Views on reducing cow methane emission from a breeding perspective

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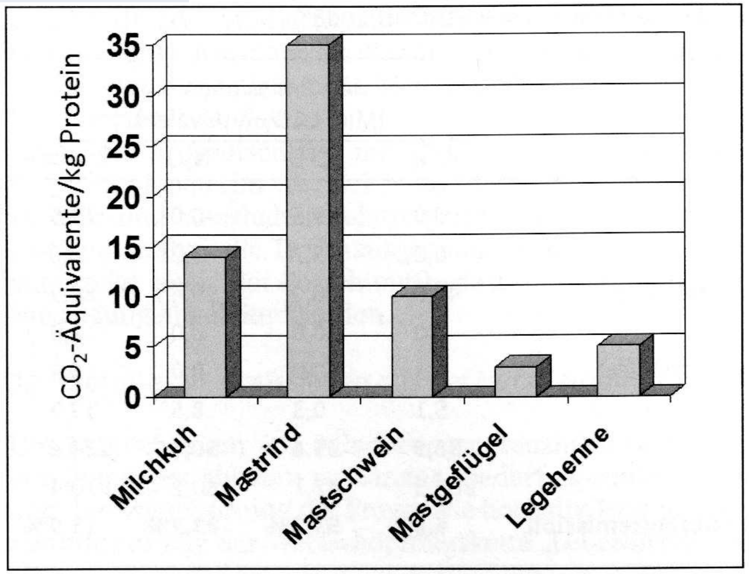
Emissions from the livestock sector

	NH_3	CH_4	N_2O	GWP_{100} *
Dairy cows	3,4	18,9	0,6	958
Layers	28,0	7,5	3,8	3791
Broiler	23,0	4,9	3,4	3448
Pigs	27,8	48,8	2,3	4689
Beef cattle	71,4	264,5	11,6	14704
Sheep	41,3	300,9	11,3	15813

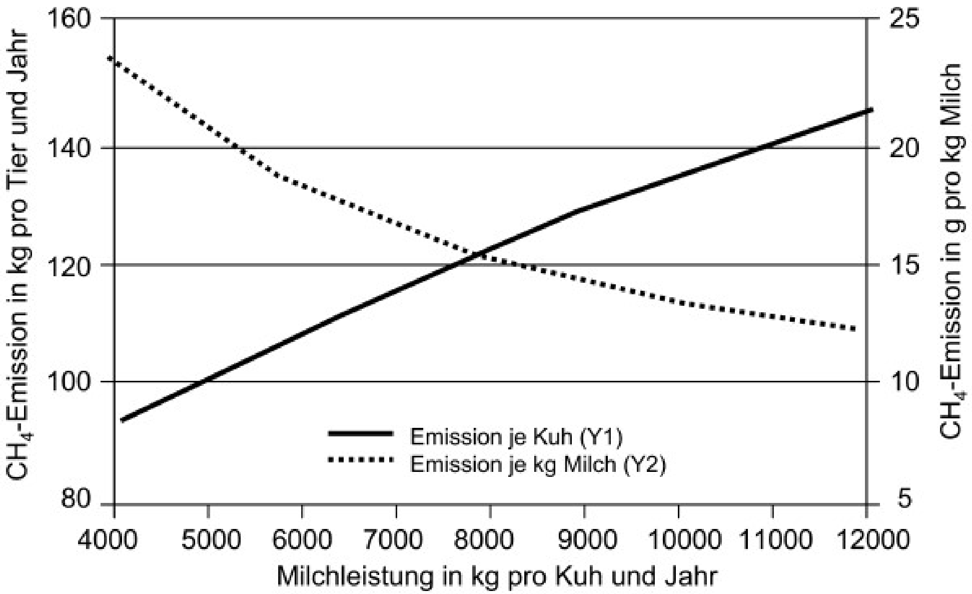
Per kg of product
(Jones, 2009)

Per kg of protein
(Schwerin et al., 2012)



