Genetic parameters for methane indicator traits based on milk fatty acids in cows

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Introduction

- Methane (CH_4) is the largest contributor to total GHG emitted by the dairy sector.
- CH_4 is 21 times more potent to CO_2 in greenhouse effect.
- Generally CH_4 is measured by respiration chamber or Sulphur hexafluoride (SF_6) method in animals.

IPCC (2007), FAO (2010), EU (1998), Johnson (1994)

CH_4 prediction from milk FA profile

- The fermentation of feed in rumen is essentially a digestion process of ruminants and CH_4 is produced
- Many volatile fatty acids are synthesized and degraded in rumen during this process
- These Fatty acids (FA) are absorbed in blood and produced by *de novo* synthesis in mammary gland and long chain FAs are secreted directly to milk ; Therefore, a link between milk FAs and CH_4 production seems to exist → prediction equations

Chilliard et al.,2000 & 2009; Moss et al., 2000; Dijkstra et al., 2011

Objectives

1. Development of Mid-infrared (MIR) equations for methane indicator traits
2. Estimation of genetic parameters for these MIR methane indicator traits

MIR CH_4 indicators

Milk samples

MIR CH_4 indicators

Milk samples

↙

MIR spectra

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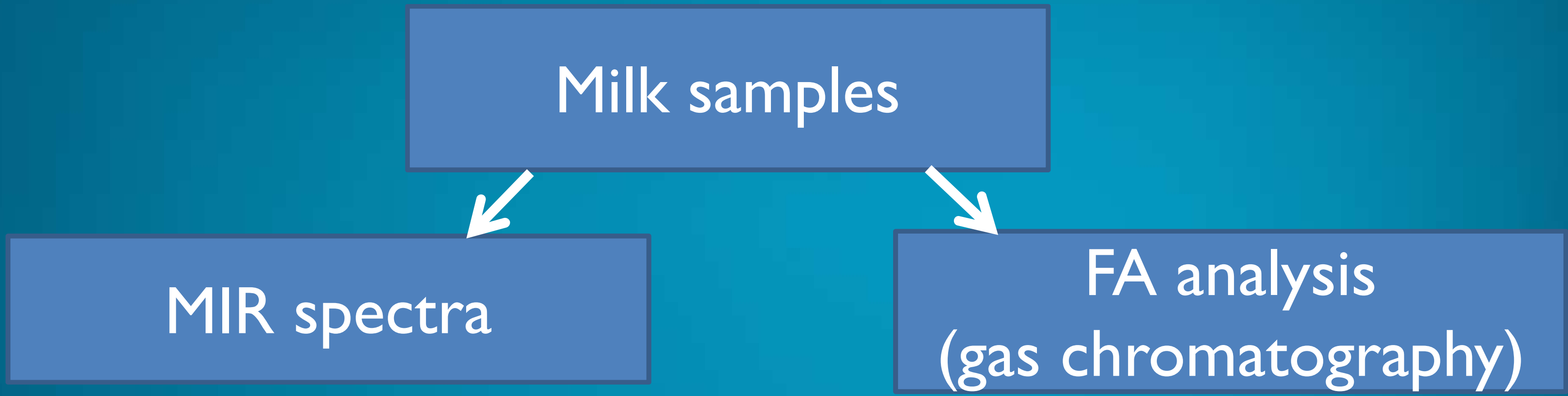
MIR CH_4 indicators



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MIR CH_4 indicators

Milk samples

MIR spectra

FA analysis (gas chromatography)

