NorFor feed evaluation system as a tool in predicting methane (CH_4) emissions from enteric fermentation

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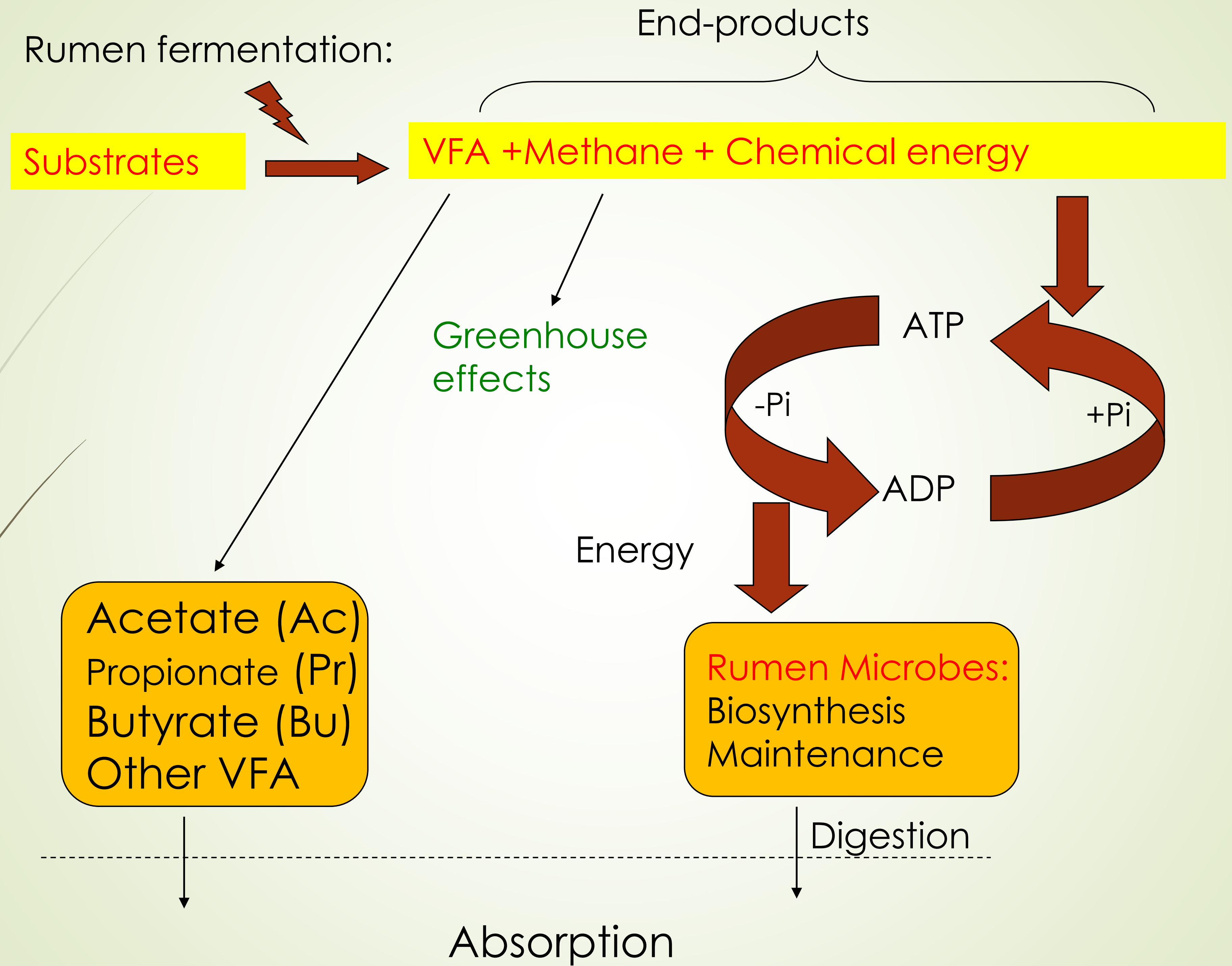
Introduction

- It is well known that feed composition affects gaseous emissions from cattle production systems
- Here we are mainly concerned with the part of gas emission coming from rumen fermentation, predominantly CH_4 (methane)
- Knowledge about this comes from detailed feeding experiments where CH_4 production is measured
- The focus should be on minimizing CH_4 per kg milk produced
- Feedstuffs that decrease CH_4 production in some cases also decrease overall rumen fermentation- resulting in lower milk production – that is not what we want!