Breeding strategies on reduced CH4 emissions

1. Increasing milk yield per cow ➔ fewer cows for a given production amount

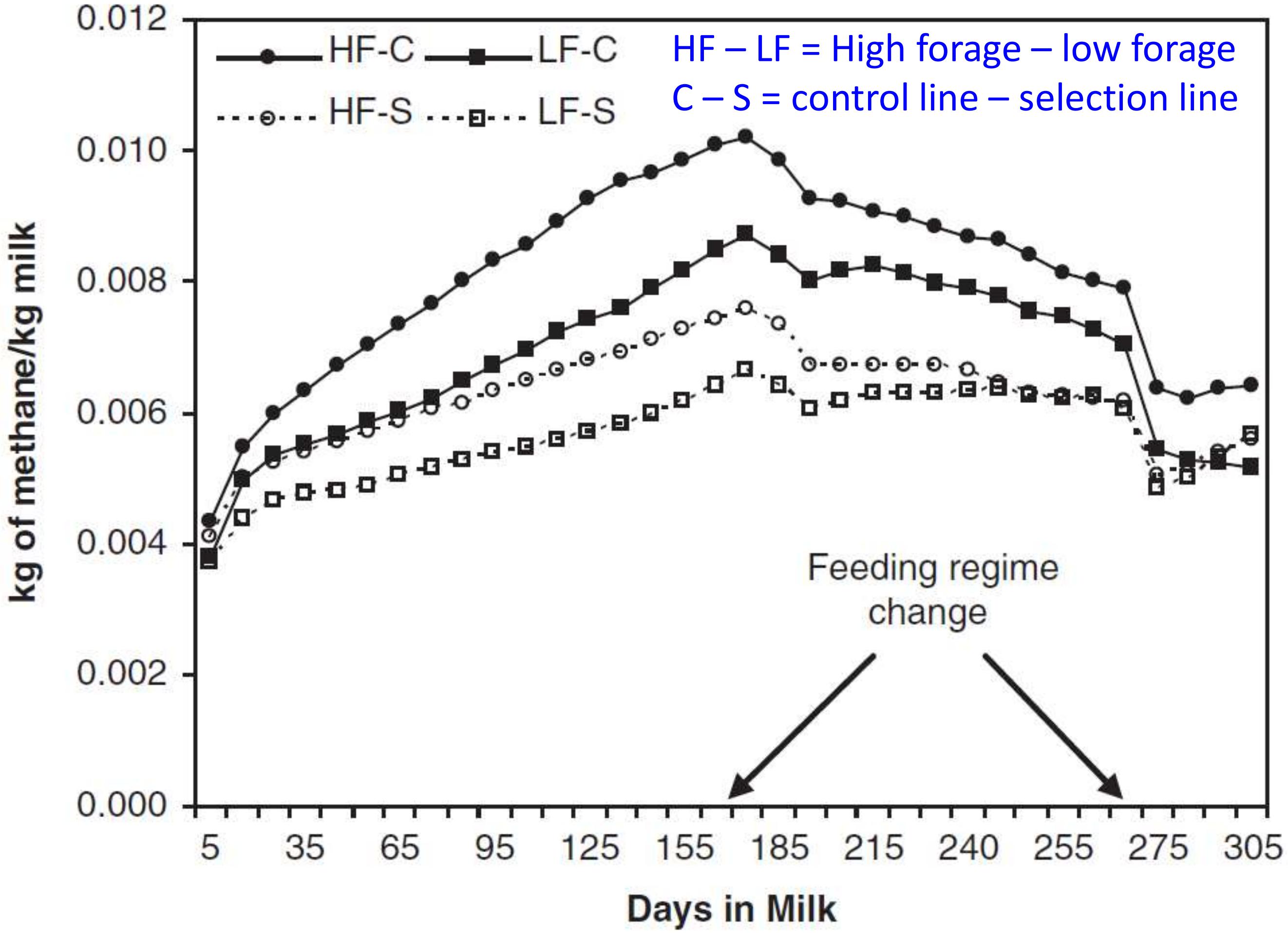


(Flachowski und Brade, Züchtungskunde, 2007)

2. Improving functional traits, especially female fertility and longevity to shorten unproductive periods (e.g., Garnsworthy, 2005)

3. Direct breeding on reduced CH4-emissions

Feeding and breeding influences on CH4 emissions
Here: Daily CH4 output in 2 selection lines

