How to use mid-infrared spectral information from milk recording system to detect the pregnancy status of dairy cows

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Context

**Milk recording system**

**Management tool**
- Mating advices
- Udder health status
- BCS monitoring
- Feeding monitoring
- Milking monitoring
- ...

**Breeding evaluation**
- Performances control
- Genetic improvement
- ...

Improve the sustainability of the dairy sector

4/6 weeks
- Whole lactations
- Technician/Farmer
- Morning/Evening milking or both

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Context

Milk recording

Mid-Infrared Spectroscopy (MIR)

Spectral database

Example of a MIR spectrum of milk

Fingerprint of the whole milk composition
Context

Fertility
► key element for the dairy farm management

➢ Pregnancy diagnosis
  ✓ Echography
  ✓ Transrectal palpation
  ✓ PAG or progesterone tests
  ✓ ...

► Costs
► Risks
► Have to be done by a veterinarian or a qualified person
Objectives

Fertility tool

- Indication of the pregnancy status of the cow (pregnant vs. open)
- At the early stage of gestation → from 20 to 120 days after an insemination event
- Useful in the context of the milk recording system

Advisory tools for the farmer

“which cows should be checked?”
Principles

- Many factors influence the shape of the milk MIR spectra:
  - Days in Milk, Parity, Breed, Farm management, ...

How to observe differences in spectra due to the pregnancy?

- Literature examples:
  - Sloth et al. 2003: Adjustment of milk parameters on a subset of healthy samples applied on a whole dataset (healthy and not) to assess udder health from milk samples
  - Staib et al. 2001: Diagnosis of rheumatoid arthritis with discriminant analysis on human blood IR spectra
Principles

Observed spectrum = Milk sample on which we want to test the pregnancy
Principles

**Observed spectrum** = Milk sample on which we want to test the pregnancy

**Expected open spectrum** = Expected open spectrum for the same day in milk if the animal was not pregnant
Principles

Residual spectrum = Observed spectrum – Expected open spectrum

Reproductive status
Unaccounted factors
Errors

Residual spectra are used to perform discrimination between two groups of classification (pregnant cow and open cow)
**Principles - Estimation of expected open spectra**

\[ y = X\beta + Z\gamma + \varepsilon \]

*\( y \): Vector of observations (spectral points)
*\( \beta \): Fixed effects
*\( \gamma \): Random effects
*\( \varepsilon \): Residual errors
*\( X \) and \( Z \): Incidence matrices

**Mixed model on a subset of spectral data from open cows!**

**Solutions applied on the whole dataset to obtain all the expected open spectra**

\[ \hat{y} = X\hat{\beta} + Z\hat{\gamma} \]

*\( \hat{y} \): Vector of estimated observations
*\( \hat{\beta} \): Estimated fixed effects
*\( \hat{\gamma} \): Estimated random effects
*\( X \) and \( Z \): Incidence matrices

**Residual spectral points**

\[ \hat{\varepsilon} = y - \hat{y} \]
Principles – Use of the residual spectra

The objective is to distinguish residual spectra coming from pregnant cow or from open cow

Discriminant analysis

\[ d'_P = d_P^2 + \ln |\Sigma_P| \quad \text{with} \quad d_P^2 = (x - \mu)_P \Sigma_P^{-1} (x - \mu)_P^T \]

\[ d'_O = d_O^2 + \ln |\Sigma_O| \quad \text{with} \quad d_O^2 = (x - \mu)_O \Sigma_O^{-1} (x - \mu)_O^T \]

\[ P(x | j) = d'_j^2 / \sum d''^2 \quad j = \text{group of classification (P/O)} \]
Data set

- Pre-processing of spectral data
  - First derivative
  - Informative area

- Modelling the expected open spectra
  - Only spectral information coming from open cows
  - 256,238 spectra

**Residual spectra**

  → Discriminant function

- Calibration
  - 2,149 residual spectra (50% open and 50% pregnant)

- Validation
  - 12,179 residual spectra from 20 to 120 days after an insemination
  - New lactations regarding to the calibration set
Results – Discriminant function

- Result of classification on residual spectra from the whole validation set
  - 0.7% error of classification

Results of classification on residual spectra from the validation set by classes of 10 days after insemination

<table>
<thead>
<tr>
<th>No. of days after insemination</th>
<th>n NP</th>
<th>n P</th>
<th>Total Error (%)</th>
<th>Specificity (%)</th>
<th>Sensibility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 21 to 30</td>
<td>216</td>
<td>1,177</td>
<td>2.2</td>
<td>88.4</td>
<td>99.6</td>
</tr>
<tr>
<td>From 31 to 40</td>
<td>128</td>
<td>1,140</td>
<td>2.0</td>
<td>87.5</td>
<td>99.2</td>
</tr>
<tr>
<td>From 41 to 50</td>
<td>36</td>
<td>1,206</td>
<td>0.6</td>
<td>94.4</td>
<td>99.6</td>
</tr>
</tbody>
</table>

Specificity: Proportion of data belonging to open cows properly classified as open
Sensibility: Proportion of data belonging to pregnant cows properly classified as pregnant

- Result of classification on observed spectra from the whole validation set
  - 55.5% error of classification
Conclusion

- **Direct use of the MIR spectra**
  - Cheap
  - Easily transferable
  - Spectral data already obtained in routine

→ Adjustment for systematic factors is useful to observe fine milk changes due to the change in the pregnancy status

- **Pregnancy detection**
  - Very promising results!
  - From 20 to 50 or 120 days after insemination
  - Late stage of gestation?

→ Advisory tool
Project and Perspectives

● OptiMIR project:
  ● 17 European partners → Common database
  ● Milk recording organizations, research centers, milk analysis laboratory

"New tools for a more sustainable dairy sector”

● Based on mid-infrared spectral information from milk
  ● Fertility
  ● Feeding
  ● Health (Udder health, …)
  ● Rejection of pollutants
  ● Milk quality

www.optimir.eu
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