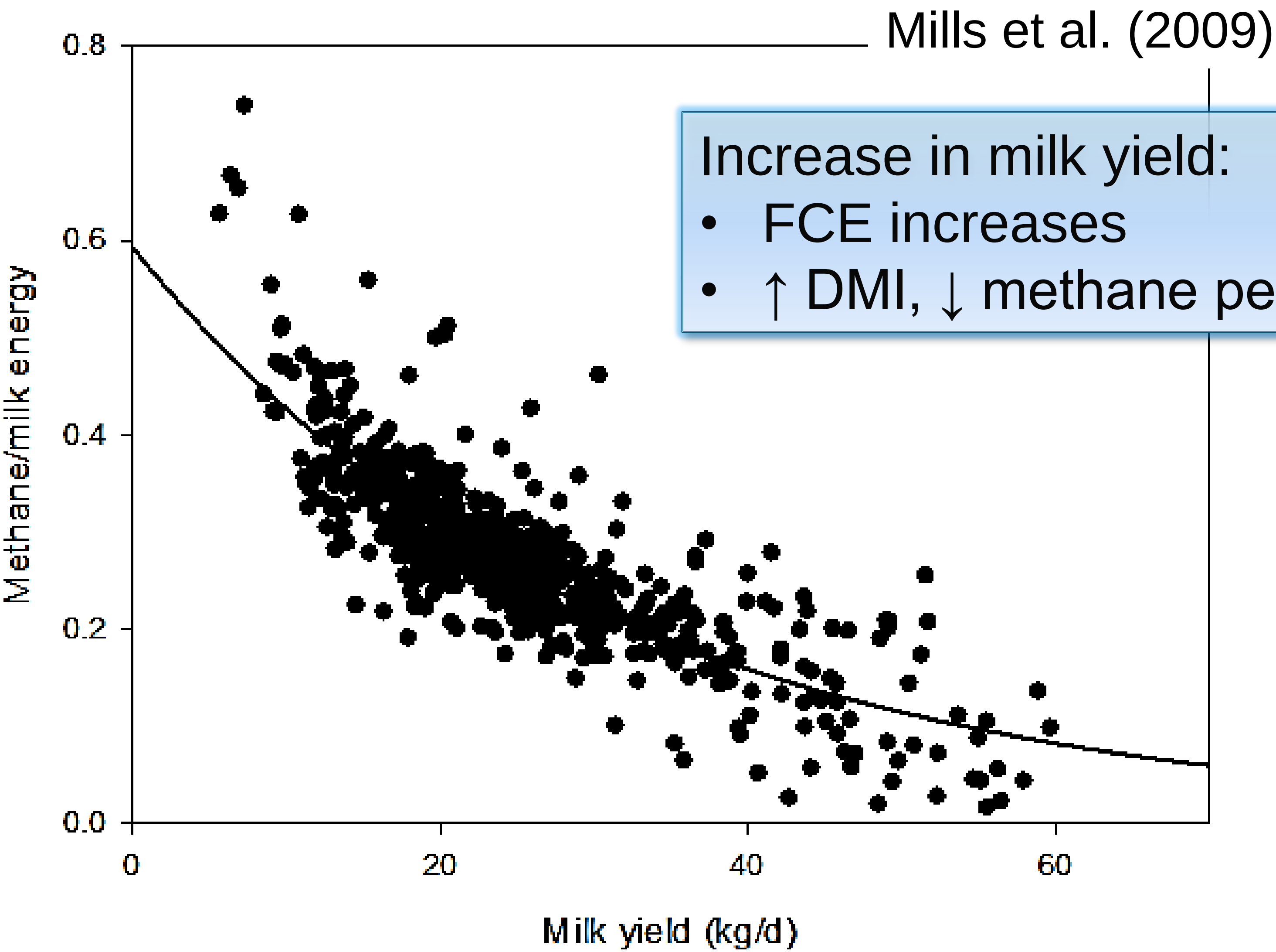
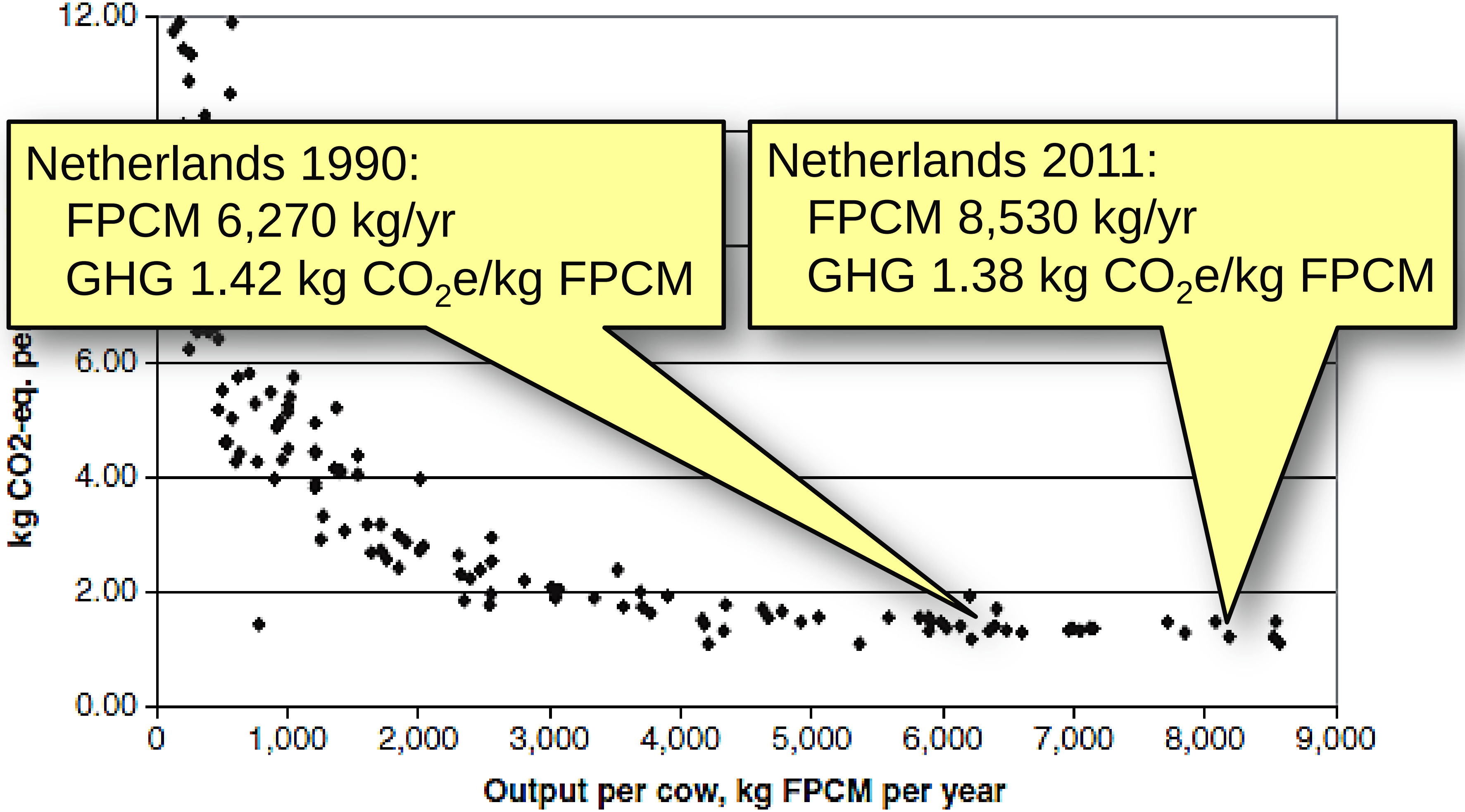
Meta-analysis: methane and milk yield