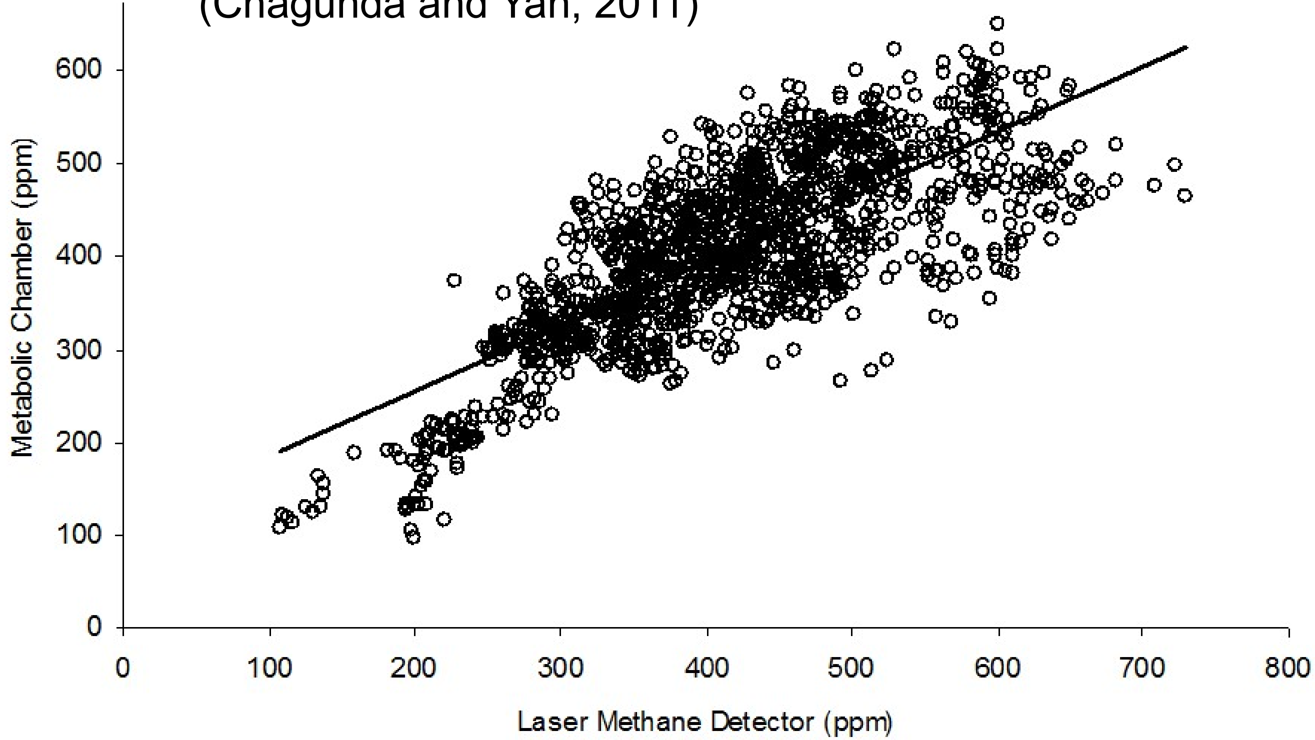


(Wall et al., 2010)

Direct breeding strategies: Only possible on the basis of deep phenotyping

Mobile **L**aser **M**ethane **D**etector (LMD)

(Chagunda and Yan, 2011)

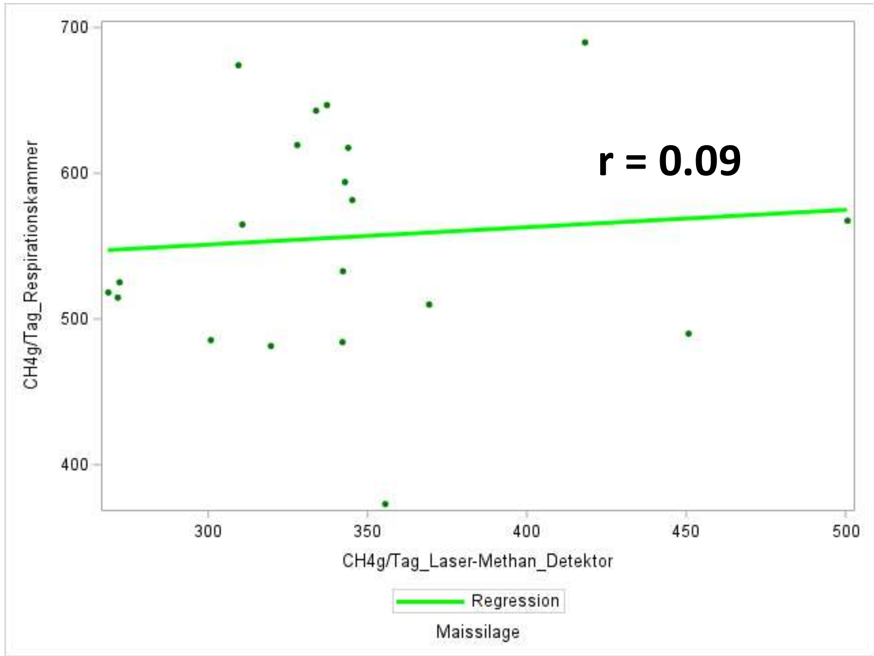


- Correlation coefficient 0.96
- Observer effect was not significant

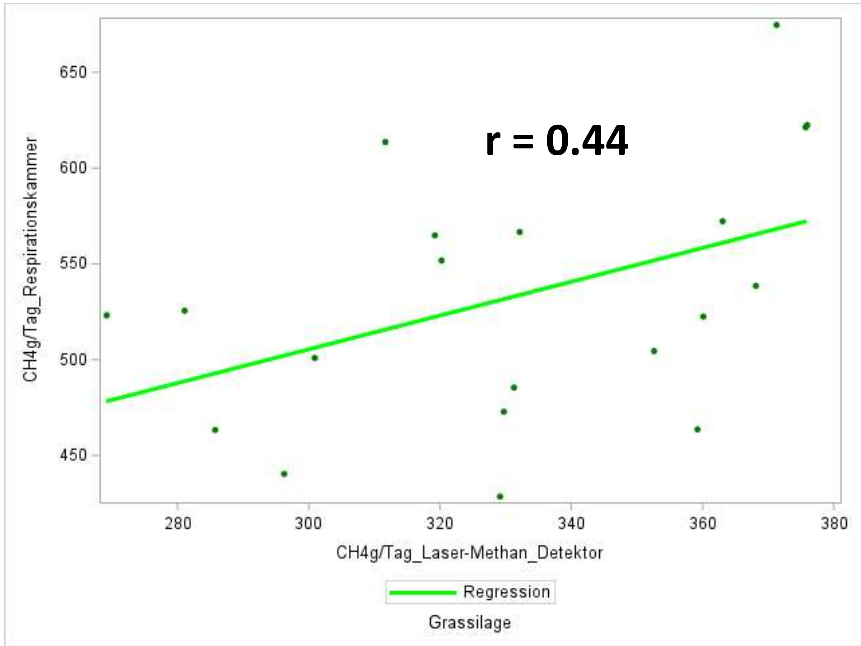
Time-lagged comparisons considering feeding aspects

Methane emission in g/day

Maize silage



Grass silage



Does the chamber environment reflect natural cow behaviour??

Evaluation of CH4 recording techniques

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.

