Predicting methane emissions from pig manure: effects of feeding and manure management

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Outlines

1. Introduction and background
2. Goals
3. Model and measurements description
4. Results
5. Conclusions

Why methane emission is important?

- Contribution of (Dutch) livestock farming (70%) to Dutch greenhouse gas emissions
- Contribution of pig farming (~15%)
- Tracks on CH_4 emissions: (in-barn) manure storage (~80%), animal
- Housing systems in the Netherlands: Traditional and Low-emission houses
- Opportunities for lower emissions

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Background

- Standards, experiment-based and model-based approaches for determination of CH_4 emissions
- Models and algorithms with different levels of complexity are available.
- A dynamic CH_4 prediction model is needed to enable emission calculations, considering:
  - metabolism of the animals such as composition of the growth;
  - amount of daily volatile solids (VS) and VS characterisation;
  - effect of housing and manure management system;
  - effect of feeding on CH_4 emissions.

Research question and goals

Can modelling be an alternative to measurements at farm-level?

- VS characterisation of the excreted manure;
- Predicting CH_4 emissions from in-barn manure pits in fattening pig farms;
- Validating the model results with experimental data and at two different housing systems (*long-storage and daily removal of manure from in-barn storage*).

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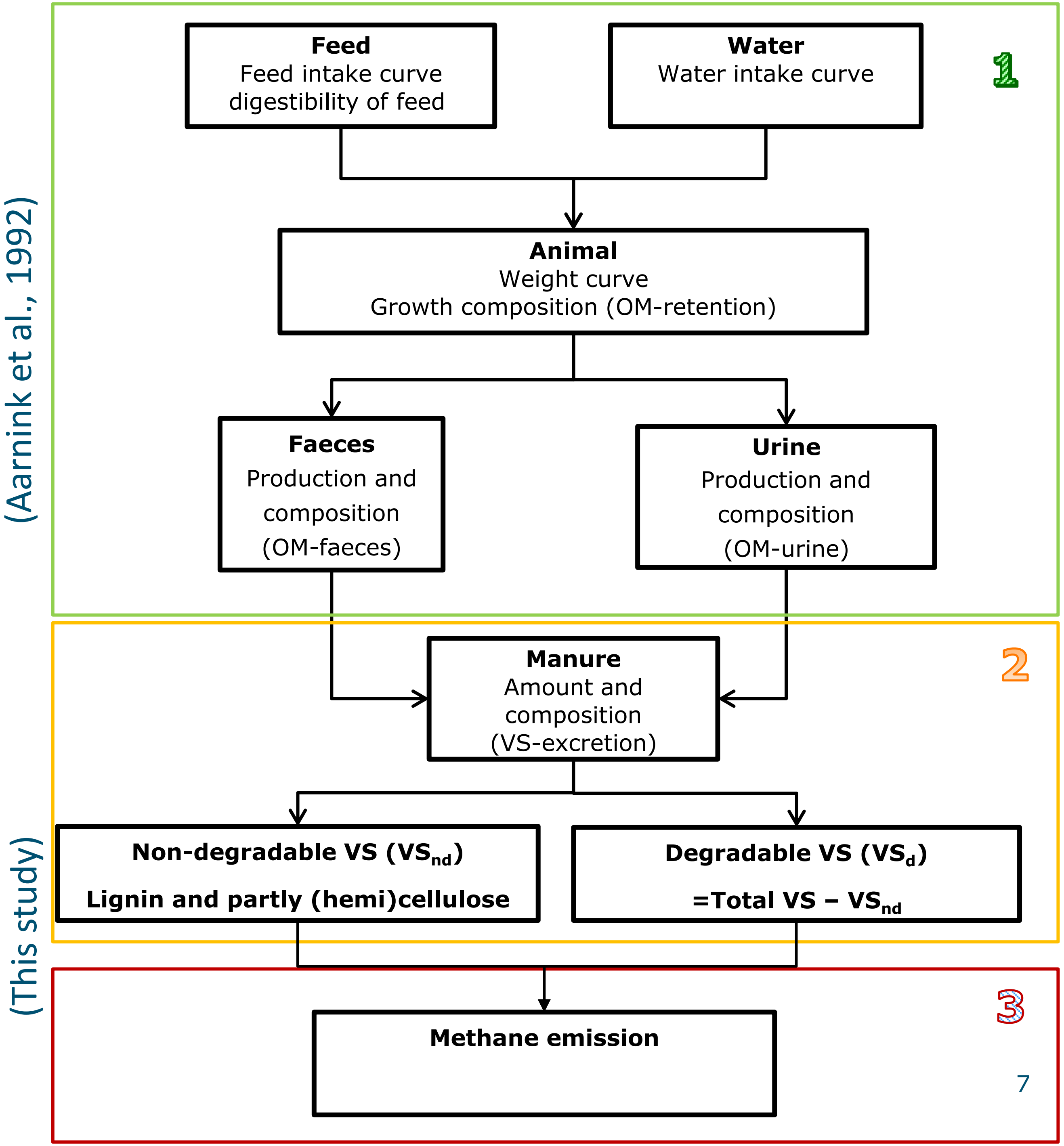
Model description