Increase in milk yield:

- FCE increases
- ↑ DMI, ↓ methane per kg DM

Limit in greenhouse gas (GHG) decline with increased milk production?



Gerber et al. (2011)

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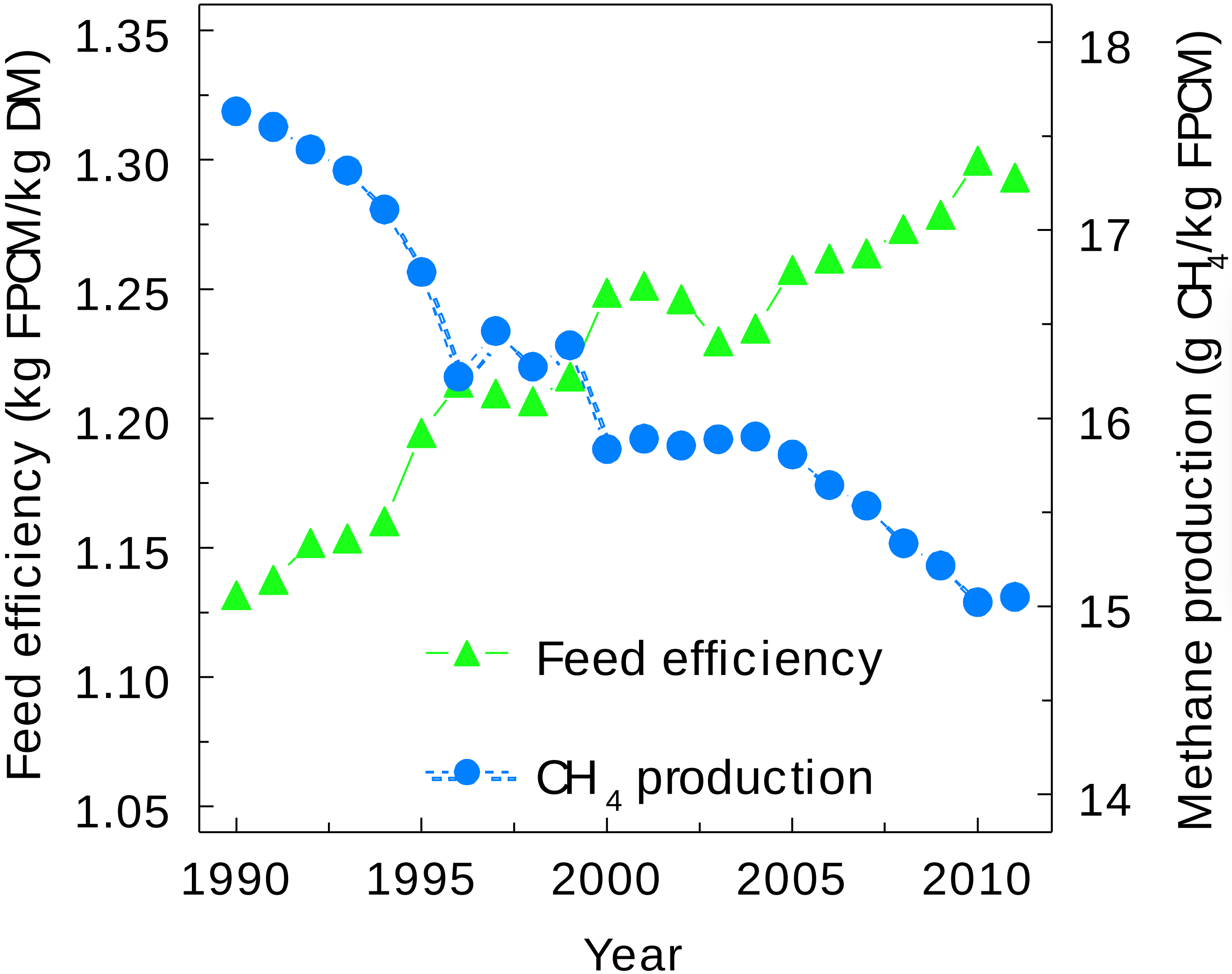
Improved feed conversion and reduced methane



- concentrate proportion diet ~
- N fertiliser ↓

Average cow Netherlands
Bannink et al. (2011)

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Roughage quality and methane production

Methane production is related with digestibility

Example: methane production at grazing

	vegetative	heading	flowering	senescent
Composition				
NDF (g/kg DM)	526	598	684	754
CP (g/kg DM)	314	132	78	44
OM digestibility (%)	77.6	74.8	63.8	56.3