(Garnsworthy et al., 2019)

Comparisons of recording techniques

Technique X	Technique Y	CH_4 measured simultaneously	Diet	Animal	No. animals	Technique X vs. Y CH_4 emission g/d* X	Y	Significance (P-value): X vs. Y	Regression coefficient (r^2)	Slope	Ref
RC	GF	No	Maize:Grass silage	Dairy heifers	4	215	198	0.54	0.06	0.23	Hammond et al. (2015)
RC	GF	No	Haylage	Dairy heifers	4	209	208	0.74	0.01	0.09	Hammond et al. (2015)
RC	GF	No	Lucerne chaff	Beef cows	5	216	209	>0.05	N/A	N/A	Velazco (2015)
RC	GF	No	Lucerne chaff	Beef steers	10	198	215	>0.05	0.85	N/A	Velazco (2015)
RC	GF	No	Lucerne silage	Dairy heifers	6	134	150	0.45	−0.36	N/A	Garnett (2012)
RC	SF_6	No	Lucerne silage	Dairy heifers	6	134	128	0.80	0.13	N/A	Garnett (2012)
RC	SF_6	No	Barley/lucerne cubes	Beef heifers	6	93.0	98.0	0.24	N/A	N/A	Boadi et al. (2002)
RC	SF_6	Yes	Ryegrass pasture	Lactating dairy cows	16	322	331	N/A	N/A	N/A	Grainger et al. (2007)
RC	SF_6	Yes	Grass silage/conc.	Lactating dairy cows	20	422	469	<0.01	0.69	0.64	Muñoz et al. (2012)
RC	SF_6	No	Ryegrass pasture/conc.	Dairy cows	8	455	431	0.14	N/A	N/A	Deighton et al. (2014b)[a]
RC	LMD	Yes	TMR	Dairy cows	2	356 ppm	396 ppm	<0.01	0.22	N/A	Chagunda et al. (2013)
GF	SF_6	Yes	Grazing forages	Dairy heifers	12	164	186	<0.01	0.40	0.41	Hammond et al. (2015)
GF	SF_6	Yes	TMR	Lactating dairy cows	16	468	467	N/A	N/A	N/A	Dorich et al. (2015)
GF	SF_6	Yes	TMR	Lactating dairy cows	48	12.8 g/kg DMI	14.7 g/kg DMI	<0.01 to 0.38	N/A	N/A	Oh et al. (2015)[b]
GF	SF_6	Yes	Lucerne silage	Dairy heifers	6	150	128	<0.05	N/A	N/A	Garnett (2012)
Technique comparisons using regression equations to predict CH_4 emission											
RC	CH_4:CO_2	Yes	30 different diets	Lactating dairy cows	157	412	345	<0.01	0.55	0.58	Hellwing et al. (2013)[c]
RC	Sniffer	No	PMR	Lactating dairy cows	12	395	2.2 mg/L	<0.01	0.79	0.57	Garnsworthy et al. (2012)[d]
RC	LMD	No	High/low conc. diets	Steers	67	175	53.4 µL/L	<0.01	0.39	N/A	Ricci et al. (2014)[e]
GF	Sniffer	Yes	Forage	Lactating dairy cows	32	453	1405 ppm	0.11	0.09	0.07	Huhtanen et al. (2015)[f]
GF	Sniffer	Yes	TMR	Lactating dairy cows	59	447	758 ppm	0.02	0.09	0.10	Huhtanen et al. (2015)[g]

(Hammond et al., 2016)