Rumen fermentation:
End-products
Substrates
VFA +Methane + Chemical energy
Greenhouse effects
ATP
-Pi
+Pi
ADP
Energy
Acetate (Ac)
Propionate (Pr)
Butyrate (Bu)
Other VFA
Rumen Microbes:
Biosynthesis
Maintenance
Digestion
Absorption

Rumen fermentation- how important?

- Food production from fibre carbohydrates and non-protein nitrogen!
- Worldwide ruminant production:
  - Most of the milk
  - About one third of the meat
- Enteric CH_4 production is driven by both the amount and composition of feed consumed

Theoretical equations for fermentation of 1 mole carbohydrate (glucose equivalent) (Beever et al., 1993)

Diet type:	Ac	Pr	Bu	CH_4	ATP	Tot VFA
High forage	1.34	0.45	0.11	0.61	4.62	1.90
High cereal	0.90	0.70	0.20	0.38	4.38	1.80
High molasses	0.94	0.40	0.33	0.54	4.50	1.67

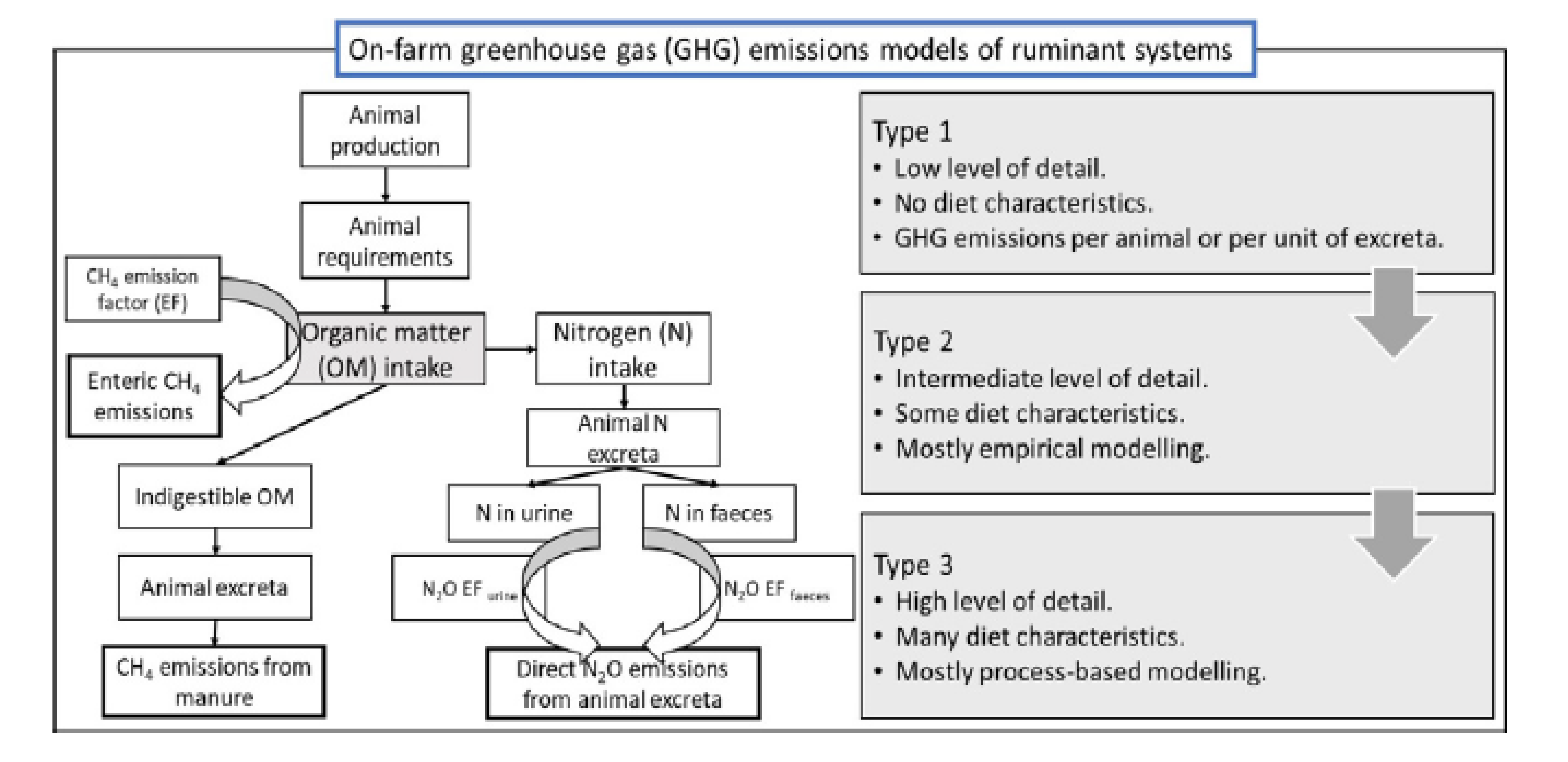
Fiber (forage) fermenting bacteria produce relatively much acetate and methane