Charolais cows, n=6, grazing monospecific timothy pasture, SF_6 method

Pinares-Patiño et al. (2003)

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Composition				
NDF (g/kg DM)	526	598	684	754
CP (g/kg DM)	314	132	78	44
OM digestibility (%)	77.6	74.8	63.8	56.3
Methane (g/kg)				
feed OM	22.6	24.4	23.6	22.8
OM digested	29.1	32.6	37.0	40.5

High NE content grass, low methane per unit NE

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Example: methane production at zero-grazing

	regrowth stage		N fertilization level	
	3 wk	5 wk	20 kg N/ha	90 kg N/ha
DM intake (kg/d)	14.7	14.5	14.3	14.9
FPCM (kg/d)	21.8	19.0	18.9	21.9
FCE (kg/kg)	1.49	1.31	1.33	1.47

HF dairy cattle, n=28, DIM 206, zero-grazing perennial ryegrass 85% of total diet DM, Wageningen respiration chambers

Podesta et al. (preliminary results)

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FPCM (kg/d)	21.8	19.0	18.9	21.9
FCE (kg/kg)	1.49	1.31	1.33	1.47
Methane (g/kg)				
feed DM	21.2	21.7	20.9	22.0
FPCM	14.5	16.6	15.9	15.1

High FCE, low methane per kg FPCM

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Reduced methane: benefit to FCE?

Hypothesis: reduced methane production will increase feed efficiency

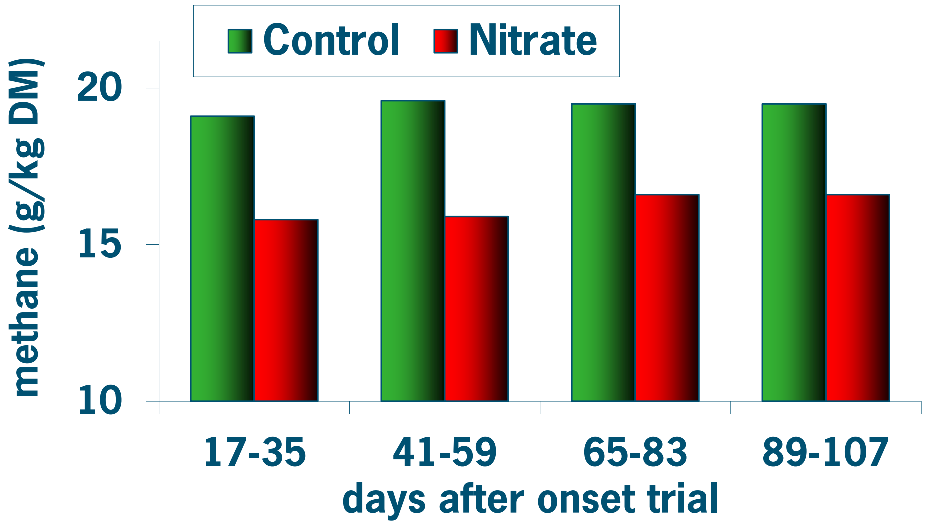
- improved feed efficiency clearly associated with less methane
  - dilution maintenance requirement
  - improved forage quality

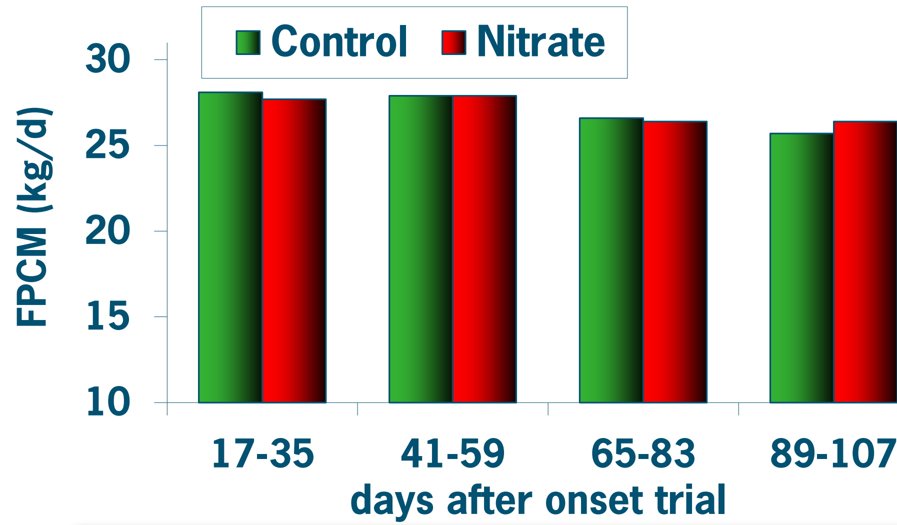
Direct mitigation of methane to improve feed efficiency?

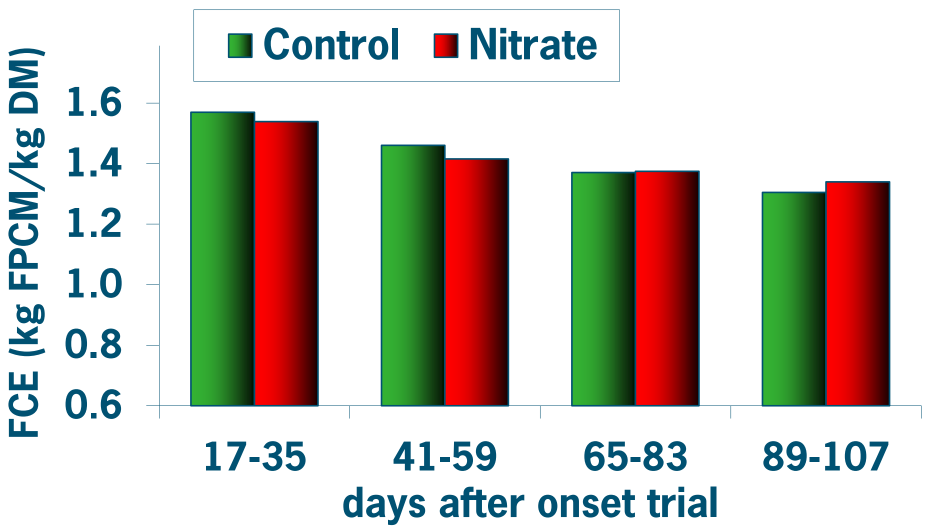
Iso-nitrogenous exchange urea and nitrate

