Proxy measures of methane: novel techniques in development

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31 Oct 11

Proxy measures of methane [in individual animals]: novel techniques in development

- Introduction
- ~~Breath~~
- Milk
- Faeces
- Other?

What is the objective?

- **Research**
  - → Experimental unit = individual animal
 - → Experimental unit = group of animals

- **Monitoring: certification**

- **Monitoring: informal**

- **Different methods may suit different purposes**

Milk fatty acid (FA) profile

- **Milk FA profile partly reflects dietary FA profile**
- **Dietary FA can affect methane production**
  - → Dilution of fermentable organic matter
  - → Consumption of H in biohydrogenation
  - → Reduction in H via partial defaunation and toxicity to cellulolytic bacteria
  - → Reduction in CH4 via effects on archaea
- **Can a simple milk FA profile predict effect of dietary FA on methane?**

Grainger and Beauchemin (2011)

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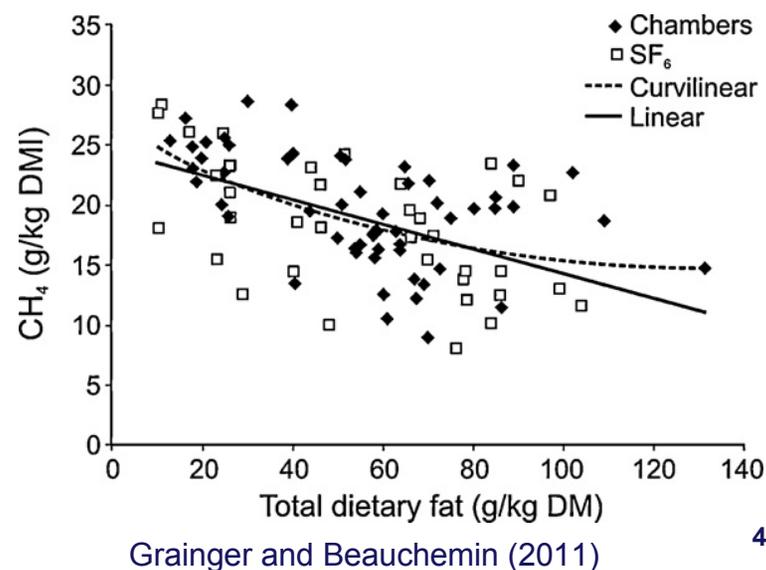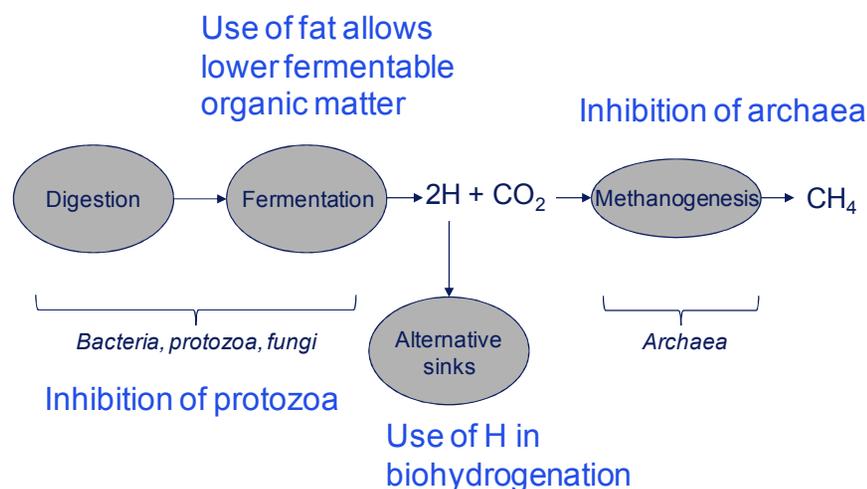
Simple milk fatty acid profile

- **Weill et al. (2009): tool to monitor effect of extruded linseed**
  - → CH_4 (g/l) = (11.368 x sum of FA <= C16:0) x ((kg milk per year)$^{-0.4274}$)