Starch (cereal) fermenting bacteria produce less methane but high amounts of propionate

The rumen fermentation is acidifying, there is a lot of H+ (hydrogen) that the system needs to get rid of.

Methane is an effective way for this, but production of propionate rather than Ac or Bu also results in a net reduction of H+

So high level of cereals in dairy cow diets generally reduces CH_4 per kg milk, but part of this can be attained by increasing the quality of the forage



Examples:

Tier 1 (IPCC)

Norfor: (Nielsen et al. 2013

Karoline-Nordic dairy cow model

Source: Vibart et al., 2021: Science of the Total Environment 769 (2021) 144989

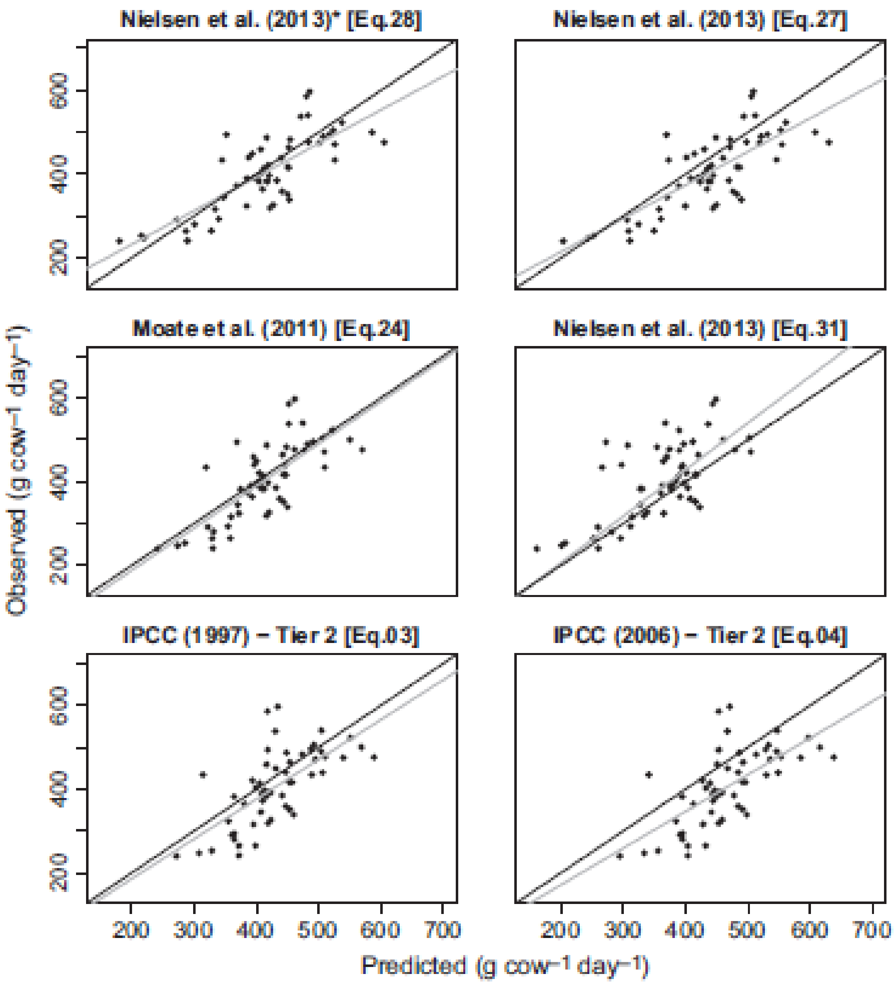