CH_4 predicted by FA contents

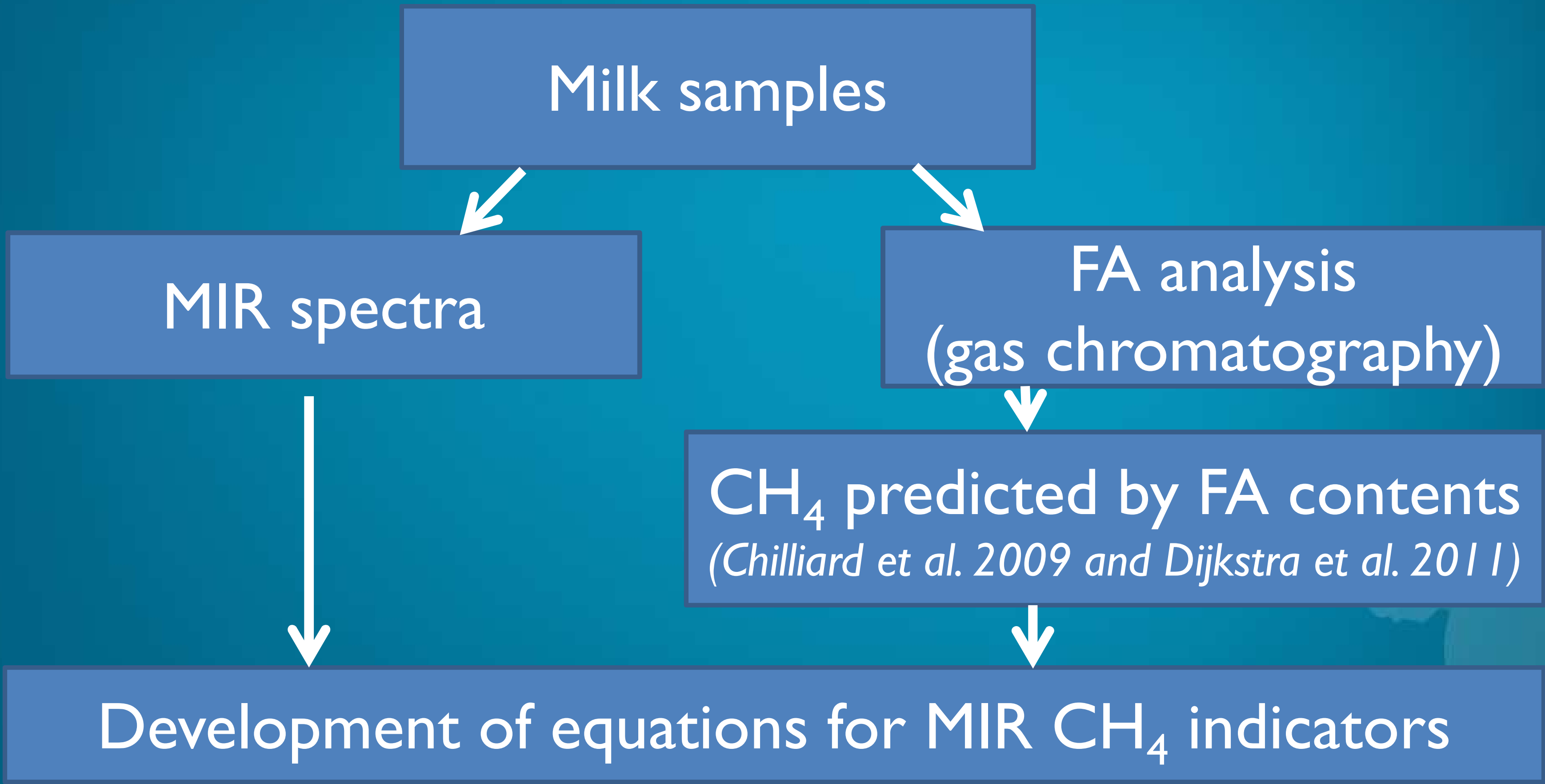
(Chilliard et al. 2009 and Dijkstra et al. 2011)

CH_4 predicted by FA contents

Prediction	Equation	R^2	Reference
Methane1 *g/day*	9.97 x (C8:0 to C16:0) - 80	**0.88**	Chilliard et al., 2009
Methane2 *g/day*	-8.72 x C18:0 + 729	**0.88**	
Methane3 *g/day*	282 x C8:0 + 11	0.81	
Methane4 *g/day*	16.8 x C16:0 - 77	0.82	
Methane5 *g/kg DM,* *17.7 kg DM/day*	24.6 + 8.74 x C17:0 anteiso – 1.97 x trans-10+11 C18 :1 – 9.09 x C18 :1 cis-11+ 5.07 x C18 :1 cis-13	0.73	Dijkstra et al., 2011

R^2 *represents the relationship between the* SF_6 CH_4 *data and the predictors*

MIR CH_4 indicators



Calibration of MIR CH_4 indicators

g/day	N	Mean	SD	R^2cv
Methane1	597	446.75	68.50	**0.92**
Methane2	602	421.52	60.71	0.91
Methane3	595	368.53	43.23	0.72
Methane4	588	459.55	88.11	**0.92**
Methane5	592	368.38	51.33	0.69

Mean= mean of reference values; SD= SD of reference values;
R^2cv= *cross-validation coefficient of determination*

