Potential of mid-infrared spectrum of milk to detect changes in the physiological status of dairy cows

A. Laine[1], A. Goubau[1], H. Hammami[1,2], C. Bastin[1], N. Gengler[1]

[1]University of Liege, Gembloux Agro-Bio Tech, Animal Science Unit, Gembloux, Belgium

[2]National Fund for Scientific Research, Brussels, Belgium

2013 ADSA – ASAS Joint Annual Meeting
July 8 – 12, Indianapolis

Introduction

Mastitis, Acidosis, Pregnancy, Negative Energy Balance, …

⟷

Changes in the physiological status of dairy cows

↓

Economic losses for the farmers (drop in the production, additional costs)

- ✓ Early and rapid detection of these changes may help the farmer to make the right decisions at the right time in order to reduce the economic losses

Introduction

Mastitis, Acidosis, Pregnancy, Negative Energy Balance, …

Changes in the physiological status of dairy cows

Economic losses for the farmers (drop in the production, additional costs)

Milk composition is affected by those changes

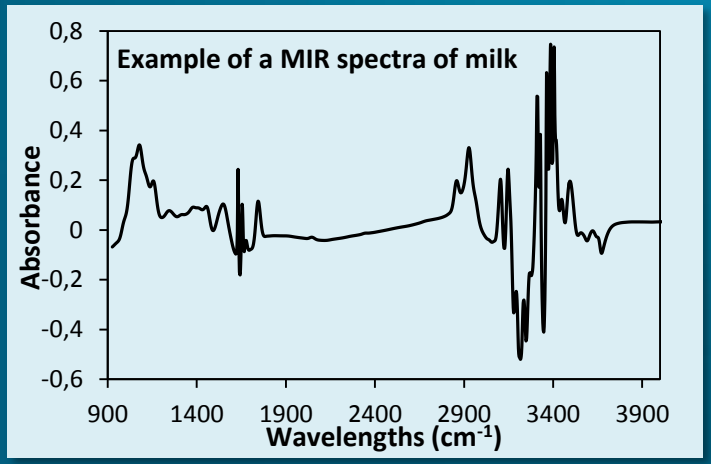
- ✓ Early and rapid detection of these changes may help the farmer to make the right decisions at the right time in order to reduce the economic losses

Introduction

Milk recording (DHI)

Mid-Infrared Spectroscopy (MIR)

Spectral database stored since 2007 (2,540,000 spectrum)



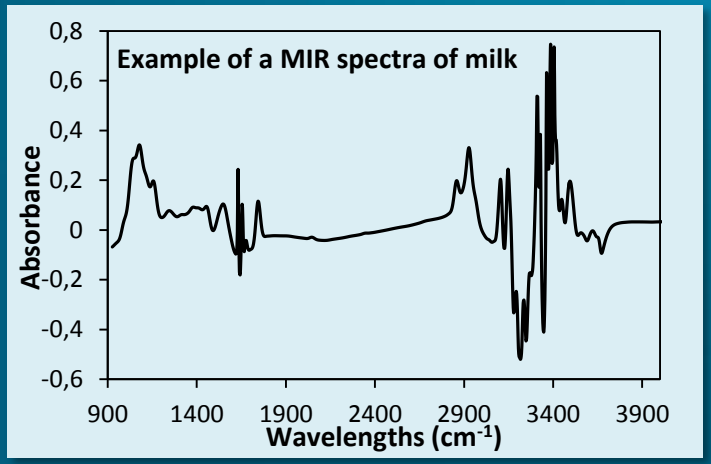
Major components : Fat, protein, lactose, urea

Introduction

Milk recording (DHI)

Mid-Infrared Spectroscopy (MIR)

Spectral database stored since 2007 (2,540,000 spectrum)