Van Zijderveld et al. (2011)

2.1% nitrate in dietary DM
nitrate-N exch. with urea-N
20 HF dairy cows, 104 DIM
Wageningen chambers







16% reduction in methane
no effect on milk production
and feed efficiency

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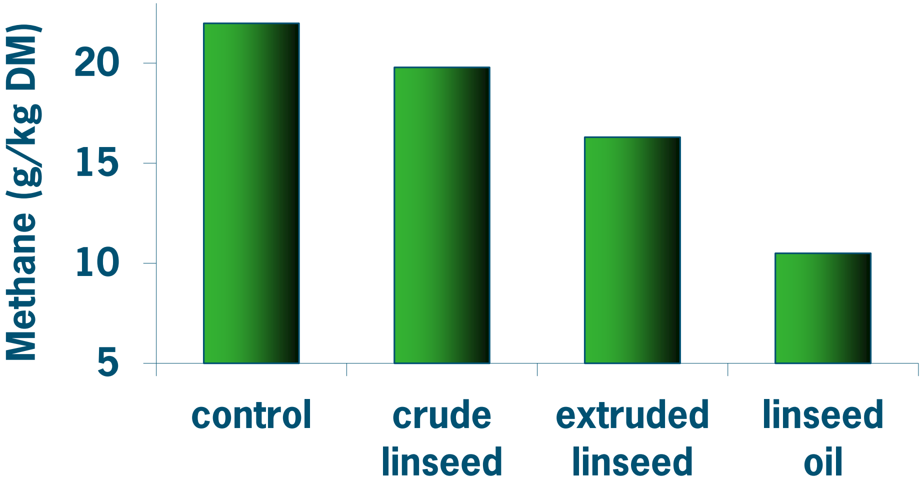
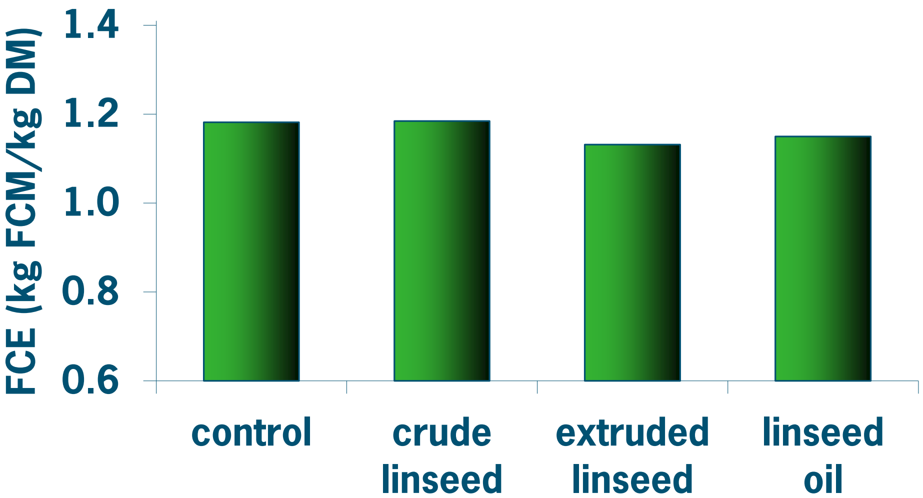
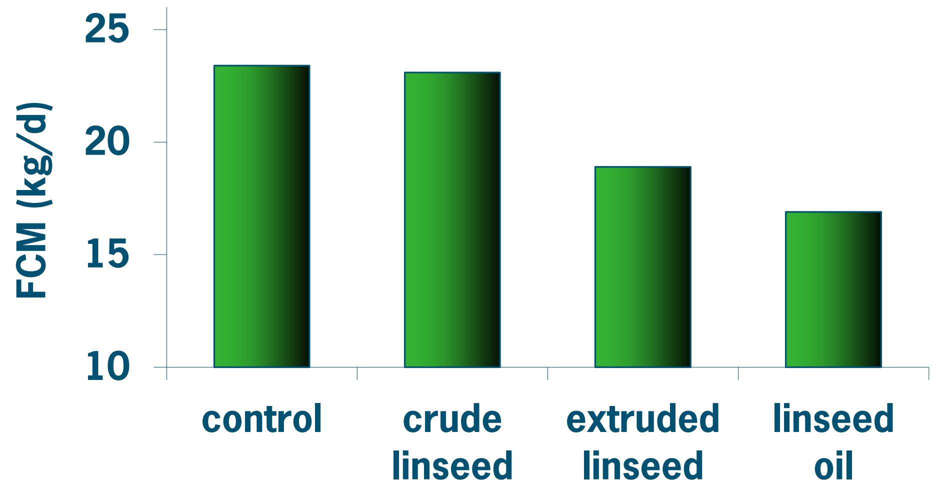
Supplementation with linseed

Martin et al. (2008)

fatty acid addition 5.7% DM
8 HF dairy cows, 213 DIM
SF_6 marker method







>50% reduction in methane
reduced milk production, and
feed efficiency not improved

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Methane and feed efficiency

- Improved feed efficiency coincides with reduced methane emission intensity
  - milk production level
  - forage quality
- Direct methane inhibition usually no improvement of feed efficiency
  - no ‘magic bullet’

This presentation

Focus on sources of variation in efficiency of feed utilisation by dairy cattle

- nutrient losses during digestion and metabolism
- pre-absorptive losses: methane
- post-absorptive losses: maintenance & lactation efficiency

