Using Milk Spectral Data for Large-Scale Phenotypes Linked to Mitigation and Efficiency


Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium
Walloon Research Centre, Gembloux, Belgium

EAAP – 26th August 2014
Introduction

Economically sustainable milk production
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Economically sustainable milk production

- Appropriate milk production and composition
- Robust cows
- Milk with a good nutritional and hygienic quality
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Economically sustainable milk production

- Appropriate milk production and composition
- Robust cows
- Milk with a good nutritional and hygienic quality

Lower environmental impact
Environmental Traits

• 3 traits studied in this presentation:

  – **Eructed methane** \((\text{CH}_4)\)
    • Contributor for greenhouse gases

  – **Dry matter intake** \((\text{DMI})\)
    • Represents the amount of feed consumed by the cows

  – **\text{CH}_4/\text{DMI}**
    • Permits to combine efficiency and greener aspect of milk production
Mid-Infrared Spectrometry (MIR)

• Fourrier Transform MIR spectrometry

• Advantages
  – Non-invasive technique
  – Fast and environmentally friendly
Mid-Infrared Spectrometry (MIR)

Absorptions of IR at frequencies correlated to the vibrations of specific chemical bonds within a molecule (Coates, 2000)
Mid-Infrared Spectrometry (MIR)

Typical chemical composition (Smith, 1996)

Vanlierde et al., EAAP 28th August
Innovative lactation stage specific prediction of CH$_4$ from milk MIR spectra


Thrusday 28$^{th}$ August – 9:45 - Session 42 ‘Livestock effects on the environment’
Milk constituents

Ruminal fermentation of fiber

Acetic

Propionic

Butyric

Vanlierde et al., EAAP 28th August

95% CH₄
### CH₄ – Milk - MIR

<table>
<thead>
<tr>
<th>Equation</th>
<th>N</th>
<th>SD</th>
<th>R²c</th>
<th>R²cv</th>
<th>SEC</th>
<th>SECV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄ (g/day)</td>
<td>446</td>
<td>127.5</td>
<td>0.75</td>
<td>0.67</td>
<td>63</td>
<td>72</td>
</tr>
</tbody>
</table>

N= number of observations; SD=standard deviation; R²c= calibration coefficient of determination; R²cv= cross-validation coefficient of determination; SEC= calibration standard error; SECV= cross-validation standard error

\[ R²c = 0.75 \rightarrow Rc=0.87 \]
\[ R²cv = 0.67 \rightarrow Rcv=0.82 \]

Vanlierde et al., EAAP 28th August
CH$_4$ – Milk - MIR

Garnworthy et al., 2012

Vanlierde et al., EAAP 28$^{th}$ August
DMI

• Prediction of DMI (NRC, 2001)

\[
DMI=\left[(0.372 \times FCM) + (0.0968 \times body\_weight^{0.75})\right] \times \left(1 - e^{-0.192 \times (week\_lactation+3.67)}\right)
\]

FCM = fat corrected milk
• Prediction of DMI (NRC, 2001)

\[
DMI = [(0.372 \times FCM) + (0.0968 \times \text{body\_weight}^{0.75})] \times (1 - e^{-0.192 \times (\text{week\_lactation} + 3.67)})
\]

FCM = fat corrected milk

Body weight?
Total requirement (UFL) 
(= production+gestation+growth+maintenance) 

Net energy for lactation (ENL - Mcal) 
= 1.7 * total requirement 

Metabolizable energy (EM - Mcal) 
= ENL/0.60 

Metabolizable energy (EM2 - MJ) 
= EM*(1/0.239) 

Methane prediction (MJ/day) 
= 8.25+(0.007*EM2) 

Methane prediction (g/day) 
= methane(MJ/j)*(16/0.8033) 

Conversion factor (Y’m) 
= 100*(methane(MJ/j)/EM2)
Total requirement (UFL) = production + gestation + growth + maintenance

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Vermorel et al., 2008
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Vermorel et al., 2008
**Total requirement (UFL)**
\(=\) \(\text{production}+\text{gestation}+\text{growth}+\text{maintenance}\)