Major components : Fat, protein, lactose, urea

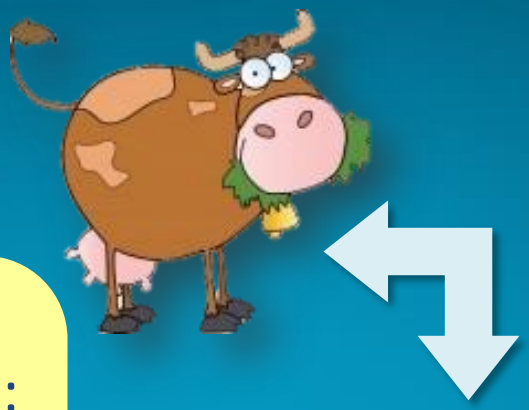
Fine milk composition : Fatty acids, minerals, lactoferrin, …

Objectives

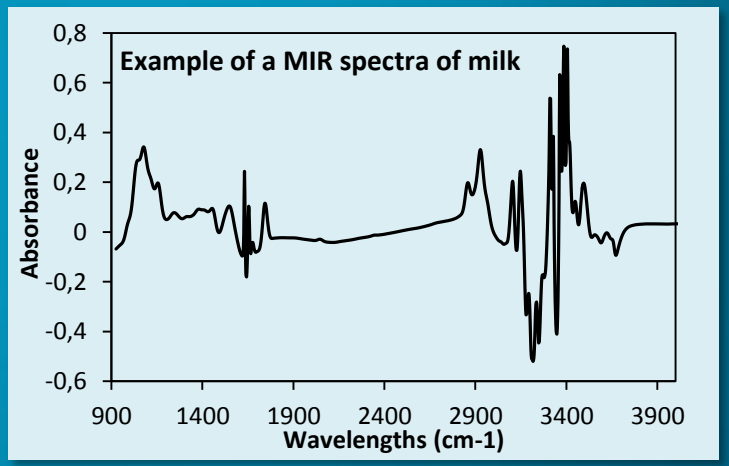
- ✓ Example of direct uses of the MIR spectra to detect changes in the animal status
  - ✓ *Does the observed MIR spectrum belongs to a pregnant cow or not ?* ➔ Pregnancy diagnosis
  - ✓ *Does the MIR spectrum allows early detection of milk samples from a cow suffering from udder health issues ?* ➔ Mastitis detection

Develop tools that will use the spectral analysis of the **Milk Recording** samples to enable a sustainable and profitable management of the milk production

Principles

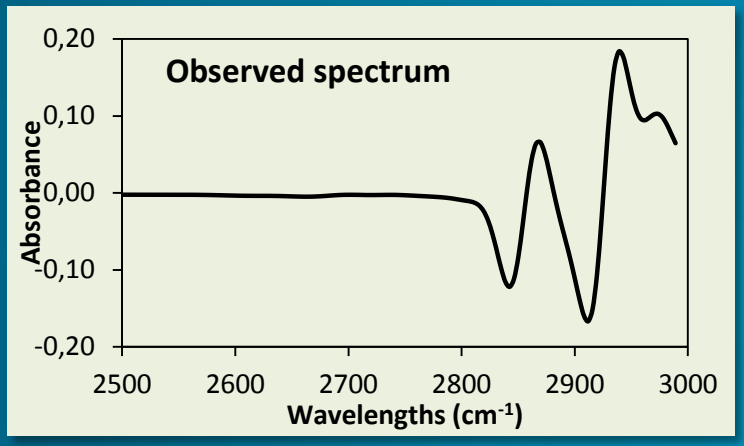


- ✓ Many factors influence the shape of the milk MIR spectra :
  - ✓ Days in Milk, Parity, Breed, Farm management, …
- ➔ *How to observe differences in spectra due to the pregnancy ?*



