Relationships between Methane Emissions and Milk Production Traits: An Unfinished Story

Nicolas Gengler, Hadi Atashi

University of Liège - GxABT, Animal Sciences

Gembloux, Belgium

Introduction

- Important:
  - Reducing methane emissions in dairy cattle (environmental concerns) **+ efficiency ← concern of producers**
- However:
  - Relationship between methane emissions and milk production traits?
- Aim of this presentation:
  - Explore associations between milk production traits and methane emissions

Background

- Methane:
  - A potent greenhouse gas contributing to global warming
- Dairy Sector:
  - A significant source of methane emissions
- Previous Studies:
  - Mixed results on the relationship between milk traits and methane emissions
- **Spoiler** ➔ we will not solve the issue…. 😉!

Objectives of This Presentation

- Give a fast overview of current knowledge
  + **mathematical derivations**
- Investigate genetic and phenotypic correlations between methane emissions and milk production traits in our Walloon population
- Assess potential trade-offs between reducing methane emissions and maintaining milk production

Key Terms and Definitions

- Milk Production Traits:
  - MY = (daily) milk yield
  - FP = (daily) fat percentage — FY = (daily) fat yield
  - PP = (daily) protein percentage — PY = (daily) protein yield
- Methane Emission Traits:
  - ME = (daily) methane emissions
  - MI = (daily) methane intensity = ME / unit of output ← mostly MY
    - Often replaced by ln(MI) hereafter called LMI (logarithm monotonic increasing)
  - MD = (daily) methane yield = ME / unit of input ← mostly DMI

What to Expect for Methane Emissions (ME) ?

- Theory:

MY ↗ → DMI ↗ → ME ↗

- But:
  - Even if higher feed intake ➔ greater total methane emissions ?
  - Complex situation as outlined in ICAR Guidelines
    https://www.icar.org/Guidelines/22-Appendix-2-Prediction-equations-for-feed%20intake-feed-efficiency-and-methane-for-dairy-cattle.pdf

Appendix 2 of Section 22 of the ICAR Guidelines - Prediction equations for feed intake, feed efficiency and methane for dairy cattle

- Alternative idea:
  - **CH_4 Efficiency** ➔ ME - Expected(ME)

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What to Expect for Methane Intensity (MI)?

- Ratio trait MI = ME / MY
  - Variation to MY on numerator or denominator?
  - A possibility to have a clearer view by defining derivative in function of MY:

$$\frac{d(MI)}{d(MY)} = \frac{1}{MY} \times \frac{d(ME)}{d(MY)} - \frac{ME}{MY^2}$$

- Consequence:

MI $\nearrow$ with ME $\nearrow$ when MY $\nearrow$ only if $\frac{1}{MY} \times \frac{d(ME)}{d(MY)} > \frac{ME}{MY^2}$

  - NB: clear why geneticists do not like MI (or Ln(MI) = LMI)

$$\frac{d(LMI)}{d(MY)} = \frac{1}{ME} \times \frac{d(ME)}{d(MY)} - \frac{1}{MY}$$

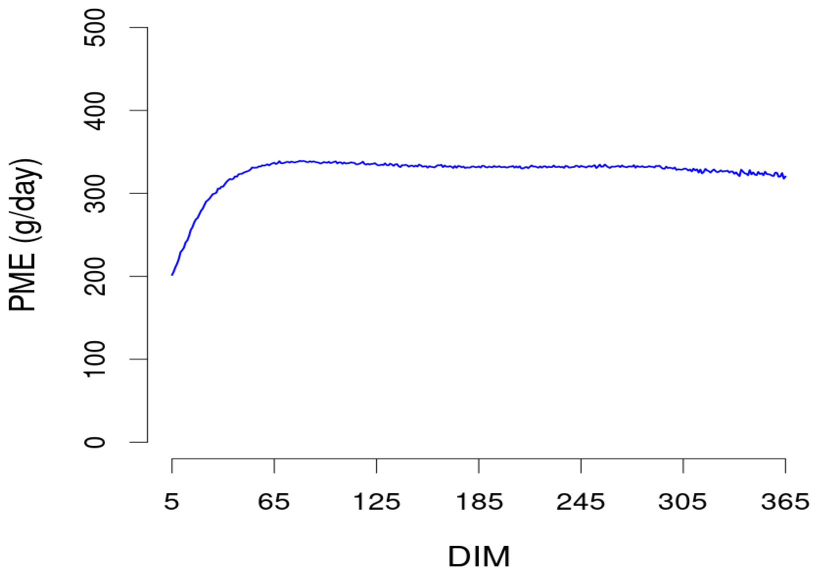
Milk Yield or Milk Energy?