- MESPRO model (Aarnink et al, 1992 & 2018):
- Dynamic model/ daily time resolution/ growth curve (Gompertz function)
- Main inputs:
    - Start weight and growth rate
    - Total feed and water intake
    - Feed composition (content of water, crude protein, crude fat, crude fibre, remaining carbohydrates, ash, K, P, Ca and digestibility coefficients, lignocellulose components of feed
- Main outputs (among others):
    - Amount of manure
    - Composition of manure
    - Methane emissions

Model framework

1. Excretion model (green part)
2. VS characterisation (orange part)
3. Methane emission (red part)



VS characterisation and CH_4 calculations

- Total volatile solids excretion: $VS_{total} = F_{VS} + U_{VS}$
- VS in the faeces: $F_{vs} = (1 - DCOM) * OMI$
- VS in the urine: $U_{vs} = {}^{60}/_{28} \times U_N$
- Non-degradable VS: $VS_{nd} = Lignin + (partially\ (hemi)cellulose)$
- Degradable VS: $VS_d = VS_{total} - VS_{nd}$
- CH_4 production rate (Sommer et al., 2004)

(81 kJ/mol)
Elsgaard et al. (2016)

$$F_t = (VS_d + 0.01VS_{nd})\, e^{\left(lnA - \frac{E_a}{R\,T}\right)}$$

(g CH_4/kg VS/h)

(kg/kg VS)

(31.3 g CH_4/kgVS/h)
Petersen et al. (2016)

(K)

(kJ/K/mol)

Farms description and measurements

- Overview of fattening pig farms visited for manure samples in the Netherlands

Farm ID	Floor type	MSS	Ave. manure removal interval	No. of visits	No. of samples
A-LS	Partly slatted	Long storage underneath slats (LS)	>2 mo	4	12
B-LS	Partly slatted	Long storage underneath slats (LS)	>2 mo	4	7
A-SS	Partly slatted	Daily removal manure channel (SS)	1 d	4	6
B-SS	Partly slatted	Daily removal manure channel (SS)	1 d	4	8

* LS: long storage; SS: short storage; MSS: Manure storage system

- In-vitro assay (adopted from Elsgaard et al., 2016)
- CH_4 production rates (g CH_4/kg VS/day) corrected for in-situ temperature
- In-vivo measurements of CH_4 emissions (24-h reference method)

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Measured and modeled CH_4 emissions