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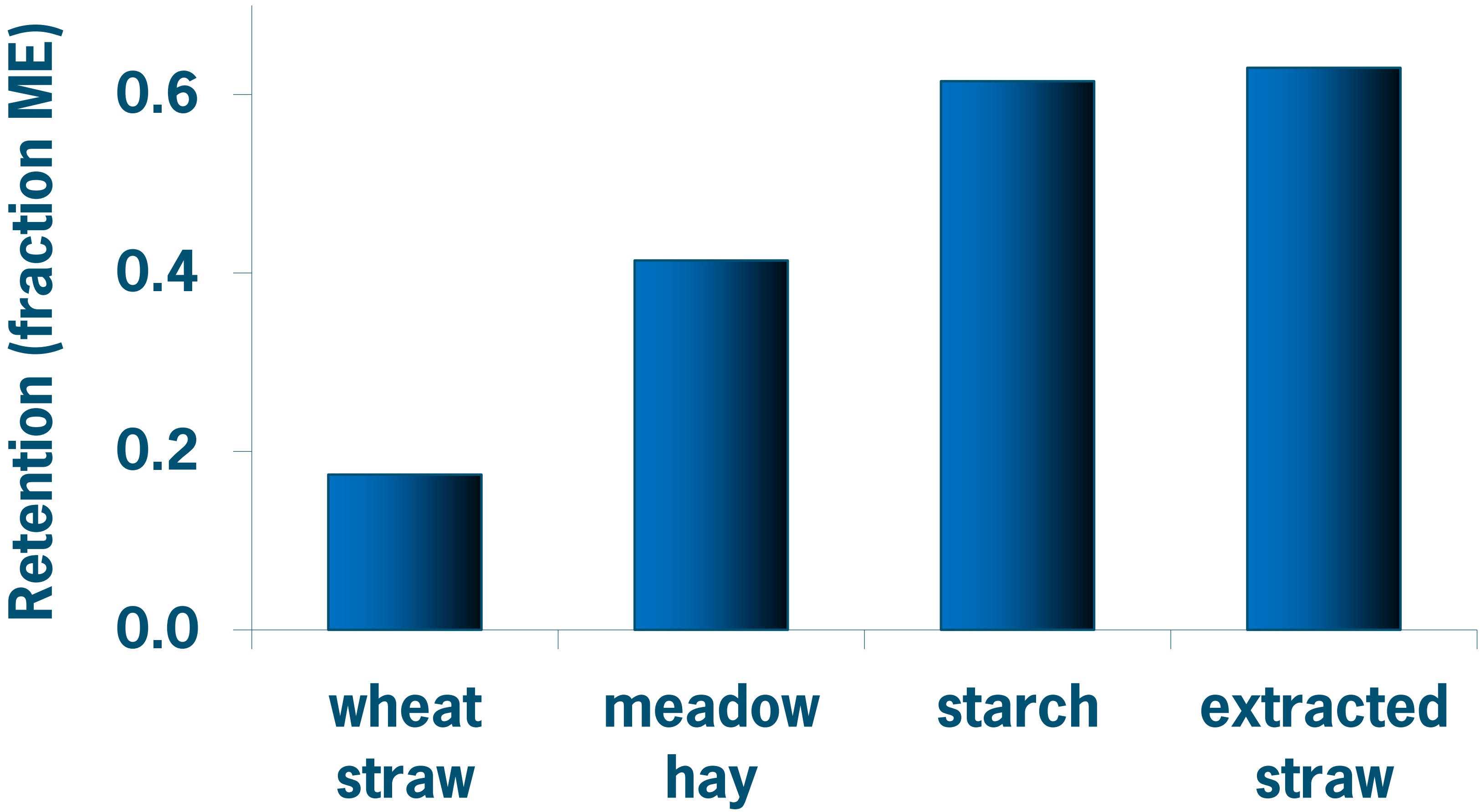
Tissue energy retention oxen



Kellner and Kohler (1900)
as cited by Reynolds (2000)

Post-absorptive losses

- Efficiency utilization absorbed nutrients into product
  - maintenance requirement
  - conversion absorbed nutrients above maintenance
- Key factor: efficiency of metabolizable energy (ME) use

Reynolds (2000)

  - roughage vs concentrate
  - forage type
  - protein level

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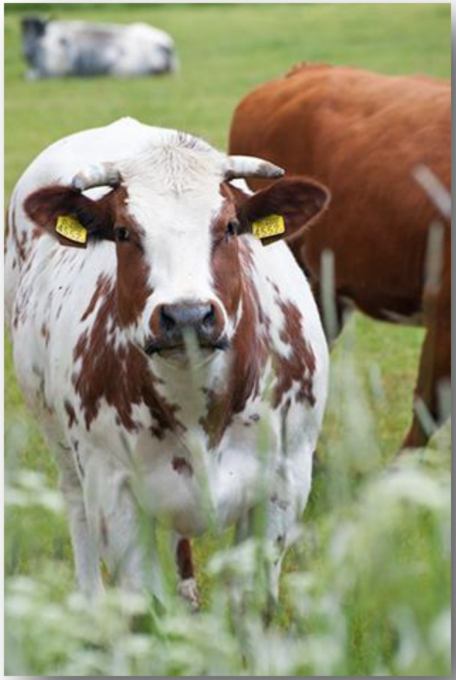
Post-absorptive losses

- Hypotheses variation in ME use
  - splanchnic tissues: ~7% of body weight but ~50% of O_2 consumption
    - high forage level / low digestibility may reflect differences in work of digestion and splanchnic mass
  - ratio of absorbed VFA
    - efficiency of absorbed acetate < propionate, butyrate
    - high forage level ↑ acetate : propionate ratio
- Efficiency of ME utilization for milk energy (k_l)
  - k_l = 0.35 ME/GE + 0.42 (AFRC, 1990; SCA, 1990)
  - k_l = 0.24 ME/GE + 0.46 (Van Es, 1978; INRA, 1989)
  - k_l = 0.12 ME/GE + 0.46 (Strathe et al., 2011)