- Milk energy output → total energy content (reflecting fat, protein + **lactose**)

- Why milk energy output?
  - Methane produced during the digestion process (enteric fermentation)
  - Closely tied to how cows convert feed into energy

- By focusing on the energy content
  → better understanding of efficiency of feed utilization (+ relation to ME)

Lactation Stage?



- Well know ME shows
  ➔ rather typical lactation curve

- Reasons
  - Variation in feed intake + negative energy balance
  - Changes in feed (feeding adjusted to lactation stage)
  - Changes in rumen microbial activity (in general)

- Hypothesis
  - As milk production level (and composition) changing
    ➔ correlations between MY and ME not constant

Different Methods CH_4 ➔ ≠ Correlations?

Table 1. Summary of the main features of methods for measuring methane output by individual animals [1].

Method	Purchase Cost [2]	Running Costs [2]	Labour [2]	Repeatability	Behaviour Alteration [3]	Throughput
Respiration chamber	High	High	High	High	High	Low
SF_6 technique	Medium	High	High	Medium	Medium	Medium
Breath sampling during milking and feeding	Low [4]	Low	Low	Medium	None	High
GreenFeed	Medium	Medium	Low	Medium	Low	Medium
Laser methane detector	Low	Low	High	Low	Low-Medium	Medium

[1] Consensus views based on experiences of METHAGENE WG2 members. [2] Per measuring unit or group of animals. [3] Compared to no methane recording: low = measuring in situ; medium = some handling, training or change in routine; high = confinement. [4] Medium if using FTIR analyser.

Comparison of Methods to Measure Methane for Use in Genetic Evaluation of Dairy Cattle *animals*

by Philip C. Garnsworthy [1,*], Gareth F. Difford [2,3], Matthew J. Bell [1], Ali R. Bayat [4], Pekka Huhtanen [5], Björn Kuhla [6], Jan Lassen [2], Nico Peiren [7], Marcin Pszczola [8], Diana. Sorg [9,10], Marleen H.P.W. Visker [3] and Tianhai Yan [11]