- **Chilliard et al. (2009): developed mainly from linseed experiments**

  - → Eqn. 1: CH_4 (g/d) = (9.46 x C16:0) – (9.76 x (c14C18:1 + t16C18:1)) + (13.3 x forage DMI, kg/d) – (78.3 x c9C14:1) + (77.4 x C18:2) – 21.2

  - → Eqn. 2: CH_4 (g/d) = (–100.8 x (c14C18:1 + t16C18:1*)) + (6.78 x C16:0) + (13.1 x forage DMI, kg/d) – 80.1

- **Limited inference space**

Weill et al. (2009) Patent WO 2009/156453 A1
Chilliard et al. (2009) J. Dairy . Sci. 92: 5199-5211

Odd and branched-chain fatty acids

🔵 **More complete FA profile may reflect dietary effects on specific microorganisms**

→ Selective incorporation of dietary FA into microbial lipids (bacterial cell wall)

- 'The OBCFA profile of rumen bacteria seems largely determined by the fatty acid synthetase of the micro-organism, and to a lesser extent by physiological and culture conditions.'

Fig. 1. Synthesis of odd- and branched-chain fatty acid in bacteria (based on Kaneda, 1977, 1991; Emmanuel, 1978; Annous et al., 1997). Asterisk (*) represents uptake of dietary fatty acids by rumen bacteria (Bauchart et al., 1990; Vlaeminck et al., 2006a); Double asterisk (**) represents α-oxidation of even-chain fatty acids (Emmanuel, 1978).

Vlaeminck et al. (2006) Anim. Feed Sci. Tech. 131: 389-417
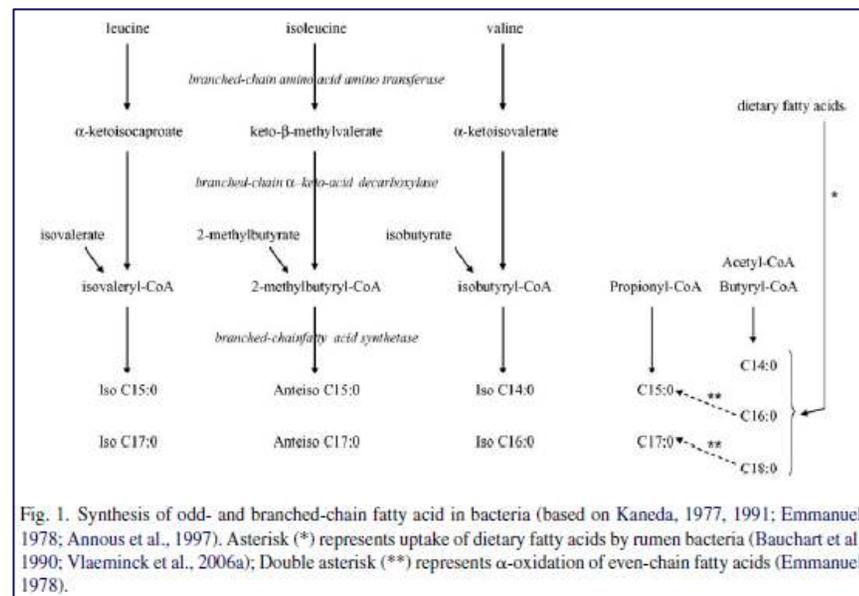
Odd and branched-chain fatty acids