Fig. 1 Observed vs. predicted value plots for the five best-performing models and updated IPCC Tier 2 model for dairy cows in North America. The black and gray solid lines represent the unity ($x = y$) and regression line for the relationship between predicted and observed values, respectively. *The Nielsen *et al.* (2013) model was modified to use apparent total tract digestible NDF instead of total NDF.

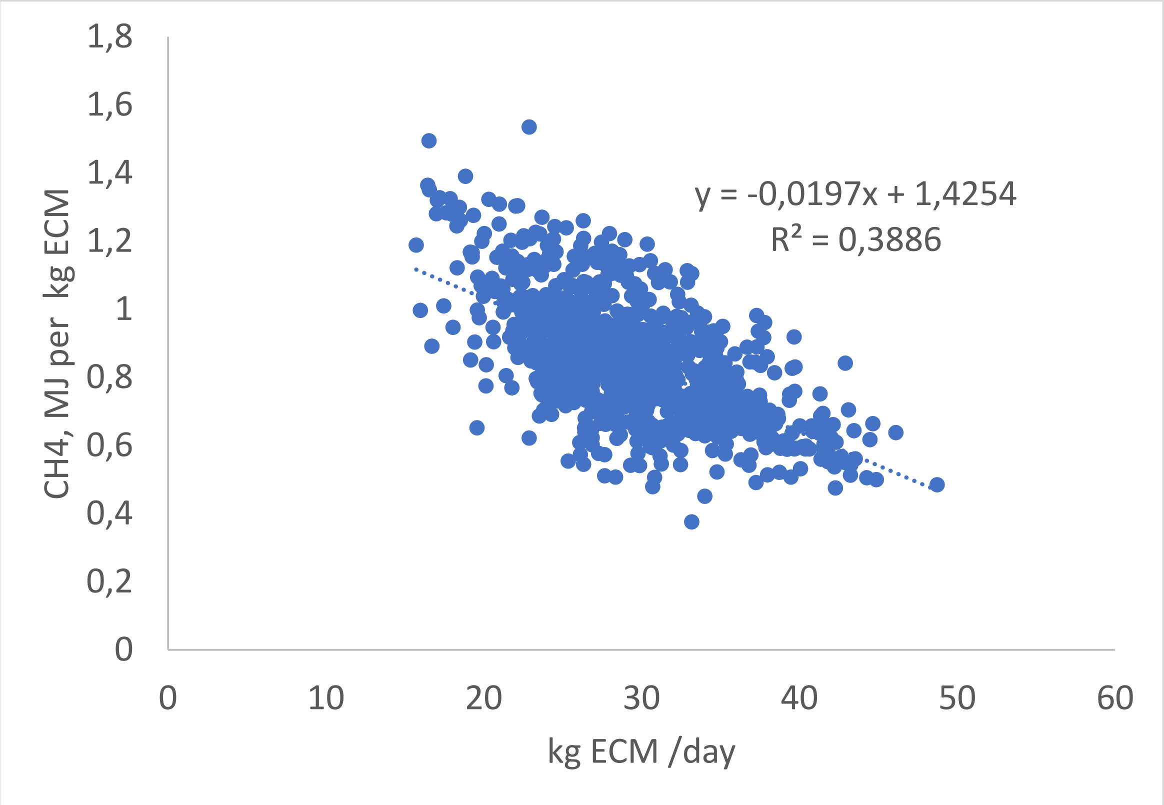
Nielsen et al 2013 – published methane model now used in Norfor

An international study (Appuhamy et al 2016) tested 40 published models predicting enteric methane emissions

The Norfor model was the best performing for American diets, but did not rank as high for European diets!

European diets in the study had much higher pasture ratio than normally is the case in the Nordic countries, in that sense we are closer to America.