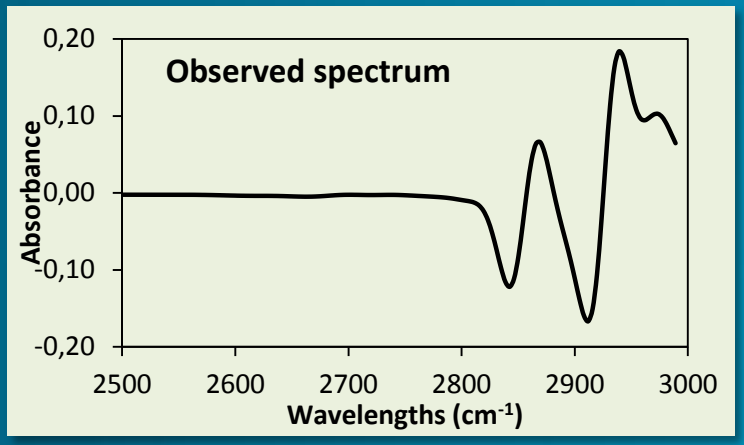
- ✓ Literature examples :
  - ✓ Sloth et al. 2003 : Adjustment of milk parameters on a subset of healthy samples applied on a whole dataset (healthy and not) to assess udder health from milk samples
  - ✓ Staib et al. 2001 : Diagnosis of rheumatoid arthritis with discriminant analysis on human blood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