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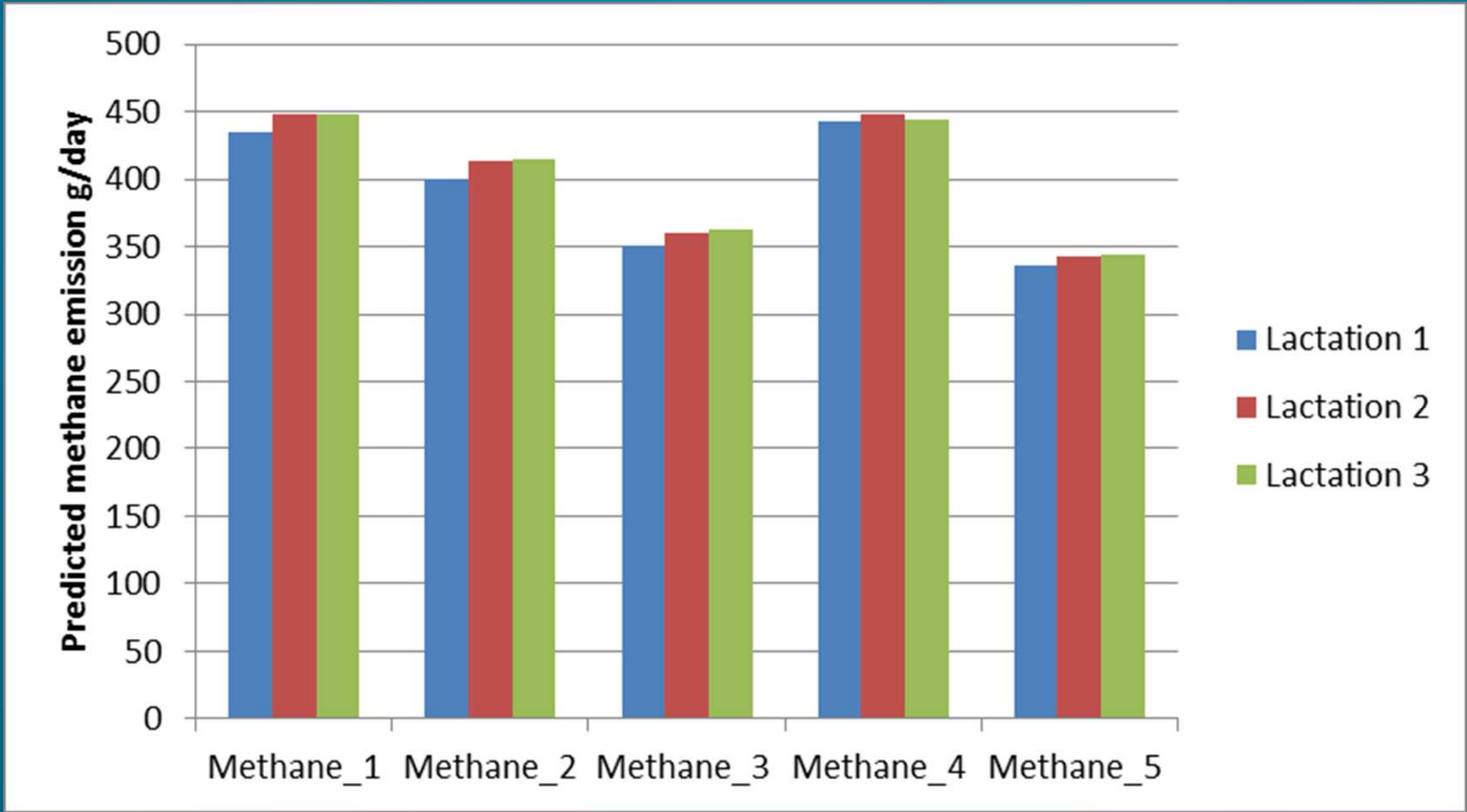
Development of equations for MIR CH_4 indicators