Animals **2019**, *9*(10), 837; https://doi.org/10.3390/ani9100837

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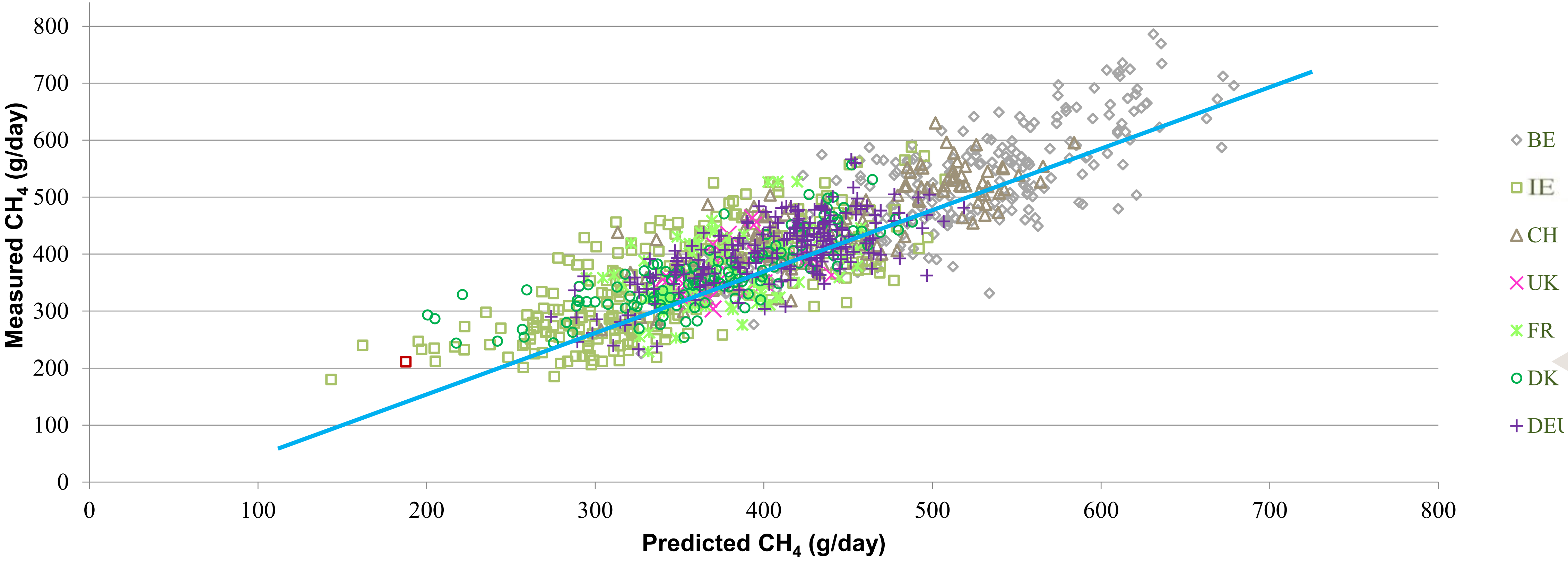
MIR-Based Equation (Used in This Study)



CH_4 Ref. method	n data	n cows	Origin	R^2c	SEC (g/d)	R^2cv	SECV (g/d)
SF_6 & RC	1,089	299	BE, IE, CH, UK, FR, DK, DE	0.73	53	0.68	57

Material & Methods

- Test-day records from routine milk recording collected between 2007 to 2021 in 1,530 Walloon herds
  - 1,529,282 records on 229,465 1st parity cows
  - 1,062,013 records on 151726 2nd parity cows
  - 642,735 records on 90484 3rd parity cows

- MY, FY, PY, FP, PP + MIR-based CH_4 data (PME and ln(PME/MY) = LMI)

- Random regression test-day ssGBLUP models
  - Genetic parameters estimated through Gibbs sampling
  - Genomic data available for 7,375 animals (1,798 males)

