Milk MIR spectra to estimate individual CH$_4$ emissions: Strengths and limitations of a scalable model

Vanlierde A., Dehareng F., Soyeurt H. & Gengler N.

23 May 2023
Feed and Gas Working group
Need of tools to quantify CH$_4$ emissions in routine

Possibility to perform large scale studies and routine uses to:

- Monitor CH$_4$ at ≠ scales: animal, herd, region, country
  - Inventory and follow-up in time (seasons, years, etc.)
  - Quantification of mitigation strategies impact

- Reduce CH$_4$ through breeding
Back to basics: Methanogenesis
Back to basics: Methanogenesis
Milk FT-MIR spectra as a proxy for enteric CH$_4$

Milk samples are collected routinely. They are analysed by MIR spectrometry.
Milk FT-MIR spectra as a proxy for enteric CH$_4$
Development of equations to estimate CH$_4$ from milk FT-MIR spectra

First equation

- Inclusion of lactation stage information
- Consideration of additional zootchnical information

What if CH$_4$ is measured with gold-standard technique?

Increase the variability included in the calibration set

Improving robustness and accuracy of predicted daily methane emissions of dairy cows using milk mid-infrared spectra

Amélie Vanlierde, Frédéric Dehareng, Nicolas Gengler, Eric Froidmont, Sinead McParland, Michael Kreuzer, Matthew Bell, Peter Lund, Cécile Martin, Björn Kuhla and Hélène Soyeurt

Journal of the Science of Food and Agriculture
Development of equations to estimate $\text{CH}_4$ from milk FT-MIR spectra

First equation
First equation

<table>
<thead>
<tr>
<th>Equation</th>
<th>N data</th>
<th>N cows</th>
<th>Origin</th>
<th>Pred. variables</th>
<th>R²c</th>
<th>SEC (g/d)</th>
<th>R²cv</th>
<th>SECV (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First equation</td>
<td>77</td>
<td>11</td>
<td>BE</td>
<td>S</td>
<td>0.85</td>
<td>69</td>
<td>0.72</td>
<td>96</td>
</tr>
</tbody>
</table>
Development of equations to estimate CH$_4$ from milk FT-MIR spectra

! Not only focus on model statistics. Importance to observe consistency of predictions! 

Garnsworthy et al., 2012

\( n = 1,672,441 \)
Development of equations to estimate CH$_4$ from milk FT-MIR spectra

First equation

Inclusion of lactation stage information

Consideration of additional zootechnical information

Increase the variability included in the calibration set

What if CH$_4$ is measured with gold-standard technique?
Inclusion of lactation stage information to reflect changes in the metabolic status of cows

Spectra (S)
Inclusion of lactation stage information to reflect changes in the metabolic status of cows

\[ x = -1 + 2 \left( \frac{\text{Days In Milk} - 5}{365 - 5} \right) \]
Inclusion of lactation stage information to reflect changes in the metabolic status of cows

Modified Spectra (MS) ➔ lactation stage dependent coefficients

\[ x = -1 + 2 \left( \frac{Days\ In\ Milk - 5}{365 - 5} \right) \]
Inclusion of lactation stage information to reflect changes in the metabolic status of cows

Garnsworthy et al., 2012

- MIR methane (g/d)
- Estimated methane (g/d)
- Days in milk
- Week of lactation

n = 1,672,441
Development of equations to estimate CH$_4$ from milk FT-MIR spectra

1. First equation
2. Inclusion of lactation stage information
3. Consideration of additional zootechnical information
4. Increase the variability included in the calibration set

What if CH$_4$ is measured with gold-standard technique?
Increasing the variability of the calibration set → Countries and reference methods

365 ± 44 g/d
347 ± 89 g/d
427 ± 127 g/d
510 ± 105 g/d
367 ± 64 g/d
405 ± 60 g/d
347 ± 89 g/d
366 ± 61 g/d
400 ± 72 g/d
451 ± 75 g/d
Increasing the variability of the calibration set → Breeds