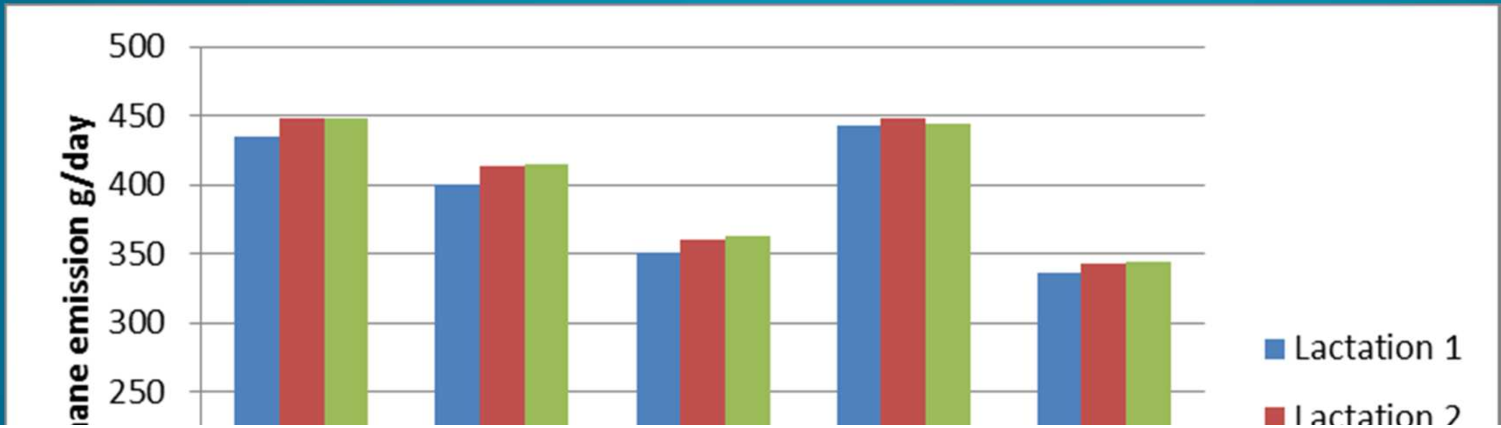
Spectral database (619,272 records from 71,188 Holstein cows in their first three lactations)

Estimated daily CH_4 emission from MIR CH_4 indicators



If we calculate for 365 days, the estimated CH_4 emission is 115 to 150 kg /year from one cow

Estimated daily CH_4 emission from MIR CH_4 indicators



Breed	CH_4 (g/day)	Method	Reference
Holstein	371-453	Respiration chamber	van Zijderveld et al., 2011
Holstein	403	SF_6	Thackaberry et. al., 2011
Jersey	356	SF_6	
Jersey*Holstein	311 (151-497)	SF_6	Cavanagh et al., 2008

Model : Single trait random regression test day

y=Xβ+Q(Zp+Zu)+e

y: separate MIR CH_4 indicators, milk, fat and protein

β: herd x test day, 24 classes of days in milk, and 3 classes of age at calving → fixed effects

p: random permanent environmental effects

u: additive genetic effects, e: random residual effect

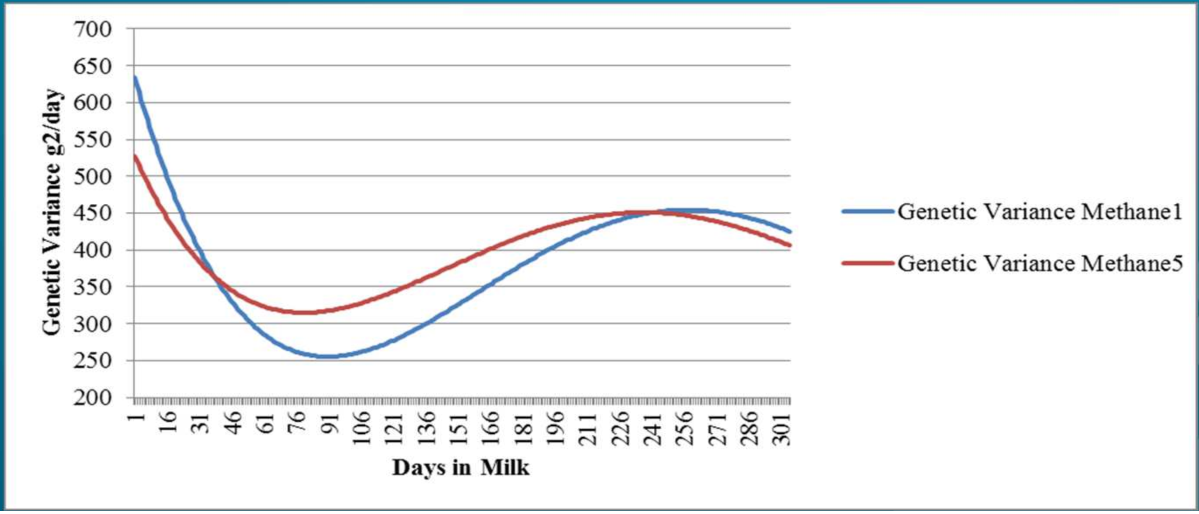
Q: coefficients of 2^{nd} order Legendre polynomials

X and **Z**: incidence matrices

Variance components were calculated by REML.