- **Cellulolytic bacteria are relatively rich in iso FA**
  - → *R.albus* rich in even iso FA (isoC14:0, isoC16:0)
  - → *R.flavefaciens* rich in odd iso FA (isoC15:0, isoC17:0)
  - → But... *F.succinogenes* rich in C15:0
- **Amylolytic bacteria relatively poor in iso FA, rich in linear odd FA**
  - → C13:0, C15:0, C17:0
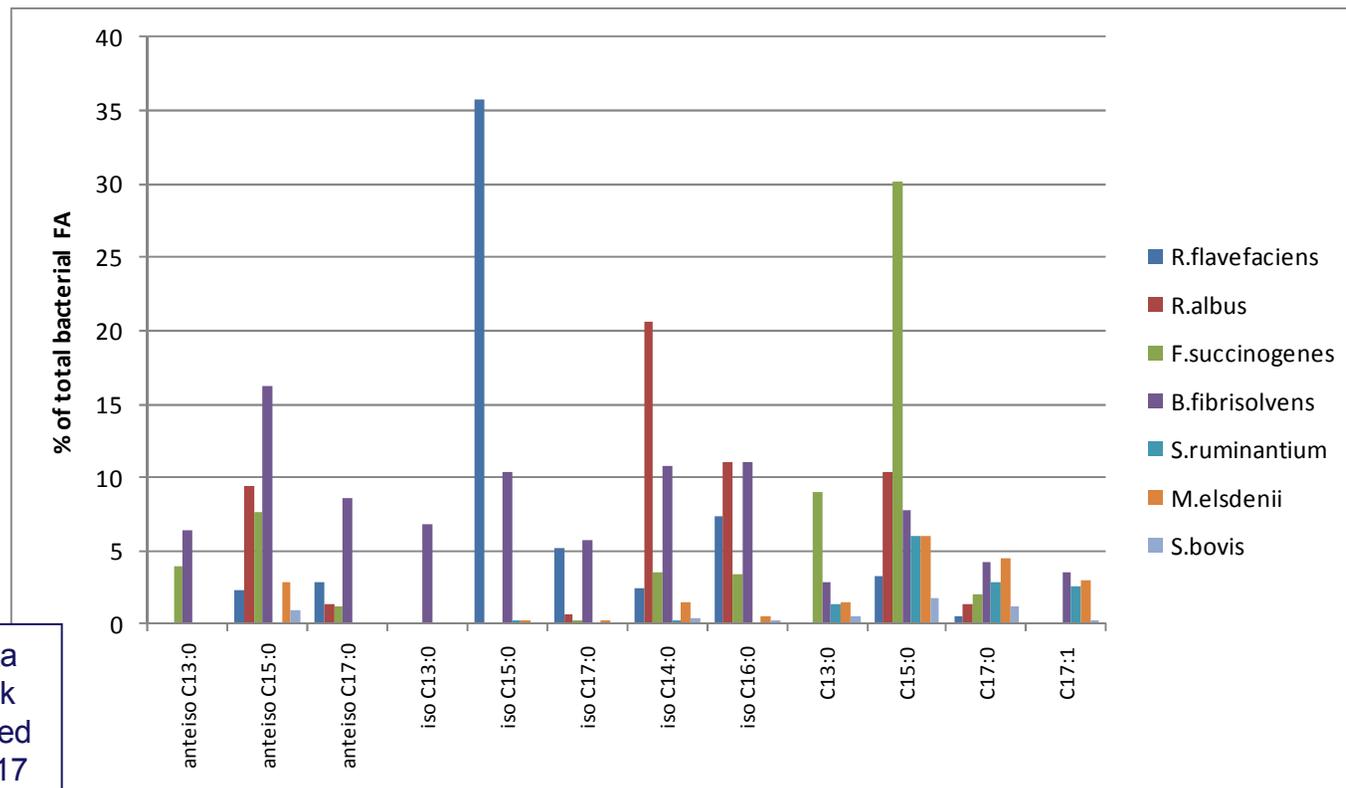
Graph drawn from data reviewed by Vlaeminck et al. (2006) Anim. Feed Sci. Tech. 131: 389-417

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More complete milk fatty acid profile

🔵 **Dijkstra et al. (2010)**

→ 3 experiments, 10 treatments, 50 observations

→ all data from open-circuit indirect respiration chambers

→ diverse dataset: fumarate, diallyldisulphide, MCFA, linseed, yucca

→ CH_4 (g/kg DM) = 24.6 + (8.74 x anteisoC17:0) – (1.97 x t10+t11 C18:1) – (9.09 x C18:1) + (5.07 x c13 C18:1)