This is how Norfor predicts enteric CH_4 emission from Icelandic dairy cows, using data (1096 records) from 5 recent dairy cow experiments in Iceland



Values calculated from this relationship (below) show how fast the release of CH_4 per kg ECM decreases with increasing ECM yield

ECM kg/d	MJ CH4 per kg ECM
15	1,13
20	1,03
25	0,93
30	0,83
35	0,74
40	0,64
45	0,54
50	0,44

Enteric methane production of cows according to Nielsen et al. (2013)

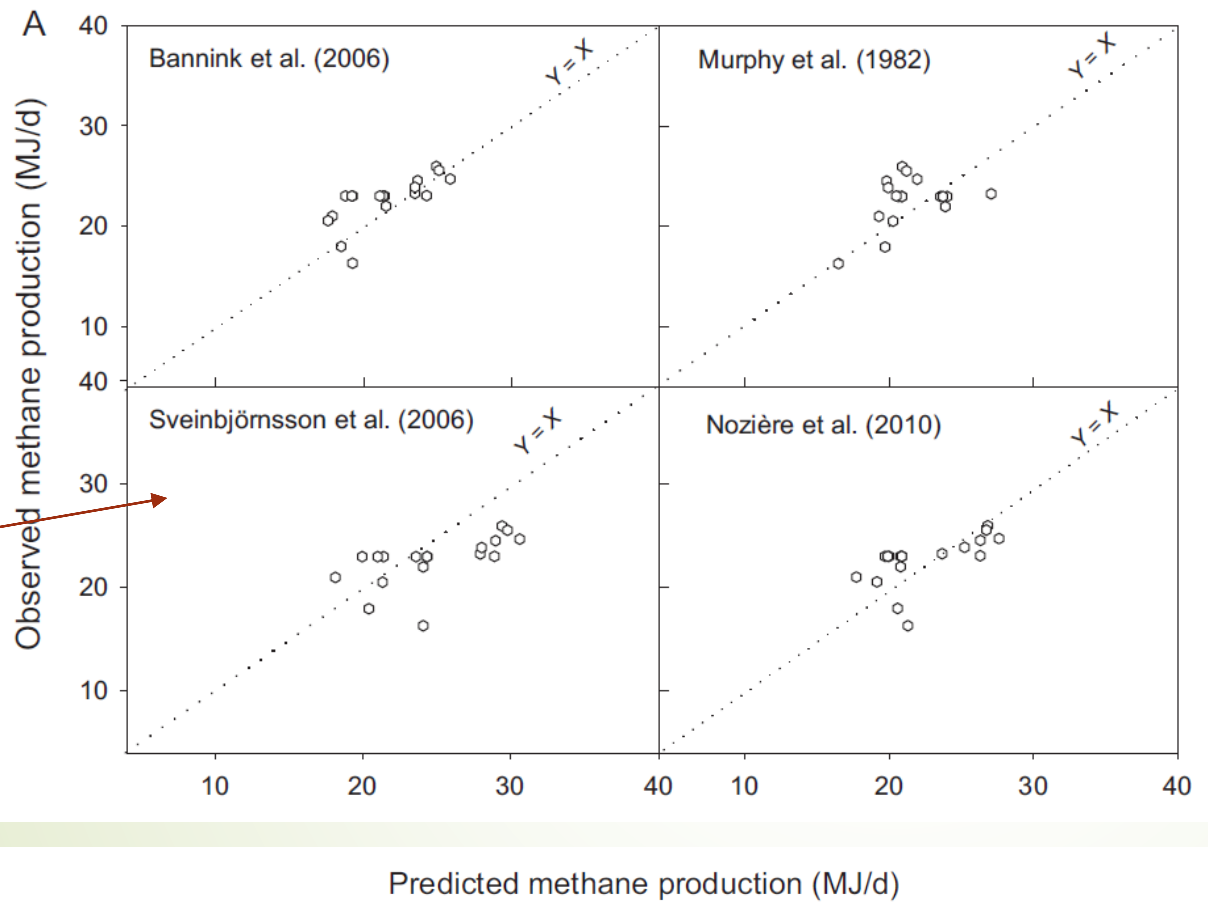
$$CH4=1.23 \cdot DMI-0.145 \cdot FA\_DM+0.012 \cdot NDF\_DM$$