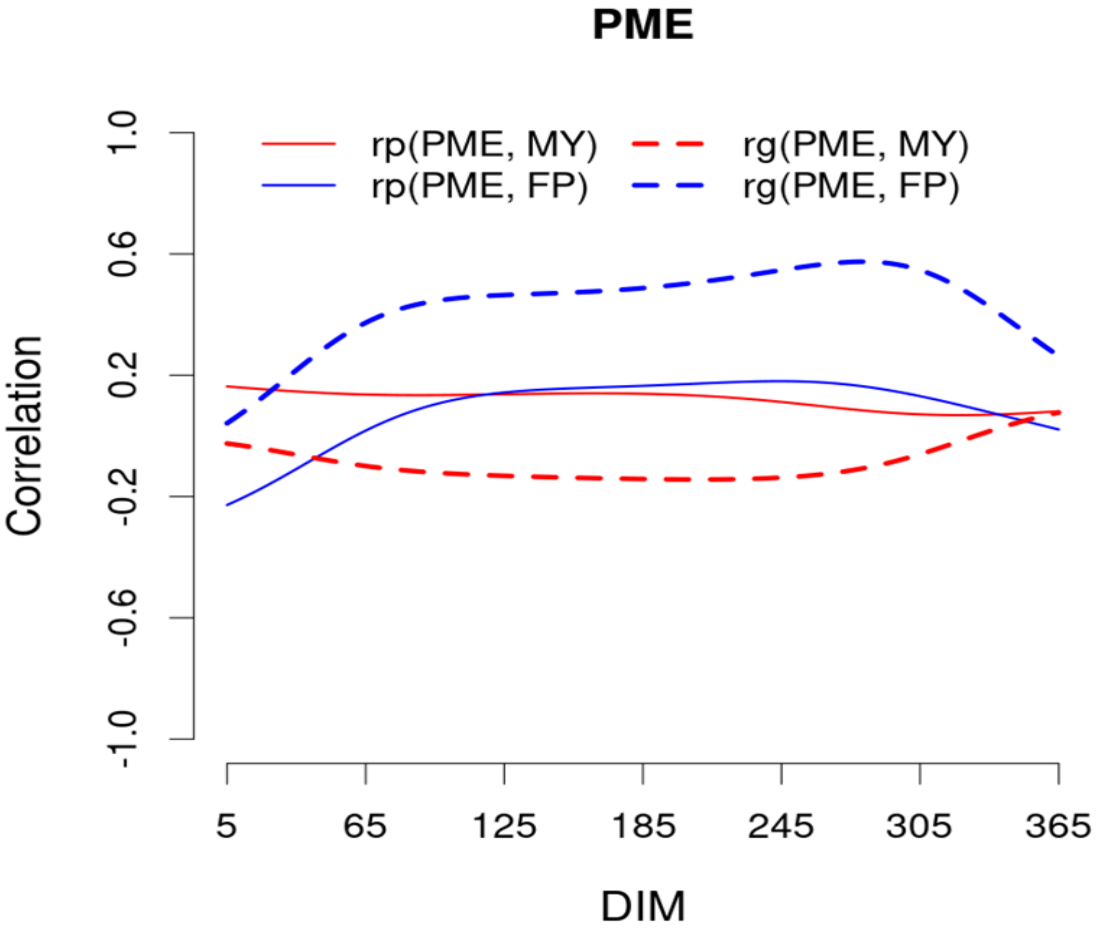
Results Averaged accross the 3 Lactations

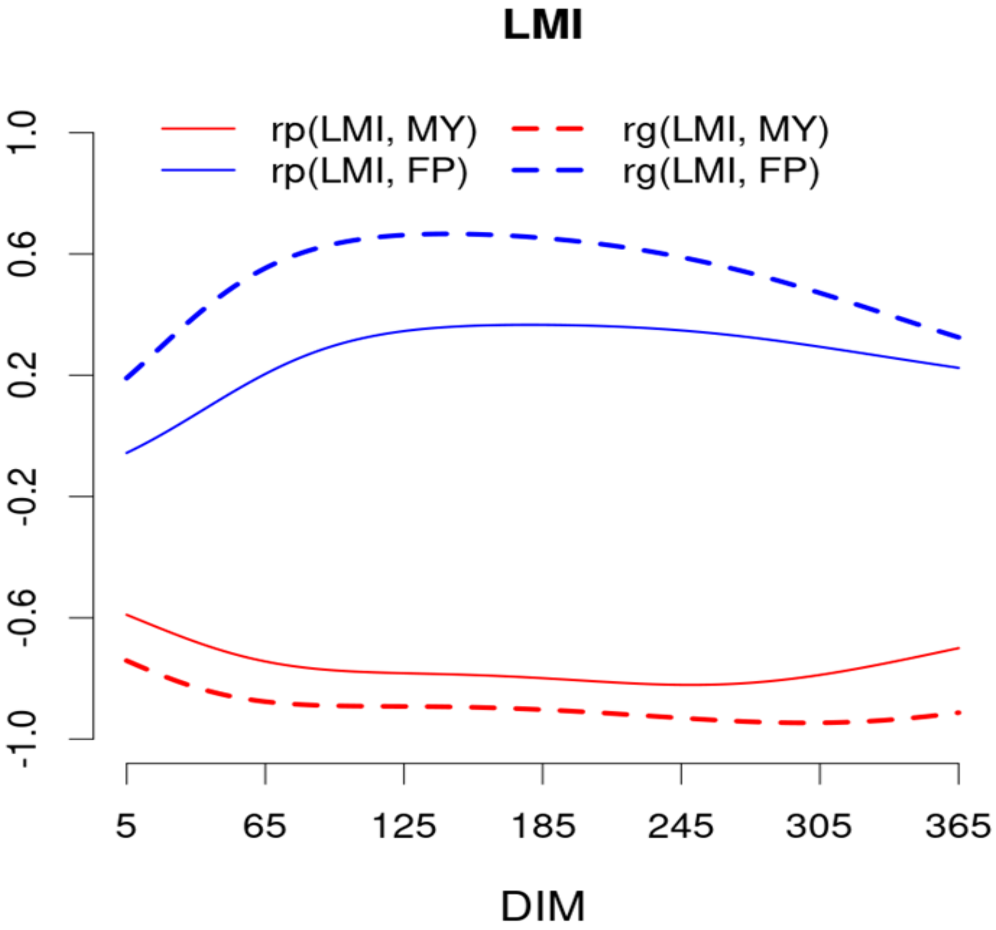
- Phenotypic and genetic correlation for PME and LMI

