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Investing in Opportunities

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INTERREG IVB

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

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Context

Improve the sustainability of the dairy sector

Management tool
- ✓ Mating advices
- ✓ Udder health status
- ✓ BCS monitoring
- ✓ Feeding monitoring
- ✓ Milking monitoring
- ✓ …

Milk recording system

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

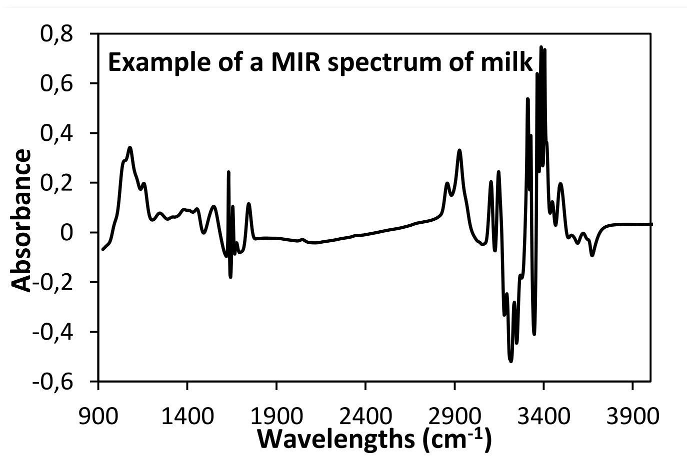
Breeding evaluation
- ✓ Performances control
- ✓ Genetic improvement
- ✓ …

Context

Milk recording

Mid-Infrared Spectroscopy (MIR)

Spectral database



Fingerprint of the whole milk composition

Context

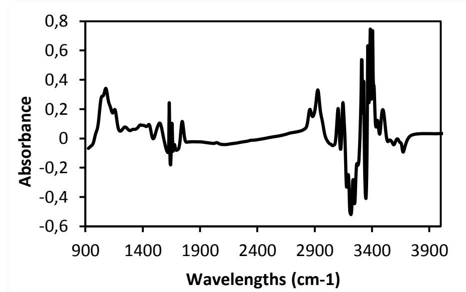
Fertility
→ key element for the dairy farm management

- **Pregnancy diagnosis**
  - ✓ Echography
  - ✓ Transrectal palpation
  - ✓ PAG or progesterone tests
  - ✓ …

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

Objectives

MIR milk spectra



Cow's state

- **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

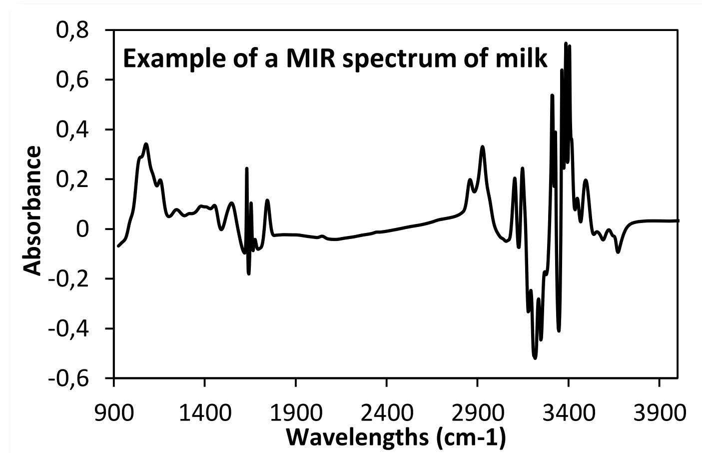
→ Advisory tools for the farmer

" which cows should be checked ? "

Principles

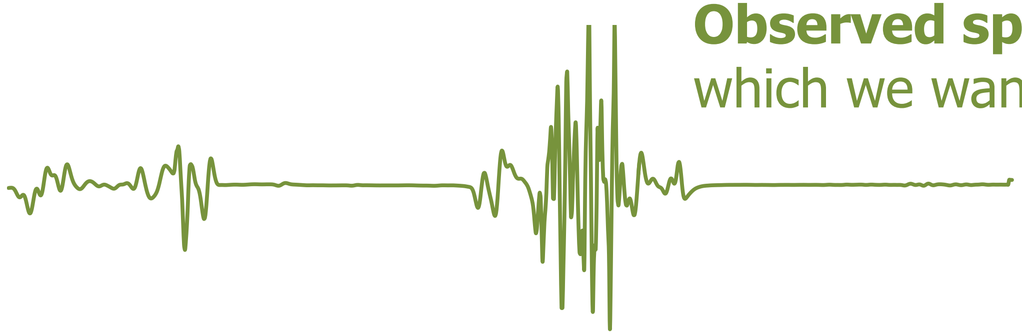
- Many factors influence the shape of the milk MIR spectra:
  - Days in Milk, Parity, Breed, Farm management, …

➔ How to observe differences in spectra due to the pregnancy ?