Principles – Pregnancy Diagnosis

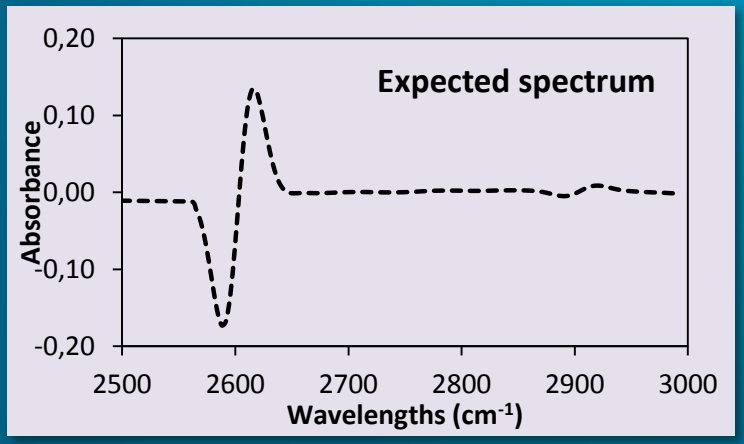


Observed spectrum = Milk sample on which we want to test the pregnancy

Principles – Pregnancy Diagnosis

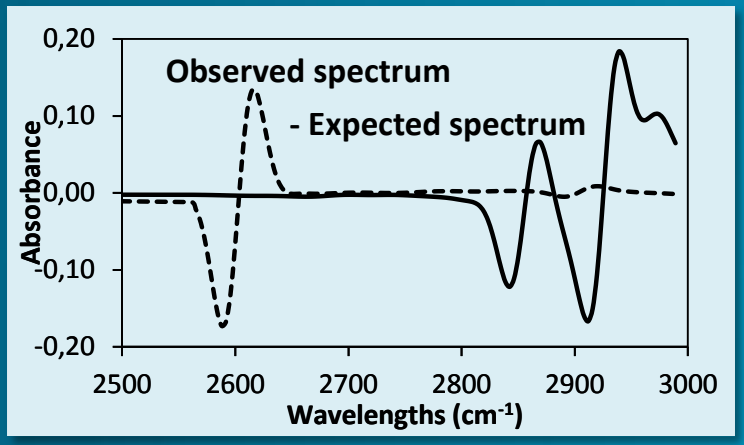


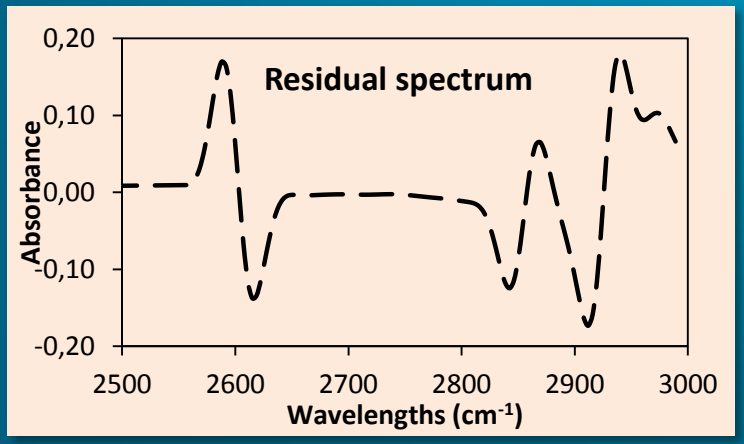
Observed spectrum = Milk sample on which we want to test the pregnancy



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

Principles – Pregnancy Diagnosis

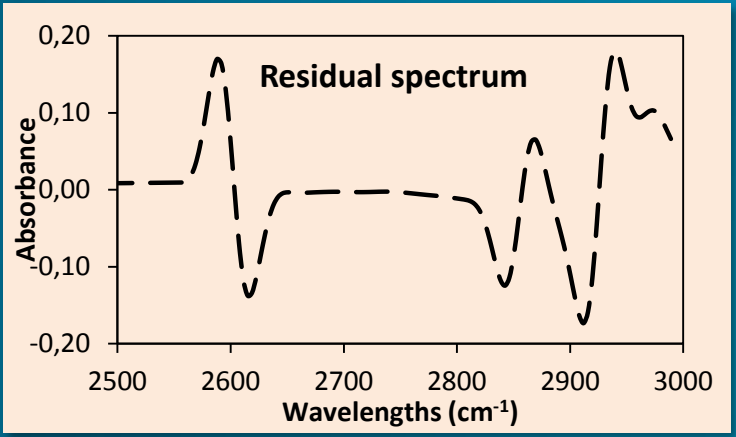




Residual spectrum = Observed spectrum - Expected spectrum

Reproductive status
Unaccounted factors
Errors

Principles – Pregnancy Diagnosis



Residual spectrum = Observed spectrum - Expected spectrum

Reproductive status
Unaccounted factors
Errors

- ✓ Residual spectrum is used to perform discrimination between two groups of classification (Pregnant cow and non-pregnant cow)

Results – Pregnancy Diagnosis

Does the observed MIR spectrum belongs to a pregnant cow or not ?

- ✓Dataset from Luxembourg
  - ✓7840 observations = spectra
  - ✓Holsteins cows
- ✓Pre-processing of MIR spectra
  - ✓First derivative : Set all spectra to a common baseline
  - ✓Informative area : Avoid noises and non-useful area
- ✓Modeling an expected spectra which is based on history of the animal and his herd
  - ✓Herd, animal, parity, breed, …
  - ✓Modeling based on a subset of non-pregnant data : 4714 spectrum

Results – Pregnancy Diagnosis

- ✓ Discriminant analysis (quadratic function)
  - ✓ Groups of classification : Pregnant and Non-pregnant
  - ✓ Predictors : Residual spectral points

Results – Pregnancy Diagnosis

- ✓ Discriminant analysis (quadratic function)
  - ✓ Groups of classification : Pregnant and Non-pregnant
  - ✓ Predictors : Residual spectral points
- ✓ Leave-one-out cross-validation (LOO CV)
  - ✓ Sensibility = 93.2 % (pregnant observations correctly classified)
  - ✓ Specificity = 98.2% (non-pregnant observations correctly classified)

Results – Pregnancy Diagnosis

- ✓ Discriminant analysis (quadratic function)
  - ✓ Groups of classification : Pregnant and Non-pregnant
  - ✓ Predictors : Residual spectral points
- ✓ Leave-one-out cross-validation (LOO CV)
  - ✓ Sensibility = 93.2 % (pregnant observations correctly classified)
  - ✓ Specificity = 98.2% (non-pregnant observations correctly classified)