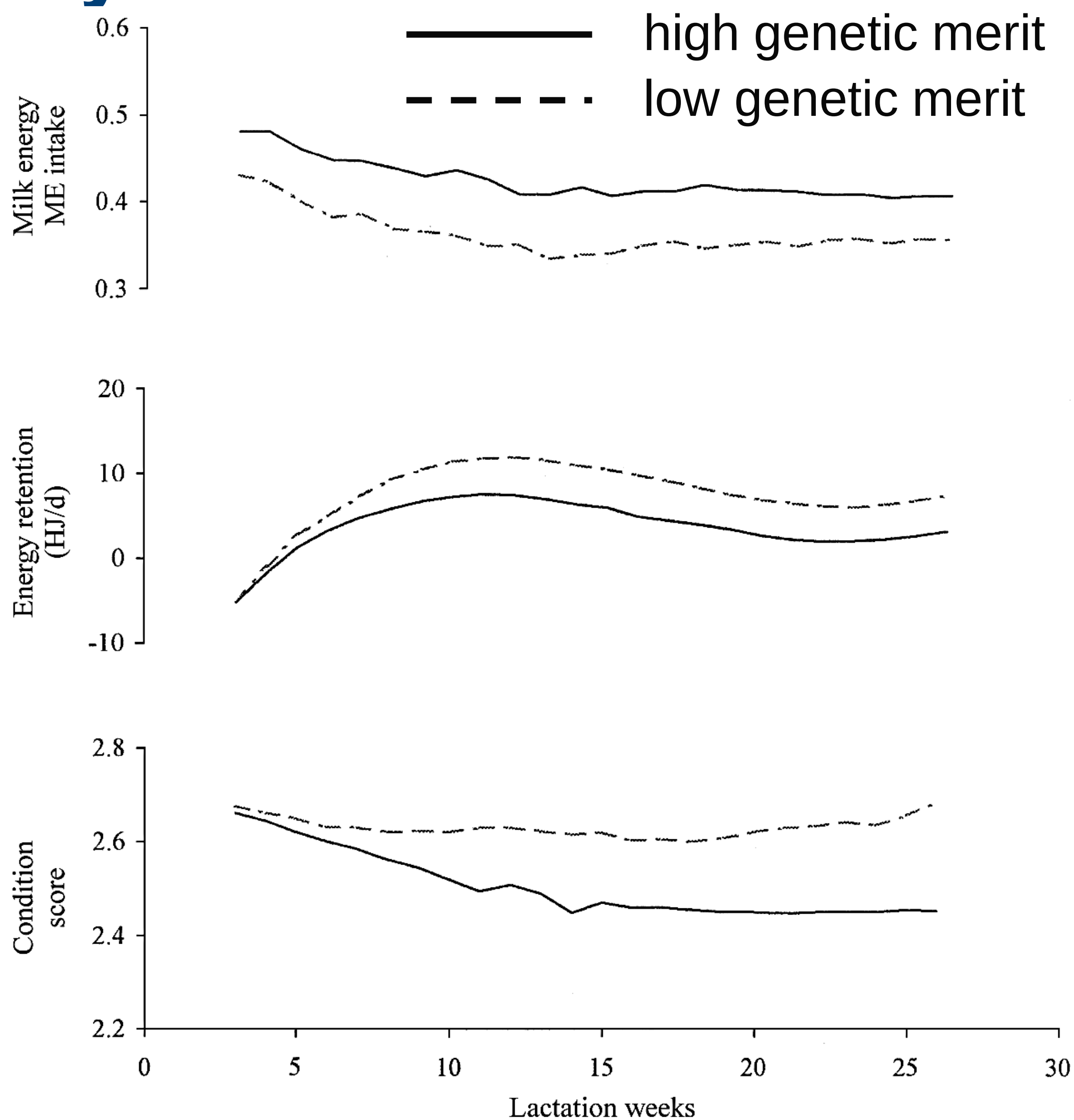
Energy utilization of today's dairy cows

- Majority energy ration systems based on studies 30 to 50 years ago
  - different diets and management
  - different animals (genetic progress)



Are today's dairy cows more efficient?

- Improved efficiency high genetic merit cows
- No difference in k_l after correction for body energy retention
- High genetic merit cows increased ability to shift partition of ME absorbed



Veerkamp et al. (1994)

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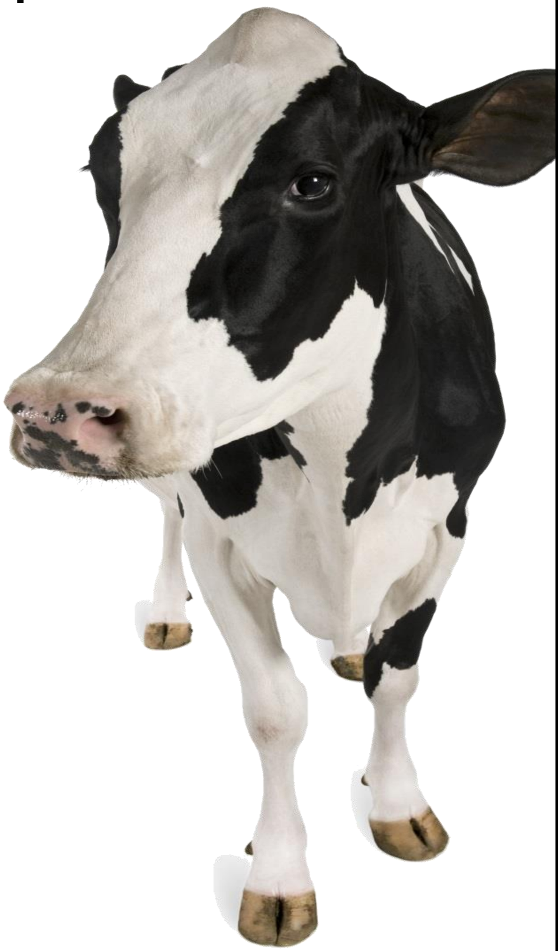
Are today’s dairy cows less efficient?

- Majority energy ration systems based on studies 30 to 50 years ago
  - different diets and management
  - different animals (genetic progress)
- Body composition may differ between traditional and modern cows
  - heat production:
    splanchnic tissues >> muscle > adipose



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Effect of approach vs data

	energy evaluation		Kebreab et al. (2003)	
	AFRC	NRC	linear	Mitscherlich
ME maintenance ($MJ/kg^{0.75}/d$)	0.49	0.51	0.65	0.59
k_l (MJ milk/MJ ME)	0.62	0.64	0.63	0.55

Kebreab et al. (2003): n=652 dairy cows, calorimetry studies UK and Ireland in 1986 to 2002

- maintenance requirement ↑
- diet and/or cow effect?