→ r^2 = 0.73

Relationship with methane

| Positive	Negative	None
iso C14:0	trans 10+11 C18:1	C15:0
iso C15:0 anteiso C17:0		C17:0

More complete milk fatty acid profile

🔵 **Castro Montoya et al. (2011)**

→ 13 experiments, 224 observations

→ Methane calculated stoichiometrically from VFA proportions, assuming constant H balance of 0.9

→ Dataset mainly forage source and forage:concentrate ratio (not lipids and feed additives)

Relationship with methane

Positive	Negative
iso C14:0	trans 10+11 C18:1
iso C15:0	C15:0
anteiso C17:0	C17:0+C17:1

Three modelling methods

Castro Montoya et al. (2011) Anim. Feed Sci. Tech. 166-167: 596-602
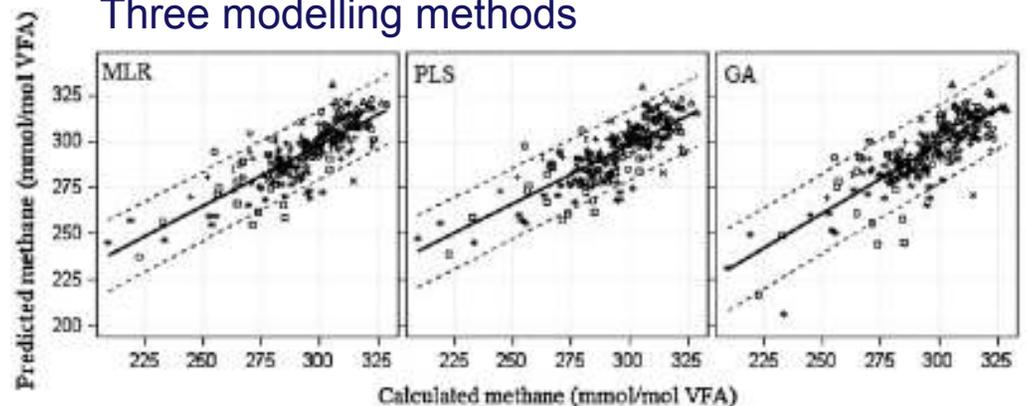
Prediction of methane from milk fatty acid profile

- **All modelling exercises conducted so far have been limited in scope and scale**
  - → use of narrow databases = small inference space
  - → different methods of measuring (or calculating) methane

- **New data being generated**
  - → e.g. ILVO/Ghent University

- **Do sufficient data now exist, globally, for a renewed modelling effort?**

- **Or is there another way?...**

Prediction directly from milk MIR spectra

- **Methane measured by SF6**
- **Methane predicted from milk MIR spectra measured at day 0, 0.5, 1, 1.5 and 2**
- **Spectra from day 1.5 gave best prediction**
- **'There is also a close correlation between FA profile and methane emission at d 1.5. However...applying directly the developed methane equation gives a better prediction than the use of correlation between FA and methane.'**
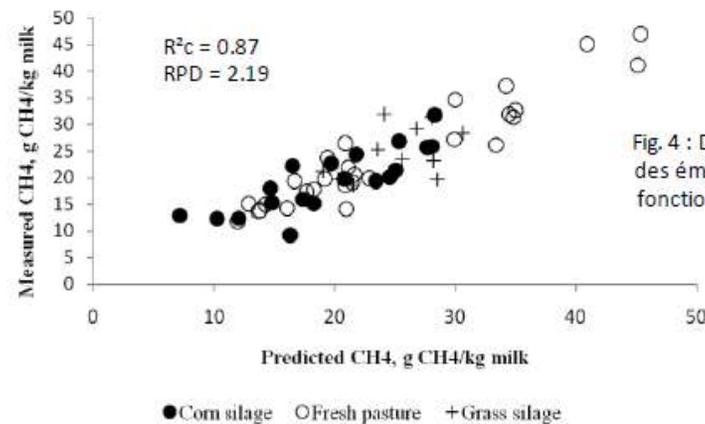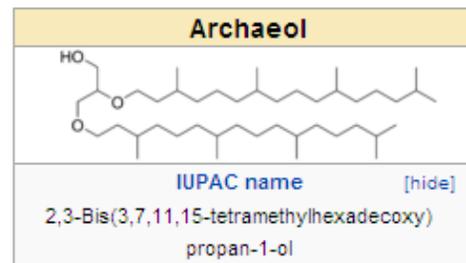

