OptiMIR: Use of MIR spectra to predict multiple cow status as advisory tools for dairy farms

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\textsuperscript{2} ULG, GxABT, Gembloux, Belgium
\textsuperscript{3} AWE, Ciney, Belgium
\textsuperscript{4} SRUC, Edinburgh, United Kingdom
\textsuperscript{5} IDELE, Angers, France
\textsuperscript{6} EMR, Ciney, Belgium
Position of the peaks → Qualitative analysis
Intensity of the peaks → Quantitative analysis
Classical use of MIR spectra

Milk control

Composition
- Fat
- Proteins
- Urea
- Lactose
- ...

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Innovative view of OptiMIR

MIR spectra

Cow state

Prediction tools fast, cheap, via milk control organisations

Information on:
- feeding (acidosis, ketosis, energy balance...)
- health (mastitis...)
- environmental impact (methane...)
- fertility (pregnancy...)
Development of new tools

MIR spectra + Reference analysis + Chemometric tools

Model predicting reference analysis from MIR spectra
OptiMir network

83 instruments
Spectral standardisation

Grelet et al. 2015 J. Dairy Sci. 98: 2150-60
- Harmonize the spectral format
- Allow merging of data
- Creation of common models

Models can be used on all instruments

Grelet et al. 2015 J. Dairy Sci. 98: 2150-60
OptiMIR models
Bjerre-Harpoth (2012) : Induced nutrient restriction

Citrate in milk as early indicator of physiological imbalance

« …greatest increase (58%) during restriction for all cows »
« …promising early indicator of physiological imbalance »
• **Statistics for citrate model (PLS)**

<table>
<thead>
<tr>
<th>Item</th>
<th>N</th>
<th>No. of LV</th>
<th>No. of Outliers</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>RMSE</th>
<th>R²</th>
<th>RPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium citrate (mmol/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-validation</td>
<td>380</td>
<td>9</td>
<td>2</td>
<td>3.88</td>
<td>16.12</td>
<td>9.03</td>
<td>2.26</td>
<td>0.7</td>
<td>0.9</td>
<td>3.21</td>
</tr>
<tr>
<td>Validation</td>
<td>126</td>
<td>-</td>
<td>-</td>
<td>4.44</td>
<td>15.16</td>
<td>9.08</td>
<td>2.03</td>
<td>0.76</td>
<td>0.86</td>
<td>2.96</td>
</tr>
</tbody>
</table>

Validation dataset

\[
y = 0.9919x + 0.0582
\]

\[
R^2 = 0.8575
\]

Allows screening, quantitative information
Negative energy balance – direct phenotype

Data:
- 526,509 daily records
- 962 cows were available from France and the UK

Data treatment:
- Spectra standardized
- Smoothed data (S.Denholm 2015)
- PLS regression

<table>
<thead>
<tr>
<th></th>
<th>$R^2_{cv}$</th>
<th>$R^2_{cv}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Balance (MJ/d)</td>
<td>0.20</td>
<td>0.58</td>
</tr>
<tr>
<td>Energy Content (MJ/d)</td>
<td>0.22</td>
<td>0.24</td>
</tr>
<tr>
<td>Energy Intake (MJ/d)</td>
<td>0.32</td>
<td>0.48</td>
</tr>
</tbody>
</table>

S. Smith, 2015
S. Smith, 2016, personal communication
### BHB and Acetone in milk known as biomarkers (Enjalbert et al., 2001)

#### Statistics for milk BHB model (PLS)

<table>
<thead>
<tr>
<th>Item</th>
<th>N</th>
<th>No. of LV</th>
<th>No. of Outliers</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>RMSE</th>
<th>R²</th>
<th>RPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHB (mmol/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-validation</td>
<td>325</td>
<td>8</td>
<td>7</td>
<td>0.045</td>
<td>1.596</td>
<td>0.235</td>
<td>0.193</td>
<td>0.109</td>
<td>0.71</td>
<td>1.77</td>
</tr>
<tr>
<td>Validation</td>
<td>108</td>
<td>-</td>
<td>-</td>
<td>0.058</td>
<td>0.755</td>
<td>0.204</td>
<td>0.136</td>
<td>0.083</td>
<td>0.63</td>
<td>2.36</td>
</tr>
</tbody>
</table>

\[
y = 1.0042x + 0.0071 \quad R^2 = 0.625
\]

**Validation dataset**

- Low BHB content (<0.200 mmol/L)
- High BHB content (>0.200 mmol/L)
- Global good classification

<table>
<thead>
<tr>
<th>Validation</th>
<th>n=77</th>
<th>n=32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted low</td>
<td>90.90%</td>
<td>9.40%</td>
</tr>
<tr>
<td>Predicted high</td>
<td>9.10%</td>
<td>90.60%</td>
</tr>
</tbody>
</table>

**Global good classification** 90.80%

**Allows discriminate high or low levels**
Ketosis – Direct phenotype

4 farms in France and Germany
1124 collected phenotypes on 214 cows

Prediction of the level of ketosis risk

- High risk: blood BHB>1.2 mmol/L or NEFA>0.8
- Low risk

Results on cross validation (n=566)

<table>
<thead>
<tr>
<th>Sensitivity = 84.5 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specificity = 84.2 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observation</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low risk</td>
<td>234</td>
</tr>
<tr>
<td>High risk</td>
<td>43</td>
</tr>
</tbody>
</table>

M.Gelé, 2015
Other models

• Fatty acids profile (32 FA and groups of FA)
  • 1827 milk samples
  • 6 countries
  • 17 breeds
  Soyeurt et al. 2011 J. Dairy Sci. 94: 1657-67
  & Bastin et al. 2011 J Dairy Sci. 94: 4152-63

• Minerals in milk
  • 1181 samples
  • 4 countries
  & Soyeurt et al. 2012 EAAP 63rd Annual meeting, 17

• Methane
  • SF6 and respiratory chambers
  • 7 countries
  Vanlierde et al. 2015 J. Dairy Sci. 98 : 5740-47
Use on field
Use of new tools on field

Standardization

New models

New phenotypes

NEB

Ketosis risk

Methane...
Ketosis tool developed by AWE (BE)

• Walloon breeding association (AWE) tool using models developed in Optimir project

• Global Ketosis index tool: Combination of BHB, acetone predictions and fat/protein ratio

• Relative approach for each biomarker: Cow value compared to population values at same DIM

Score 0,1 or 2 for each component

Score 0

Score 1

Score 2
Ketosis tool developed by AWE (BE)

- Global score from 0 to 6 as a global indication for ketosis status

- Currently in test in 75 farms

- Good feedback from cattle breeders
Conclusion

- Creation of Standardization procedure
  - Network of 83 MIR instruments currently standardized in routine
  - Creation of common spectral data base
  - Possible to use all existing and future models on all instruments

- Creation of new models
  - Prediction of Negative energy balance
  - Prediction of ketosis risk

- Upgrade of existing models: Methane, fatty acids, minerals, ...

- Creation of [European Milk Recording] (European Milk Recording)
Thank to all our partners