**Net energy for lactation (ENL - Mcal)**
\[= 1.7 \times \text{total requirement}\]

**Metabolizable energy (EM - Mcal)**
\[= \frac{\text{ENL}}{0.60}\]

**Metabolizable energy (EM2 - MJ)**
\[= \text{EM} \times \left(\frac{1}{0.239}\right)\]

**Methane prediction (MJ/day)**
\[= 8.25 + (0.007 \times \text{EM2})\]

**Methane prediction (g/day)**
\[= \text{methane(MJ/j)} \times \left(\frac{16}{0.8033}\right)\]

**Conversion factor (Y'm)**
\[= 100 \times \frac{\text{methane(MJ/j)}}{\text{EM2}}\]

**Known Unknown but...**

**Bottom-Up Approach**

Vermorel et al., 2008
Total requirement (UFL) = production + gestation + growth + maintenance

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Methane prediction (g/day)

= methane(MJ/j) * (16/0.8033)

Conversion factor (Y’m)

= 100 * methane(MJ/j) / EM2

Prediction of body weight is therefore possible

Known
Unknown but...

BOTTOM-UP APPROACH

Vermorel et al., 2008
DMI – Prediction of BW

\[ R^2 = 0.7438 \]
Estimation of Genetic Parameters

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Multiple traits animal model from data collected on Hostein cows in their first five parities.
Effect of Lactation Stage And Parity

Week of lactation

Dry matter intake (kg/day)
Effect of Lactation Stage And Parity

Week of lactation

CH4 (g/day)

lactation 1
lactation 2
lactation 3
lactation 4
lactation 5
## Genetic parameters

### Heritability values, genetic and phenotypic correlations

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Heritability \( CH_4 \)

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**Moderate heritability** for \( CH_4 \) (g/day)

- Animal differences in \( CH_4 \) between 7 and 18% from calorimetry studies (Boadi et al., 2002; Grainger et al., 2007)
- 0.35 predicted from DMI (De Haas et al., 2011) however phenotypic correlation with DMI=1
- 0.31 predicted from MIR FA (Kandel et al. 2013)
- No studies about the heritability of CH4 measured from respiratory chambers
Heritability values, genetic and phenotypic correlations

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Moderate heritability for DMI (kg/day)

→ 0.44 from first 26 weeks of lactation (Veerkamp and Brotherstone, 1997)
→ heritability between 0.10 and 0.30 throughout the lactation (Berry et al., 2009)
→ 0.18 ± 0.06 for measured DMI and 0.22 ± 0.05 for predicted DMI (Vallimont et al., 2010)
## Genetic Correlations – CH$_4$

### Heritability values, genetic and phenotypic correlations

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As expected:
- Negative correlation with milk
- Positive correlations with fat and protein
Genetic Correlations – DMI

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→ 0.59 from first 26 weeks of lactation (Veerkamp and Brotherstone, 1997)
→ 0.52 between FCM and DMI (Vallimont et al., 2010)
Genetic Correlations – DMI

Heritability values, genetic and phenotypic correlations

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Positive correlations with %Fat and %Protein
## Phenotypic correlations

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0.31 between FPCM and DMI (De Haas et al., 2011)
### Heritability values, genetic and phenotypic correlations

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Positive correlation with \( \text{CH}_4 \)

--> De Haas et al. (2011) predicted \( \text{CH}_4 \) from feed intake \( \rightarrow \) correlation equal to 0.99
### Phenotypic correlations

**Heritability values, genetic and phenotypic correlations**

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De Haas et al. (2011) predicted CH₄ from feed intake → correlation = 0.99

Why this value is not higher although correct relationship is observed for DMI with the other studied traits? Maybe extreme variability for methane emission...
Relationship between CH$_4$ and DMI

\[ R^2 = 0.9924 \]
CH$_4$/DMI

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Single trait animal model from data collected on Holstein cows in their first five parities
CH$_4$/DMI

Heritability = 0.11
Conclusion

- CH$_4$ predicted by MIR, DMI derived from MIR CH$_4$ and animal requirements are **heritable** as suggested by other studies
- The use of **MIR spectrometry** through the routine milk recording could permit to generate easily a large number of indicators useful to mitigate the **greenhouse gases** and to improve the **feed efficiency**
  - Walloon spectral database = more than 3,000,000 test-day records
  - Other countries have started the creation of a spectral database (ireland, UK, France, Germany, Finland...)
- The proposed strategy to create an efficiency trait could be used as **novel phenotype** for genomic selection
Using Milk Spectral Data for Large-Scale Phenotypes Linked to Mitigation and Efficiency


Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium
Walloon Research Centre, Gembloux, Belgium

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