Laser Methane Detector (LMD)
Recording procedure

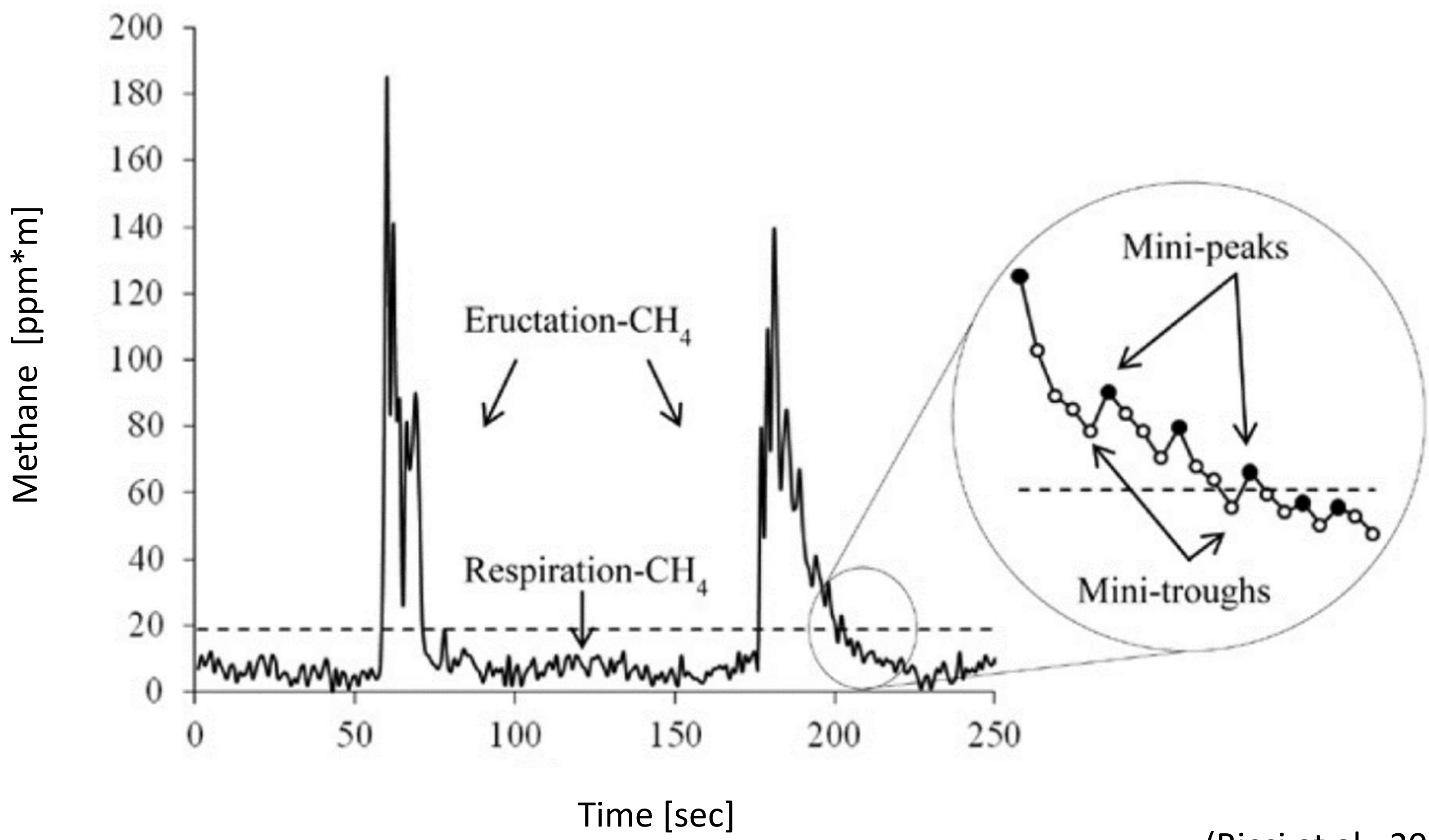
- Laser methane detector mini (Crowcon Laser Methane Mini, Tokyo Gas Engineering Co Ltd., Tokyo, Japan)
- Cow fixed for the duration of the measurement (three minutes)
- Laser is orientated towards the cow‘s nostril in ~1 m distance
- Records two values (in ppm) per second
- Approx. 360 methane values per observation
- Optimal: Measurements at 3 consecutive days
- Recording of „disturbing environmental impact“
  - humidity, wind speed, temperature

Mobile **L**aser **M**ethane **D**etector
Costs: ~ 15‘000 €

Further “disturbing” environmental impact: CH4 in the air barn

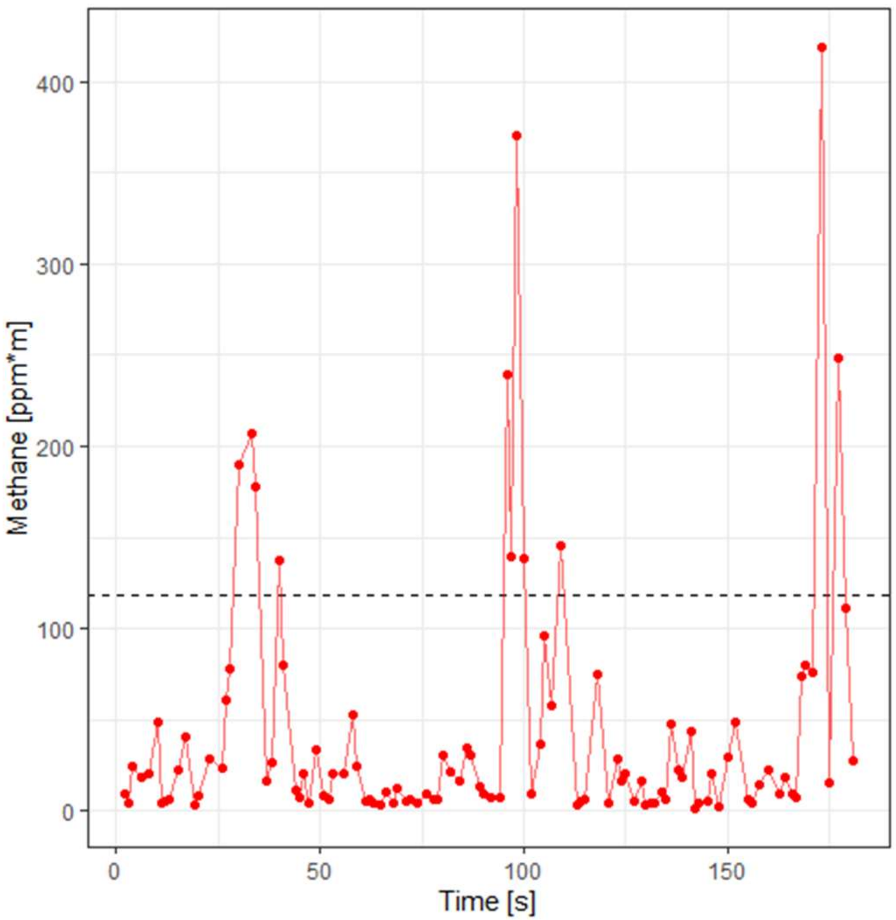
- Portable device from MSA
- “Plug and play”
- 4 sensors for the determination of
  ammonia, methane, carbon dioxide and nitrous oxide
- Records one value per second for each gas in ppm or vol.%