		MY	FY	PY	FP	PP
PME	Phenotypic	0.12	0.16	0.11	0.09	0.01
PME	Genetic	-0.09	0.32	0.05	0.44	0.28
LMI	Phenotypic	-0.77	-0.56	-0.72	0.28	0.29
LMI	Genetic	-0.90	-0.37	-0.73	0.54	0.55

- Results similar to Kandel et al. 2017 (https://doi.org/10.3168/jds.2016-11954)
  - Using similar data but much smaller dataset!

Results Averaged for DIM





Results & Discussion

- Phenotypic and genetic correlation for PME and LMI

		MY	FY	PY	FP	PP
PME	**Phenotypic**	**0.12**	**0.16**	**0.11**	**0.09**	**0.01**
PME	**Genetic**	**-0.09**	**0.32**	**0.05**	**0.44**	**0.28**

- Results also **similar** to Van Dormaal et al. 2023 (https://journal.interbull.org/index.php/ib/article/view/1906/1881)
  - Genetic: -0.13, 0.38 and -0.11 with MY, FY, PY
  - Phenotypic: -0.06, -0.18 and 0.01 with MY, FY, PY
  - Using also MIR-based equation (but a complete different one….) but only a window of DIM

Results & Discussion

- Phenotypic and genetic correlation for PME and LMI

		MY	FY	PY	FP	PP
PME	**Phenotypic**	**0.12**	**0.16**	**0.11**	**0.09**	**0.01**
PME	**Genetic**	**-0.09**	**0.32**	**0.05**	**0.44**	**0.28**

- Results **sightly different** when CH_4 obtained using sniffers, e.g., Pszczola et al. (2019) (https://doi.org/10.3168/jds.2018-16066)
  - Genetic correlations for Holsteins (n = 483):
    MY (0.15), FY (0.21), PY (0.07), FP (0.04) and PP(0.07)
  - **Missing link to energy** in milk (FP), rather remarkable

Discussion

- Results from genetic correlations ME vs. milk production traits followed some hypotheses:
  - Energy related
  - Lactation stage
  - Measurement systems

- We did not address **supplementary topic → non-linear relationship** i.e., correlations depend themselves on MY (FP, PP, FY or PY)
  - ME and especially LMI dependent on level of MY (and ME)

Conclusions

- Presentation gave only limited insight ➔ very **complex topic**
  - Contributions from this whole session expected

- Detailled and **comprehensive reviews necessary**

- **Imporant** issue for any **practical breeding use of CH_4**

- Also if we want to define expectations of CH_4 correctly
  ➔ definition of **CH_4 Efficency**: CH_4 – Expected(CH_4)

Acknowledgements

- Support of the Futurospectre partnership
  - Awé groupe – Comité du Lait – CRA-W – ULiège-GxABT
- CECI Consortium for computational resources
- Service Public de Wallonie
- National Fund for Scientific Research
- Support by different European Projects
- Many international partners….

Thank you for your attention

Nicolas Gengler
ULiège - GxABT
nicolas.gengler@uliege.be