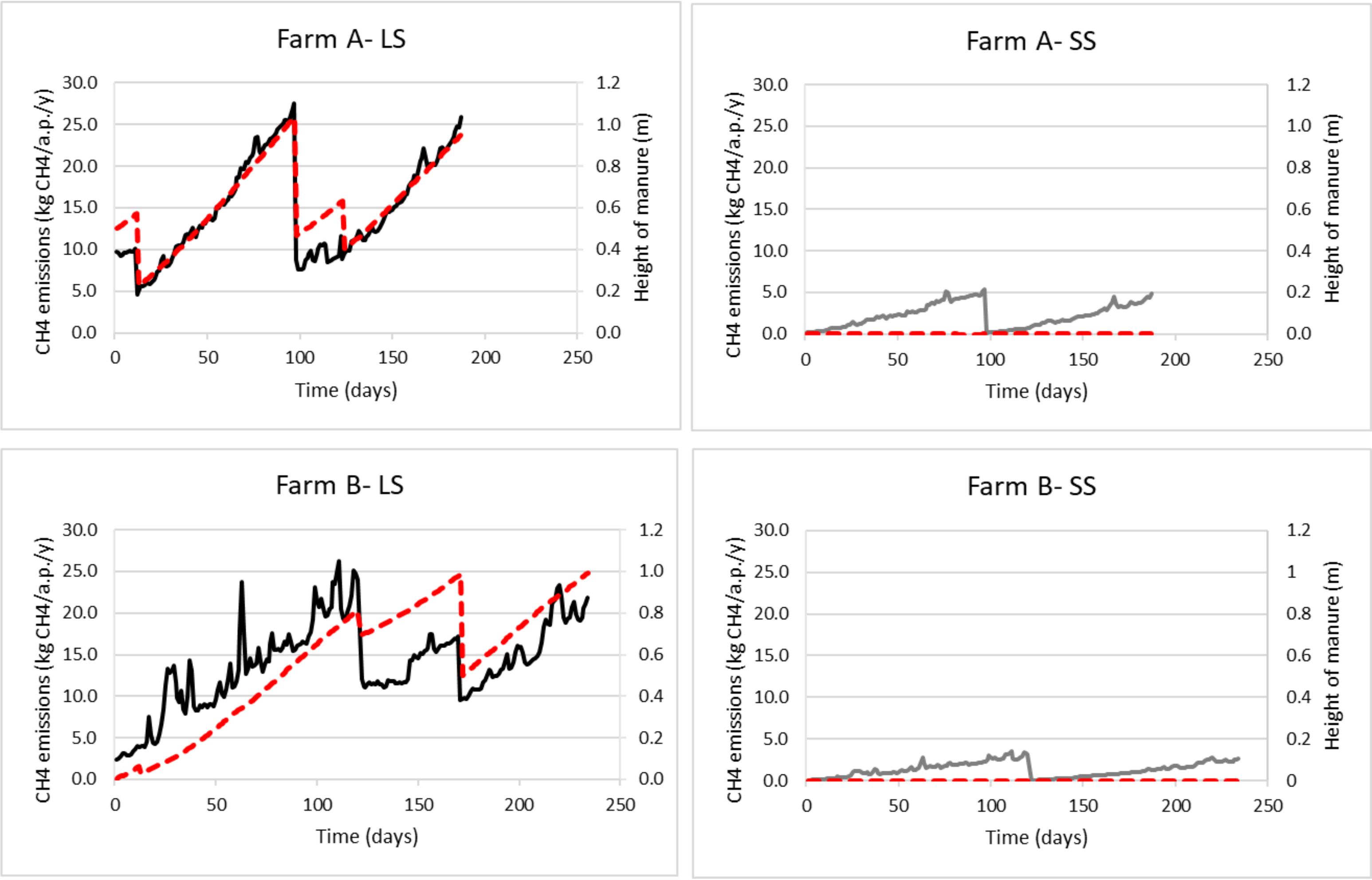
Results of monitoring pig farms in the Netherlands (SD)			
		In-vitro	**Model**
Average CH_4 production rate	g CH_4 kg^{-1} VS d^{-1}	1.4 (0.2)	2.2 (0.2)
Average VS content	g kg^{-1} fresh wt	66 (0.01)	80 (0.01)
Average fraction of VS_d	kg kg^{-1} VS	-	0.71 (0.02)

Average CH_4 production rate at in-barn storage:
Petersen et al., 2016: 1.97 g CH_4 kg^{-1} VS d^{-1}

Average degradable VS:
Sommer et al., 2004: 0.89 kg/kg VS in fresh excreta
Petersen et al., 2016: 0.51 kg/kg VS in stored manure

Model predictions of CH_4 emission and height variations

- CH_4 emission during short- and long-term storage as predicted with the height of residual slurry fraction in the storage.
- Lower CH_4 emission in SS vs. LS



LS: long storage; SS: short storage;
Solid line: CH_4 emission; Dashed line: height of slurry

Model results and validation

Average CH_4 emissions (SD), comparison between modelled and measured values

	Model	in-vitro	in-vivo*	R^2	RMSE
	(kg CH_4/animal/year)			(-)	(kg CH_4/animal/year)
Long storage (manure)	14.3 (5.8)	13.6 (6.1)	26.6 (9.9)	0.84	0.02
Short storage (manure)	1.8 (0.74)	1.0 (0.52)	2.9 (1.2)	0.61	0.002
Previous works (manure+animal)		*15*			

* Total CH_4 emissions (manure +enteric)

Annual CH_4 emissions:
Dutch inventory, 2019: 6.7 kg CH_4 animal.place^{-1} year^{-1}

Higher in-vivo results can be explained by:

1) *methane emissions from the animals;*
2) *model can not predict the presence of active methanogens in the sedimentary layer;*
3) *one missing value of the measured data.*

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Conclusions

- The need for improving estimations of CH_4 emissions from manure at farm-scale as affected by manure management and feed;
- Low emission housing system (frequent emptying) caused ~95% reduction in methane emissions from manure;
- The most important effect of frequent manure removal (at daily basis in this study) is the small volume of manure at in-barn storage (in which the methane can be formed). SS houses are equipped with external storage and/or anaerobic digester.

Conclusions

- Results indicated that with additional work, particularly on the methanogenic activity in the manure, the model could be a tool for estimation of CH_4 emissions for inventories;
- It is recommended to estimate lnA (Arrhenius parameter) for different manure types, ages and per country;
- The model may be used for farm-level assessments and to investigate mitigation scenarios.

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Thank you for your attention

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