Heritabilities

Indicator	Averaged daily heritabilities			Lactation heritabilities		
	Lact 1	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3
Methane_1	0.34±0.01	0.37±0.01	0.34±0.01	0.68±0.01	0.74±0.01	0.67±0.02
Methane_2	0.30±0.01	0.33±0.01	0.30±0.01	0.66±0.01	0.71±0.02	0.64±0.02
Methane_3	0.29±0.01	0.39±0.01	0.22±0.01	0.65±0.01	0.75±0.01	0.54±0.02
Methane_4	0.35±0.01	0.40±0.01	0.38±0.01	0.73±0.01	0.76±0.01	0.72±0.02
Methane_5	0.16±0.01	0.17±0.01	0.14±0.01	0.73±0.02	0.72±0.02	0.60±0.02



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Methane_2	0.30±0.01	0.33±0.01	0.30±0.01	0.66±0.01	0.71±0.02	0.64±0.02
Methane_3	0.29±0.01	0.39±0.01	0.22±0.01	0.65±0.01	0.75±0.01	0.54±0.02
Methane_4	0.35±0.01	0.40±0.01	0.38±0.01	0.73±0.01	0.76±0.01	0.72±0.02
Methane_5	0.16±0.01	0.17±0.01	0.14±0.01	0.73±0.02	0.72±0.02	0.60±0.02

0.33±0.17 (FTIR measurement)
Lassen et al., 2011
0.35 (RFI)
de Haas et al., 2011
0.13 Sheep
direct measurement (Chamber)
Vercoe et al., 2011

Short chain fatty acids h^2 0.35-0.45
Long chain polyunsaturated fatty acids 0.20
Bastin et al., 2011

Phenotypic and Genetic Correlations

Traits	Methane_2	Methane_3	Methane_4	Methane_5	Milk	Fat	Protein
Methane_1	0.99	0.56	0.88	0.62	-0.05	0.23	0.23
Methane_2		0.57	0.87	0.65	-0.05	0.21	0.25
Methane_3			0.32	0.24	0.25	0.00	0.05
Methane_4				0.65	-0.17	0.29	0.16
Methane_5					-0.15	0.17	0.20
Milk						-0.37	-0.36
Fat							0.50

- +ve phenotypic correlations among MIR methane indicator traits
- Low –ve phenotypic correlation with milk production except methane_3
- +ve phenotypic correlations with milk fat and protein contents

Phenotypic and Genetic Correlations

Traits	Methane_1	Methane_2	Methane_3	Methane_4	Methane_5	Milk	Fat
Methane_2	0.98						
Methane_3	0.56	0.61					
Methane_4	0.81	0.76	0.20				
Methane_5	0.69	0.67	0.11	0.73			
Milk	-0.19	-0.18	-0.12	-0.11	-0.02		
Fat	0.54	0.53	0.31	0.43	0.29	-0.50	
Protein	0.33	0.38	0.18	0.16	0.15	-0.36	0.58

- +ve genetic correlations among MIR methane indicator traits
- –ve genetic correlation with milk production
- +ve phenotypic correlations with milk fat and protein contents

EBV for sires which have daughters with MIR CH_4 indicator traits

[kg/lactation (305 days)]

Traits	Lact 1(N=2,532)		Lact 2 (N=2,369)		Lact 3 (N=2,095)	
	SD	Range	SD	Range	SD	Range
Methane_1	3.33	24.21	3.82	29.44	3.77	27.68
Methane_2	2.75	20.16	3.06	23.72	2.99	22.13
Methane_3	2.88	21.01	2.70	20.34	2.50	18.84
Methane_4	4.46	34.32	5.19	41.66	5.07	40.72
Methane_5	1.39	11.99	1.56	12.74	1.42	11.75

Appreciable genetic difference was observed for e.g. Methane_1 24.21 kg in lactation 1

EBV for cows with MIR CH_4 indicator traits [kg/lactation (305 days)]

Traits	Lact 1(N=53,578)		Lact 2 (N=41,626)		Lact 3 (N=29,222)	
	SD	Range	SD	Range	SD	Range
Methane_1	3.44	31.50	4.25	37.65	4.07	33.36
Methane_2	2.81	25.58	3.38	30.32	3.18	25.80
Methane_3	3.01	27.77	2.85	27.06	2.58	24.14
Methane_4	4.86	43.25	5.81	52.42	5.61	49.32
Methane_5	1.45	13.40	1.63	15.57	1.46	12.16

Appreciable genetic difference was observed for e.g. Methane_1 31.50 kg in lactation 1

Conclusions

- Possible predictions of MIR CH_4 indicators
- Preliminary heritability estimates are good enough to select animals
- Genetic variability of CH_4 production seems to exist

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