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Cow genetic merit and lactation efficiency

	UK Profit Index (PIN)		
	< £ 3	£ 3 - 15	> £ 15
	net energy maintenance (MJ/kg$^{0.75}$/d)		
common k_l : 0.632	0.449	0.434	0.441
	k_l (MJ milk/MJ ME)		
common NE_m: 0.442	0.631	0.638	0.643

Dong et al. (2013): n=736 dairy cows, calorimetry studies UK

- cow genetic merit does not affect NE_m or k_l
- univariate analysis may provide biased estimates

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Year of experiment and energetic utilization

- Analysis energy utilization dairy cattle USDA Beltsville (USA) chambers
- n=1111 cows; 45 studies
- Estimate decade specific parameters (1963-1973; 1973-1983; 1983-1995)
- Sound statistical model
  - multivariate model under Bayesian framework
  - minimally informative priors assigned to parameters
  - statistical interference based on Markov Chain Monte Carlo methods

Moraes et al. (2013)

Year of experiment and energetic utilization

	1963-1973	1973-1983	1983-1995
NE_m (MJ/kg$^{0.75}$/d)	0.25	0.31	0.41
k_l (MJ milk/MJ ME)	0.57	0.60	0.65
k_T (MJ milk/MJ body tissue)	0.87	0.91	0.89
k_G (MJ body tissue/MJ ME)	0.55	0.63	0.68

Today's cows have increased reliance on mobilised body reserves for milk production

Inefficiencies in body stores mobilization (k_T) and accretion (k_G)

⇨ loss in 40 kg BW mobilization / re-accretion ~ 250 kg FPCM

Year of experiment and energetic utilization

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NE_m ($MJ/kg^{0.75}/d$)	0.25	0.31	0.41
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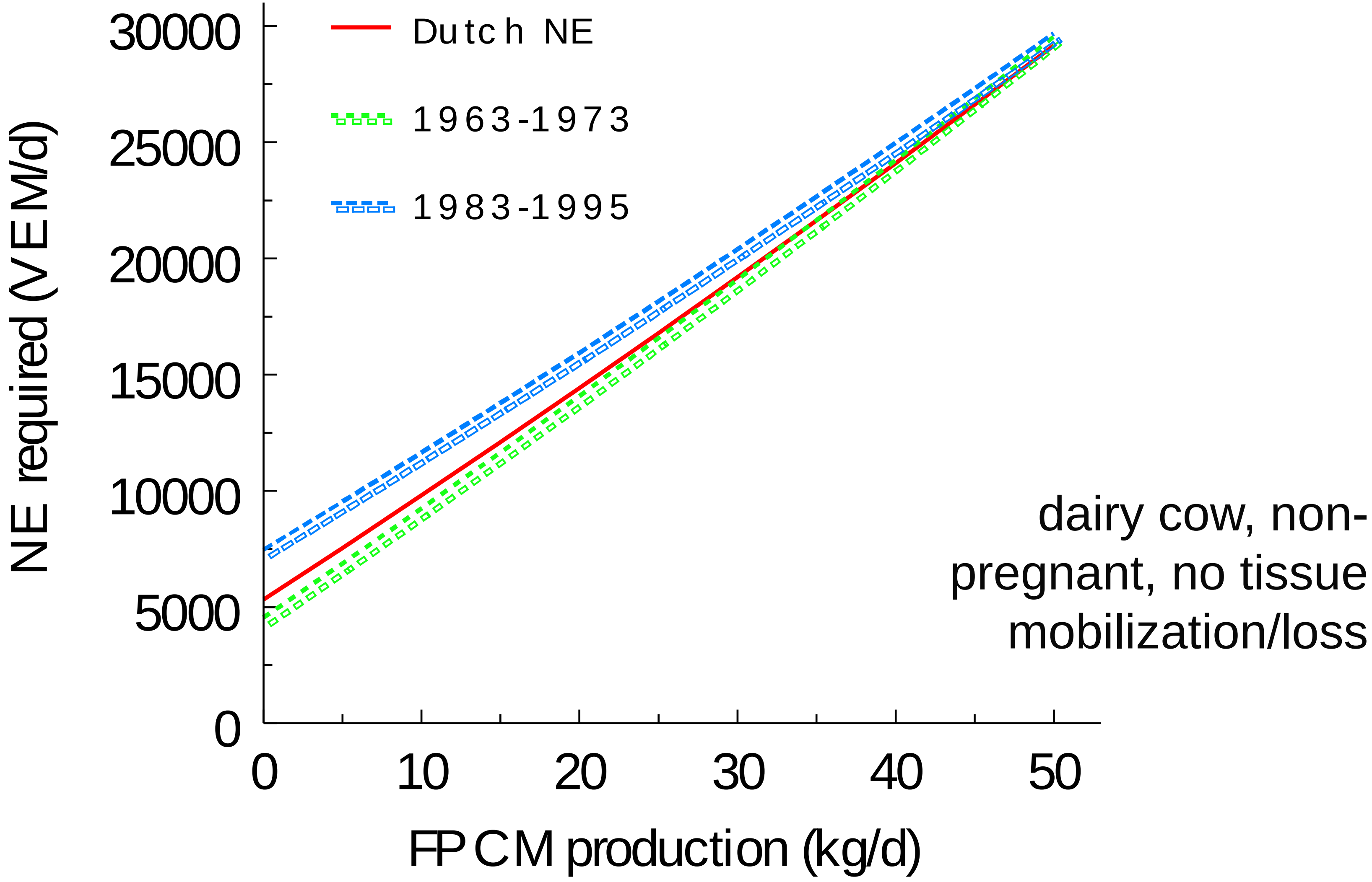
k_G (MJ body tissue/MJ ME)	0.55	0.63	0.68
NE_l system Netherlands (Van Es, 1978)			
NE_m ($MJ/kg^{0.75}/d$)		*0.29*	
k_l (MJ milk/MJ ME)		*0.58*	

preliminary results Moraes et al. (2013)