The challenge: Data preparation



(Ricci et al., 2014)

Derivation of methane traits: Only based on mini-peaks



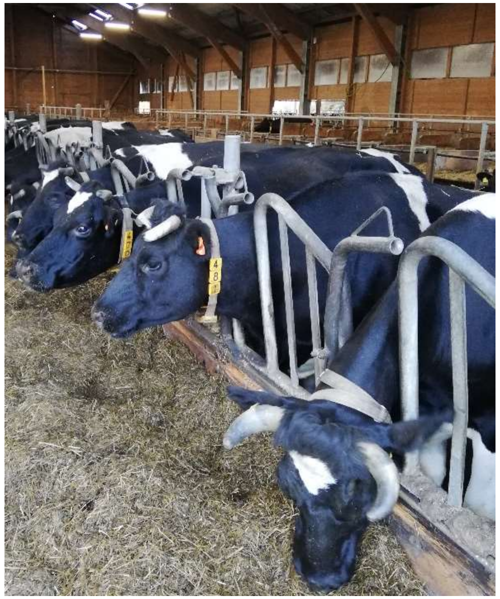
- Respiration methane (resp):
  - all analysed methane values under the threshold
  - as summed up (respsum) and as mean value (respmean)
- Eructation methane (eruc):
  - all analysed methane values above the threshold
  - as summed up (erucsum) and as mean value (erucmean)
- Added methane (allsum):
  - all analysed methane values of one oberservation summed up
- Mean methane (allmean):
  - mean value of all analysed methane values of one measurement

LMD-CH4 recording at JLU Giessen

- Measurements in the framework of the collaborative project CCCfarming

- Consideration of 7 farms from one German federal state
  - 3 compost bedded pack barn
  - 3 cubicle housings
  - 1 deep litter barn

- More than 2000 measuremts from more than 1200 cows!

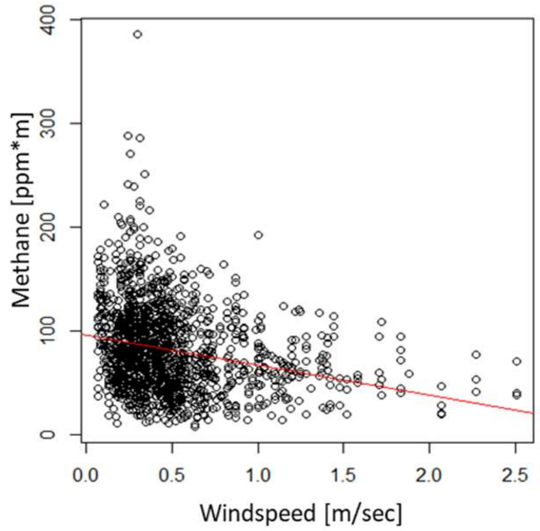


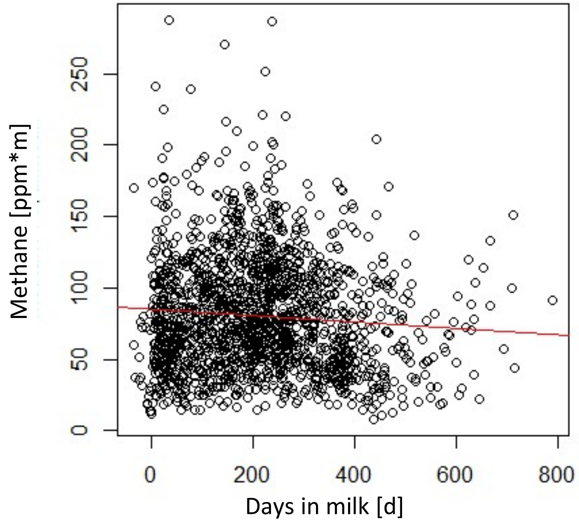
Impact of fixed effects on CH4 traits: Statistical model

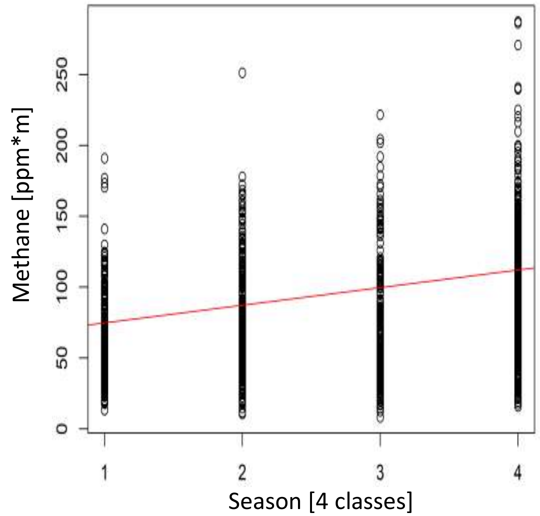
Model: $Y_{ijklmnopq} = W_i * T_j * H_k + Time_l + DIM\_CH4_m + LA_n + S_o + LMD\_Erf_p + B_q + e_{ijklmnopq}$