Where CH_4 is enteric methane production (MJ per day), DMI is the dry matter intake (kg per day) and FA_DM the fatty acid concentration in the ration (g/kg DM)

This is a simple empirical equation that takes into account only some of the parameters that could have biological meaning and thereby affect CH_4 production (Type 2 model)

Several mechanistic, process based models (Type 3) have been developed. These models simulate in more or less detail the stoichiometry of rumen fermention. So (at least theoretically) they should be able to describe better the effect of diet composition on the production of different end- products including both the VFAs (acetate, propionate, butyrate) and methane (CH_4)

A.W. Alemu et al. / Animal Feed Science and Technology 166–167 (2011) 761–778



Karoline model

Fig. 4. Observed (A) and residual methane production (B) *versus* predicted methane production estimated from VFA proportions calculated using stoichiometric models (MJ/d, data set 2, $n = 18$). Observed methane production values were the reported measured values. The independent variable (predicted methane production) was centered around the mean before the residuals were regressed on the predicted methane production values. The equations were: Bannink et al. (2006), $Y = 1.14(\pm 0.41) - 0.36(\pm 0.163)(X - 21.5)$, $R^2 = 0.25$, P=0.04; Murphy et al. (1982), $Y = 1.23(\pm 0.53) - 0.56(\pm 0.23)(X - 21.4)$, $R^2 = 0.27$, P=0.03; Sveinbjörnsson et al. (2006), $Y = -2.20(\pm 0.47) - 0.64(\pm 0.12)(X - 24.8)$, $R^2 = 0.62$, P<0.001; Nozière et al. (2010), $Y = 0.14(\pm 0.47) - 0.55(\pm 0.15)(X - 22.5)$, $R^2 = 0.44$, P=0.003.

This is a part of a comparison between four published Type 3 models, showing a relatively good performance of the Nordic Karoline model in predicting CH_4

Later, Karoline model was updated, with special emphasis on CH_4 prediction (Ramin and Huhtanen, 2015)

The updated Karoline model was compared to the American model Molly by Kass et al (2019) – two next slides