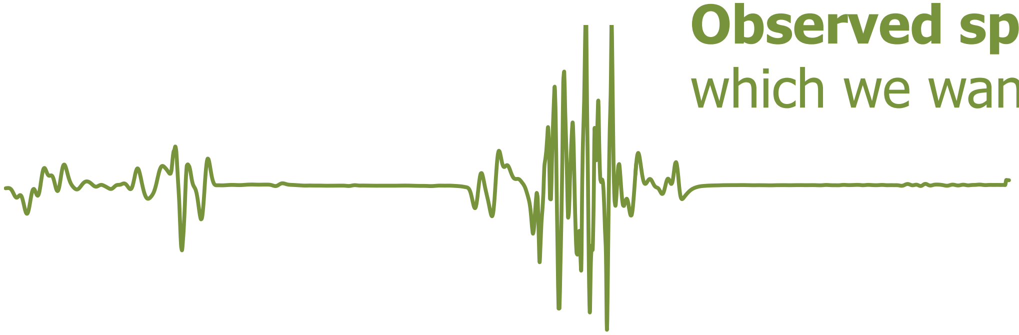
- Literature examples :
  - Sloth et al. 2003: Adjustment of milk parameters on a subset of healthy samples applied on a whole dataset (healthy and not) to assess udder health from milk samples
  - Staib et al. 2001: Diagnosis of rheumatoid arthritis with discriminant analysis on human blood IR spectra

Principles



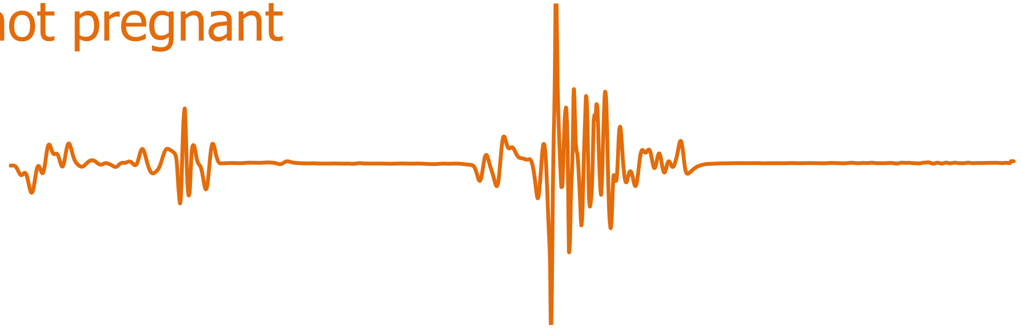
Observed spectrum = Milk sample on which we want to test the pregnancy

Principles

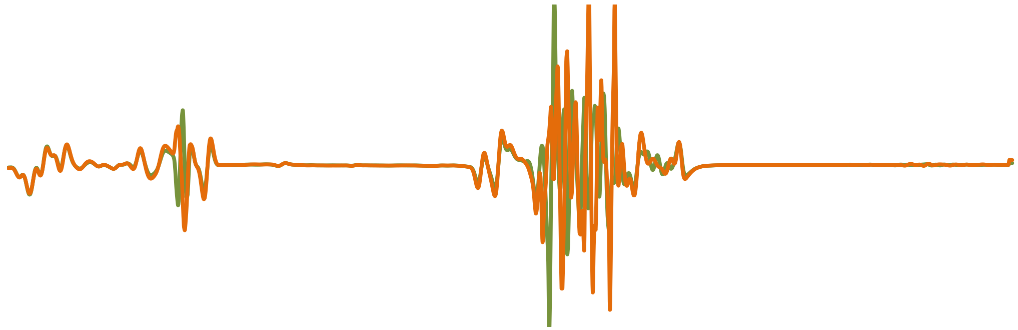


Observed spectrum = Milk sample on which we want to test the pregnancy

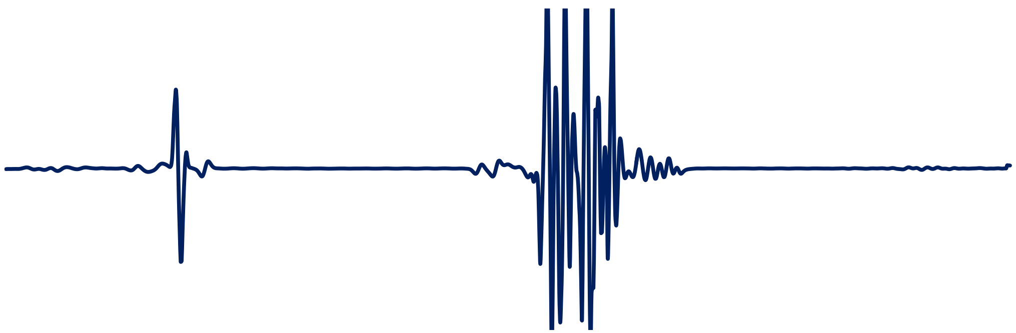
Expected open spectrum = Expected open spectrum for the same day in milk if the animal was not pregnant