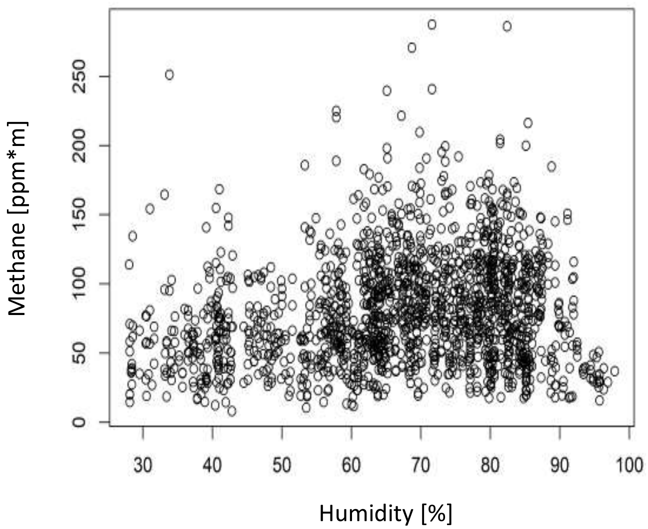
$Y_{ijklmnop}$	= observation (2.000) for methane (ppm*m)
W_i	= covariable windspeed (m/s)
T_j	= covariable temperature (°C)
H_k	= covariable humidity (%)
$Time_l$	= covariable observation-hour
DIM_CH4_m	= covariable days in milk
LA_n	= fixed lactation effect (8 classes)
S_o	= fixed year-season effect (season 1-4 from 2020)
LMD_Erf_p	= fixed LMD effect (4 classes)
B_q	= fixed farm effect (10 classes)
$e_{ijklmnopq}$	= random residual effect

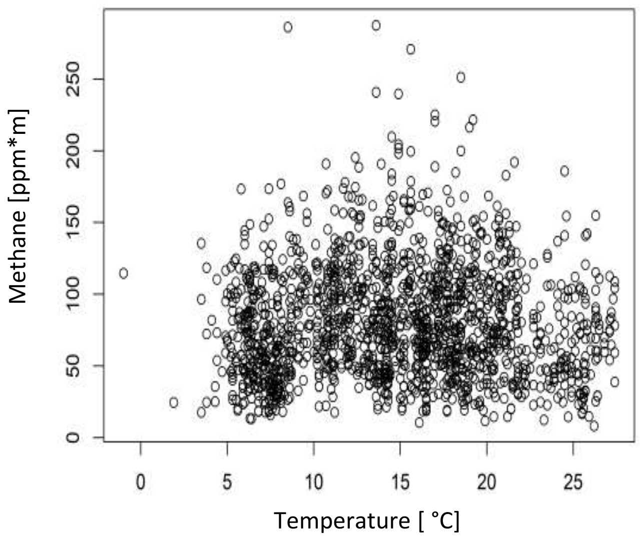
Impact of fixed effects on CH4 traits: Some results