Efficiency energy utilization today's dairy cows

- Weight of evidence suggests modern dairy cattle:
  - higher feed efficiency related to dilution of maintenance effect
  - maintenance energy requirements 30 to 40% higher than currently used
  - efficiency of ME to milk energy not much different (range: -10% to +15%)
- Significant impact on FCE

Efficiency energy utilization today's dairy cows



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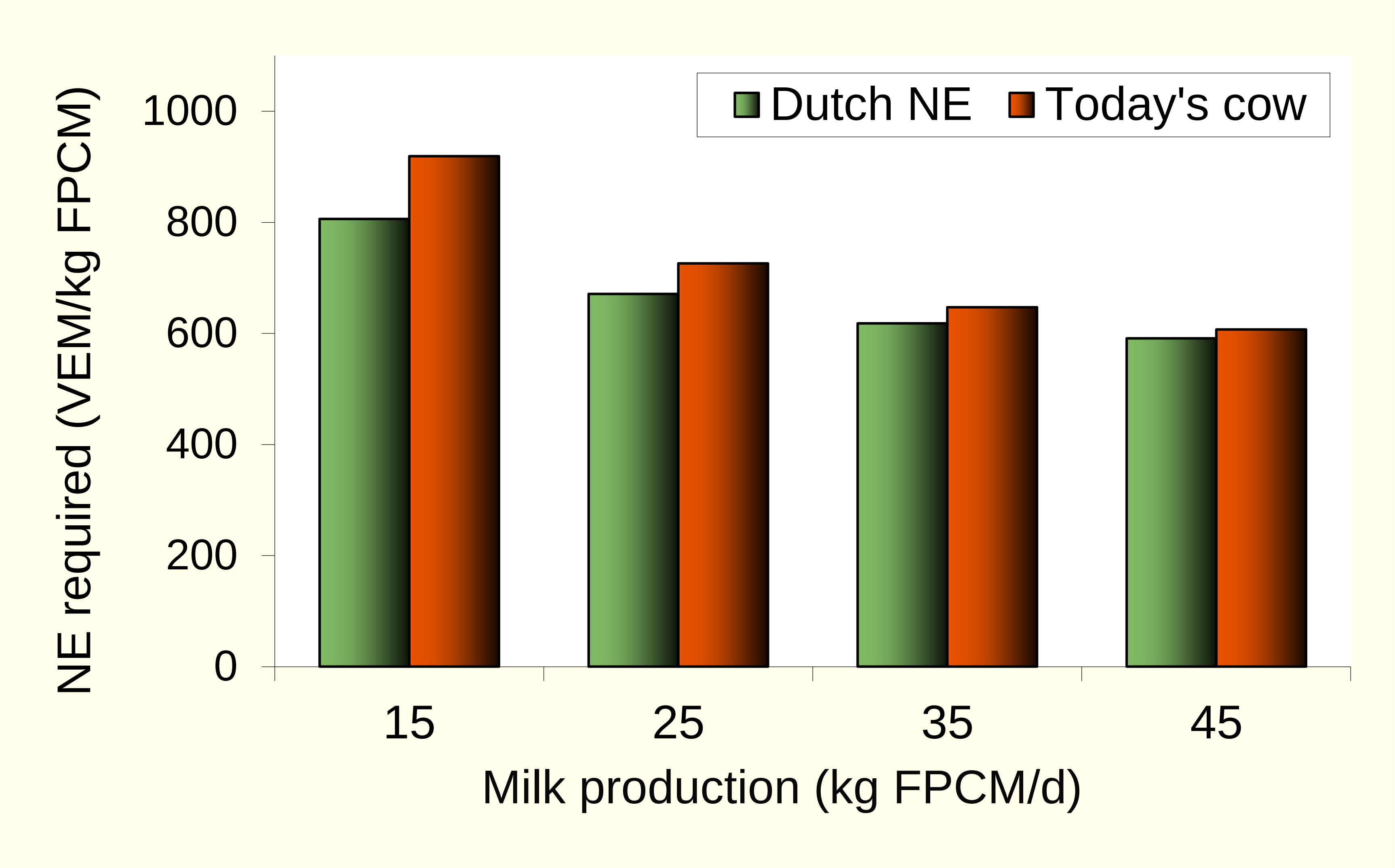
Energy required per kg milk



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Conclusions

- Key role ruminants in global food security
  - convert cell wall material into food
- Sound nutritional research into feed efficiency requires interdisciplinary, fundamental approach

  'improvement in feed conversion efficiency will depend on our ability to understand the control of nutrient metabolism, partitioning and feed intake' – Bauman et al. (1983)

Conclusions

- Focus on milk production level and forage quality for improved feed efficiency and reduced methane emission intensity
  - grass management: reduce maturity → early cutting
- Direct methane inhibition usually no improvement of feed efficiency
  - but improved feed efficiency usually reduces methane emission intensity

Conclusions

- Energetic parameters of today's lactating cows not in line with current feed evaluation systems
  - higher maintenance requirements
  - utilization of absorbed nutrients for milk (k_l) slightly more efficient
  - increased milk production even more important to improve feed conversion efficiency
  - need updated feed evaluation systems

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Acknowledgements

André Bannink and Jennifer Ellis

Wageningen University – NL

Chris Reynolds

University Reading – UK

Ermias Kebreab, Luis Moraes, James Fadel

University California, Davis – USA

James France

University Guelph – Canada

THANK YOU

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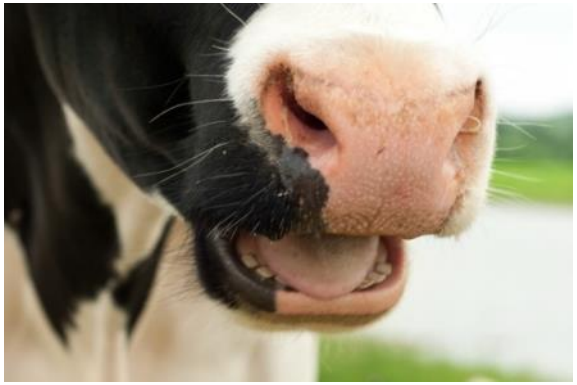

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