Fig. 4 : Droite de régression linéaire des émissions de CH_4 mesurées en fonctions des prédites au jour 1.5.

● Corn silage   ○ Fresh pasture   + Grass silage

Vanlierde et al. (2011) J. Dairy Sci. 94(S1): 757. Graph from:
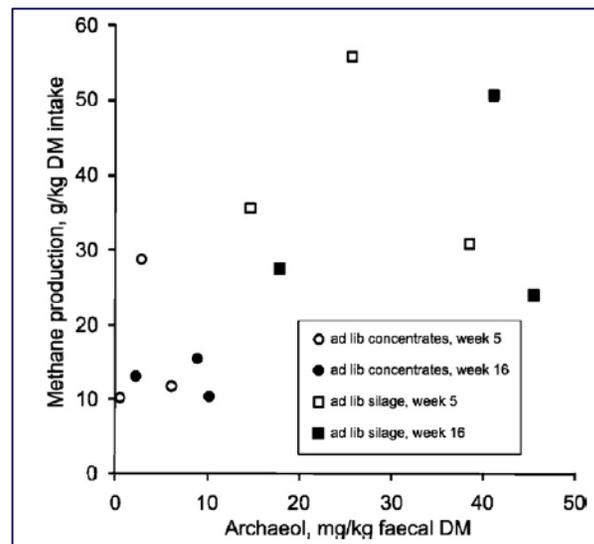http://www.fsagx.ac.be/zt/Manifestation/PDF/Carrefour%202011/Poster/P12_Methamilk.pdf m

Prediction of methane from faecal analysis

- **Bacterial membrane lipids**
  - → Glycerol, phosphate, 2 x fatty acids (ester links)
- **Archaeal membrane lipids**
  - → Glycerol, phosphate, 2 x isoprenoid chains (ether linked)
  - → Archaeol is simplest example

- **Does the appearance of archaeol in faeces correlate with methane production?**

Archaeol

IUPAC name   [hide]

2,3-Bis(3,7,11,15-tetramethylhexadecoxy) propan-1-ol

Gill et al. (2011) Anim. Feed Sci. Tech. 166-167: 87-92

Prediction of methane from faecal analysis

- **12 steers, high versus high concentrate plus grass silage**
- **Methane measured by SF6**

- **Generally poor relationship**
  - → Measurement error
  - → Variation in methane production rate per archaeon
  - → Not all archaea are methanogens

Gill et al. (2011) Anim. Feed Sci. Tech. 166-167: 87-92

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Cow methane proof 'is in the pat'

Research suggests the amount of methane that ruminants such as cows produce is correlated to quantities of a molecule in their faeces called archaeol.

Methane production by ruminants is a large unknown, and is relevant in climate science as it is a powerful greenhouse gas.

Current methane measurement methods are labour-intensive or invasive.

The new work, **in Animal Feed Science and**

The discovery is one step toward quantifying animals' contributions to greenhouse gases

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Conclusion

- **Different methods may suit different purposes**

- **Milk**
  - → Too early to conclude that prediction from milk FA profile won't work, at least for monitoring
  - → Prediction directly from MIR spectra holds considerable promise
- **Faeces**
  - → Initial studies with archaeol not encouraging

- **Other approaches?**
  - → I'm only reading the literature
  - → What do the practitioners think?