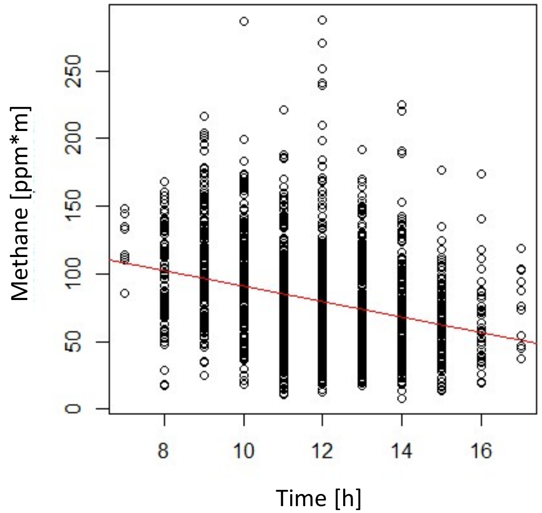








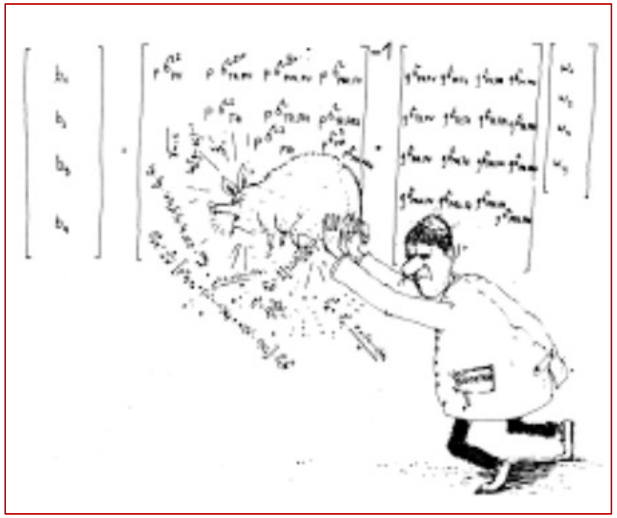




Heritabilities for CH_4

Technique	Animal	No. animals	CH_4 emission	Heritability	Reference
Sniffer in AMS	HF	485	g/ DIM	0.23 – 0.3	Pszczola et al. (2017)
Sniffer in AMS	HF	3,121	g/d	0.21	Lassen and Lovendahl (2016)
Sniffer in AMS	HF	3,121	g/d	0.25	Lassen et al. (2015)
Sniffer in AMS	HF	1,508	ppm	0.11	Van Engelen et al. (2017)
MIR (milk mid-infrared spectra)	HF	1,905	g CH_4/kg DMI	0.12 – 0.44	Van Engelen et al. (2015)
MIR	HF	33,555	g/d	0.15 – 0.42	Vanrobays et al. (2015)
Respiration chamber	Angus	40	g/d	0.19 – 0.27	Donoghue et al. (2015)
Respiration chamber	Angus	40	g CH_4/ kg DMI	0.19 – 0.29	Hayes et al. (2016)
LMD	HF	1,726 (57 LMD)	g/d (predicted CH_4) ppm (LMD)	0.11 – 0.13	Pickering et al. (2015)

Genetic correlations between CH4 and other breeding goal traits



Overall breeding goal definitions via selection index equations require a broad pattern of genetic parameters (heritabilities, correlations, variances) and of economic weights: This is not a trivial task!

CH4 : Milk yield  (e.g., Yin et al., 2015; Kandel et al., 2017; Zetouni et al., 2018)

CH4 : Female fertility traits (days open, calving interval)  (Yin et al., 2015; de Haas et al., 2017)

CH4 : Clinical mastitis, longevity, body weight, conformation  (Zetouni et al., 2018; Yin et al., 2015; Lassen and Lovendahl, 2016; Pszczola et al., 2019)

Breeding on reduced CH_4 emissions:
Does it really contribute to global warming aspects??

Dairy cattle and global greenhouse gas emissions

Calculation by Weber, 2009:

- 14.3% of greenhouse gas emissions are due to methane

(56% fossil fuel, 20% deforestation, 8% laughing gas)

  - 19% of methane emissions are due to dairy cattle

  (31% wetlands, 9% garbage dumps, 9% rice fields)

➔ Impact of dairy cattle on global greenhouse gas emissions = **2,7%**

Number of cattle livestock per country (in 1.000 animals; year 2018)

Country	No. of cattle
Total	**987.288**
India	281.400
Brasil	179‘788
China	105.722
US	94.491
Argentina	54.260
Columbia	30.755
Germany	12.988
UK	9.910
The Netherlands	3.996
Dänemark	1.570

11.519 dairy cattle

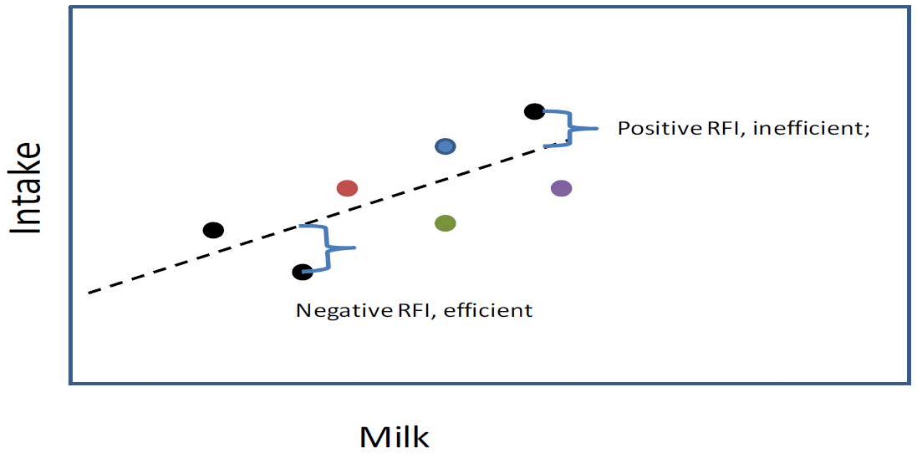
10,290 HOL, SIM, BS
~ 1% of the global cattle stock

2.7% of greenh. gases from cattle
x 1 % HOL, FLV, BS = **0.03 %**
x heritability of 0.15…..
„Global“ value of cow CH4 reduction**??**

Current importance of methane recording

Trait of interest: Residual feed intake (RFI) =
measured energy intake - predicted energy intake for a given milk yield level

- Efficient and environmental friendly cows are cows with negative values for RFI
- RFI determination implies knowledge of dry matter intake; equipment is very expensive!



Alternative: Utilisation of CH_4 traits to predict RFI, because breeding on low CH_4 emissions is associated with small values for RFI (Hegarty et al, 2007; Bell et al., 2010; de Haas et al., 2011; Jiao et al., 2014)

Conclusions

1. Dairy cows are efficient cows, but all possibilities to improve resource efficiency such as reduction of CH4 emissions should be applied!

2. Methane emissions can be recorded in commercial dairy cow herds via Sniffer- or LMD-technology

3. A protocol for recording and processing LMD-CH4 records has been developed at JLU Gießen, and records from almost 1,500 cows are available for genetic studies

4. Individual methane emmions are moderate heritability traits

5. Challenge is: To get all estimates for pairwise correlations among all breeding goal traits, in order to define an overall selection tool. So far, economic weights for methane traits are missing!

6. Methane measurements are valuable indicator traits to predict energy efficiency

Thank you!!