Molly

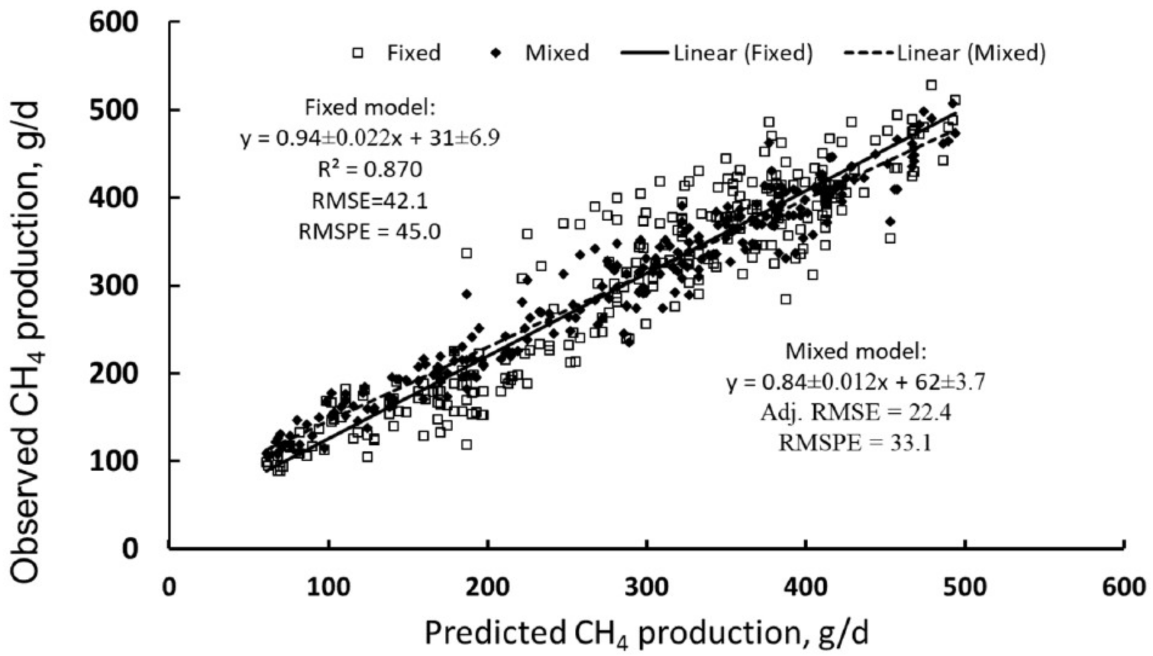


Figure 1. Relationship between predicted and observed CH_4 production with fixed and mixed model regressions model regression analysis using the Molly model. RMSE = root mean square error; RMSPE = root mean square error of prediction; adj. = adjusted.

Karoline

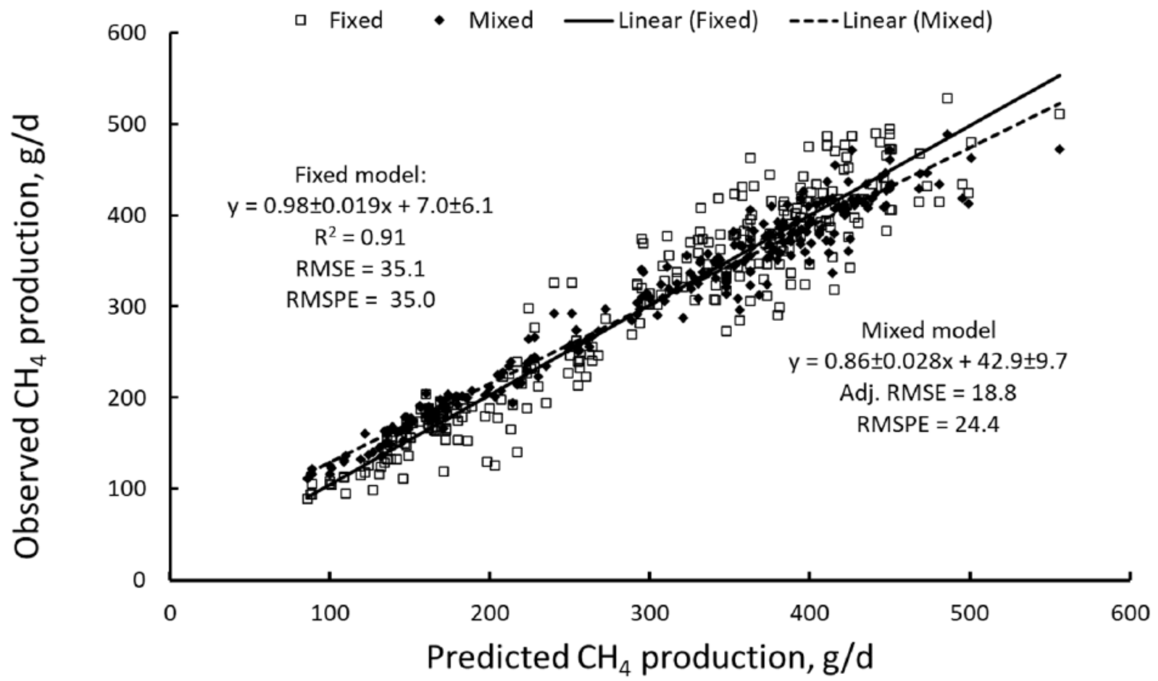


Figure 2. Relationship between predicted and observed CH_4 production with fixed and mixed model regressions model regression analysis using the Karoline model. RMSE = root mean square error; RMSPE = root mean square error of prediction; adj. = adjusted.

Summary and conclusions

- There is a considerable potential to reduce methane (CH_4) emissions from enteric fermentation relative to yield (milk or meat)
- It is well proven that Type 2 models, that have some elements related to animal and feed characteristics, perform much better in predicting CH_4 from enteric fermentation than Type 1 models (like Tier 1, IPCC)
- The Norfor feed evaluation system uses a Type 2 model for this purpose, it has performed well in comparison with other Type 2 and Type 1 models.
- Mechanistic or process-based models like the Nordic Karoline model allow capturing variation in on-farm emissions, based on more detailed information about diet composition
- There is a trend towards use of a hybrid Type 2/Type 3 approaches.

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