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)
β = Fixed effects
γ = Random effects
ε = 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

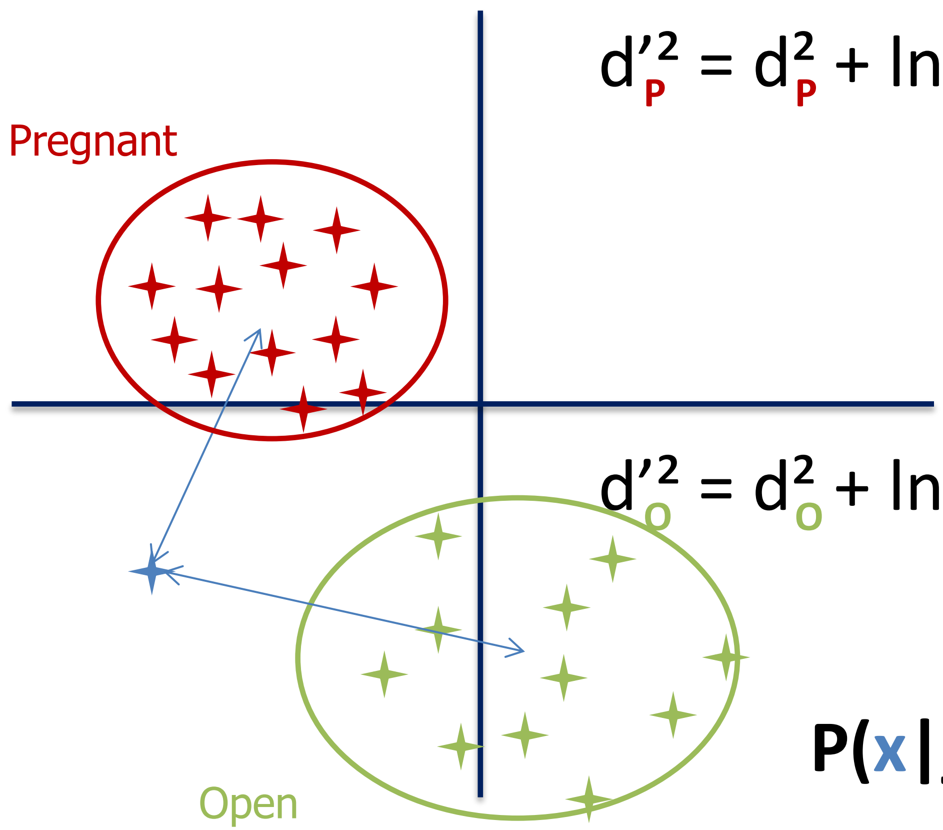
$$\hat{\varepsilon} = y - \hat{y}$$

Residual spectral points

Principles – Use of the residual spectra

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

Discriminant analysis



$$d'^2_P = d^2_P + \ln|\Sigma_P| \quad \text{with} \quad d^2_P = (\mathbf{x}-\mu)\,\Sigma_P^{-1}\,(\mathbf{x}-\mu)^T$$

d^2 = Mahalanobis distance
μ = Vector of the average spectral point
Σ = Within covariance matrix
$\mathbf{x}$ = Vector of new observation

$$d'^2_O = d^2_O + \ln|\Sigma_O| \quad \text{with} \quad d^2_O = (\mathbf{x}-\mu)\,Z_O^{-1}\,(\mathbf{x}-\mu)^T$$

$$\mathbf{P(x|j) = d_j'^2 / \sum d'^2}$$

j = 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

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

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?

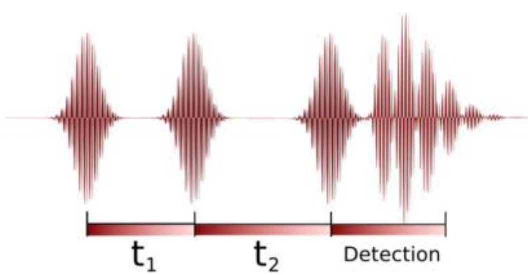
→ Advisory tool

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



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- Fertility
- Feeding
- Health (Udder health, …)
- Rejection of pollutants
- Milk quality

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Acknowledgments

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