Discriminant analysis using raw spectra
LOO CV :
- ✓ Sensibility = 50.3%
- ✓ Specificity = 62.2%

➔ **Better results when using residual spectra in the discriminant function**

Results – Pregnancy Diagnosis

Distribution of errors of classification by classes of 15 days after AI

Number of days after AI (classes of 15 days)	% Error Non-Pregnant	% Error Pregnant	n NP data	n P data	n data
0-14	24.0	4.4	956	226	1182
15-29	17.6	3.7	770	269	1039
30-44	7.8	4.1	549	254	803
45-59	5.7	2.0	405	265	670
60-74	3.7	2.7	332	252	584
75-89	2.0	1.7	266	252	518

Results – Pregnancy Diagnosis

Distribution of errors of classification by classes of 15 days after AI

Number of days after AI (classes of 15 days)	% Error Non-Pregnant	% Error Pregnant	n NP data	n P data	n data
0-14	24.0	4.4	956	226	1182
15-29	17.6	3.7	770	269	1039
30-44	7.8	4.1	549	254	803
45-59	5.7	2.0	405	265	670
60-74	3.7	2.7	332	252	584
75-89	2.0	1.7	266	252	518

➔ Errors are mainly situated during the first 30 days after AI

➔ Interesting period for a pregnancy diagnosis in the context of the milk recording

Results – Mastitis detection

Conclusion

- ✓ MIR spectra of milk could be used as a tool of dairy cow status diagnosis
  - ✓ Pregnancy diagnosis
  - ✓ Mastitis detection
  - ✓ …

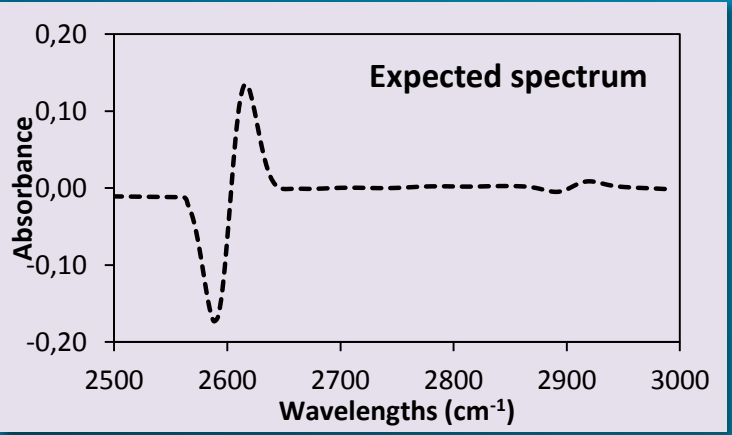
- ✓ An adjustments for some factors (Days in milk, parity, …) has to be done on the MIR spectral point in order to observe differences between two spectra of the same animal at a different status

Acknowledgements

- ✓ Public Service of Wallonia (SPW – DGARNE, project D31 – 1207)

Corresponding's authors e-mail :
aurelie.laine@ulg.ac.be

Principles – Pregnancy Diagnosis



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

$$y = X\beta + Z\gamma + \varepsilon$$

y = Vector of observations (spectral points)
β = Fixed effects
γ = Random effects
ε = Residual errors
X and Z = Incidence matrix

Mixed model on a subset of non pregnant data !

Solutions applied on the whole dataset to obtain all the expected spectrum

Results – Pregnancy Diagnosis

Does the observed MIR spectrum belongs to a pregnant cow or not ?

- ✓Modeling an expected spectra which is based on history of the animal and his herd
  - ✓Fixed effects : *Milking moment* (am, pm, mixed samples), *parity, herd*
  - ✓Regression coefficients : *DIM* and *DIM²*
  - ✓Random effects : *Cow x lactation*
  - ✓Random regression coefficients : *DIM x cow x lactation*, *DIM² x cow x lactation*
- ✓Subset of non-pregnant data : 4714 spectrum