<table>
<thead>
<tr>
<th>Breed</th>
<th>n data</th>
<th>% of data</th>
<th>n cows</th>
<th>% of cows</th>
<th>CH$_4$ (g/d) mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOL</td>
<td>891</td>
<td>82</td>
<td>222</td>
<td>74</td>
<td>415 ± 107</td>
</tr>
<tr>
<td>JER</td>
<td>67</td>
<td>6</td>
<td>10</td>
<td>3</td>
<td>342 ± 42</td>
</tr>
<tr>
<td>BSW</td>
<td>78</td>
<td>7</td>
<td>39</td>
<td>13</td>
<td>458 ± 69</td>
</tr>
<tr>
<td>RED</td>
<td>21</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>427 ± 74</td>
</tr>
<tr>
<td>X</td>
<td>32</td>
<td>3</td>
<td>20</td>
<td>7</td>
<td>391 ± 67</td>
</tr>
</tbody>
</table>
Increasing the variability of the calibration set → Lactation stage
Increasing the variability of the calibration set → FT-MIR spectra
Increasing the variability of the calibration set → FT-MIR spectra
**Equation developed**

![Graph showing the relationship between Measured CH₄ (g/day) and Predicted CH₄ (g/day).](image)

<table>
<thead>
<tr>
<th>CH₄ Ref. method</th>
<th>n data</th>
<th>n cows</th>
<th>Origin</th>
<th>R²c</th>
<th>SEC (g/d)</th>
<th>R²cv</th>
<th>SECV (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF₆ &amp; RC</td>
<td>1,089</td>
<td>299</td>
<td>BE, IE, CH, UK, FR, DK, DE</td>
<td>0.73</td>
<td>53</td>
<td>0.68</td>
<td>57</td>
</tr>
</tbody>
</table>
Practical applications: Large scale studies

5 – 365 DIM
GH < 5
Holstein cows in RW
→ n = 538,510
Development of equations to estimate CH$_4$ from milk FT-MIR spectra

First equation

Inclusion of lactation stage information

Consideration of additional zootechnical information

Increase the variability included in the calibration set

What if CH$_4$ is measured with gold-standard technique?

Robustness & accuracy
Main strengths and limitations of milk MIR spectra as a proxy for CH₄ emissions?

**Strengths**

- Milk sampling and MIR analyses already implemented in routine
- Fast
- Cost effective
- Error of prediction known
- Scalable
- Maybe closer to physiology (H $\rightarrow$ CH₄)

**Limitations**

- Specific variability need to be included to avoid extrapolation (GH spectra, diet, breed, THI conditions, etc.)
- Effect of some diet additives on CH₄ emissions can not be considered
- Need standardized milk MIR spectra
- Only for lactating dairy cows
Getting access to the model?

2 Options

a) Research collaboration

Provide reference data (CH$_4$ + Milk MIR spectra)
- from a country not yet included
- from cows receiving an innovative diet/additive
- from a breed/lactation stage… not covered
- etc.

Win/Win situation

Reference data never shared,
only updated coefficients of the equation

⚠️ Need of standardized spectra

b) European milk recording

www.milkrecording.eu
In the future?

➢ Keep improving the model - respiration chamber & SF$_6$ tracer gas methods

➢ Same collaborative approach with greenfeed data on its way - challenge about CH$_4$ values

➢ Merging Greenfeed system data with respiration chamber and SF$_6$ tracer gas ?

➢ Considering other informative values as predictors ?

➢ Extension towards genomics (← new opportunities for collaborations)
Take home messages

- Prediction of CH$_4$ emissions from milk MIR spectra: indirect and scalable model.
- Importance to observe model statistics AND consistency of predictions.
- Collaborations are the key to join efforts and obtain robust models.
- Need to standardise spectra to merge reference datasets and to apply the model.
- Limitations are known (SE, additives with late impact on methanogenesis process, ...).
- To be validated: MIR predictions closer to physiological CH$_4$ (H generation potential).
- You can use it with different purposes if you are a nutritionist, a geneticist, etc.

Keeping that in mind to ensure a wise use, milk MIR spectra is a very effective proxy to predict individual CH$_4$ emissions from lactating dairy cows.
Thank you for your attention