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Milk mid-infrared spectrometry: Take information from light

Soyeurt H.

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Gembloux Agro-Bio Tech, it is …

- A


ESTONIA
LATVIA
North Sea
Inner Seas
DENMARK
Baltic Sea
LITHUANIA
UNITED KINGDOM
IRELAND
NETHERLANDS
POLAND
GERMANY
BELGIUM
CZECH REP.
LUX.
SLOVAKIA
FRANCE
AUSTRIA
HUNGARY
SWITZ.
SLOVENIA
CROATIA
ROMANIA
MONACO
SAN MARINO
BOSNIA AND HERZ.
SERBIA
ANDORRA
VATICAN
MONTENEGRO
ITALY
SPAIN
PORTUGAL
Tyrrhenian
ALBANIA


ALLEMAGNE
PAYS-BAS
Amsterdam
BELGIQUE
Bruxelles
Lille
Cologne
GEMBLOUX
Liège
Arlon
Francfort
Luxembourg
Paris
Strasbourg
SUISSE
Genève

- An **expertise** in fields related to the **life science** and the **bio-engineering**

- 1,378 students
  - 41 % of **students**
  - 32 % of **foreign students**
  - 40 **nationalities**
  - 327 **PhD students**

(statistics from May 2018)

- 499 members in the staff
  - 307 **researchers**
  - 44 **professors**
  - 61 **assistants**

(statistics from May 2018)

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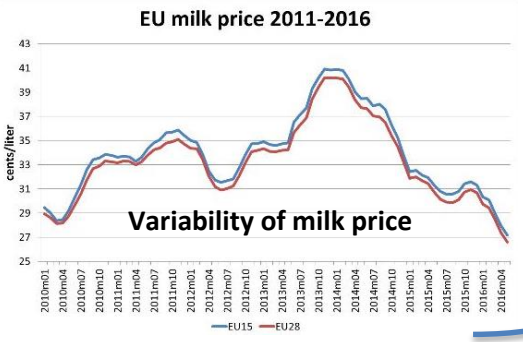
Milk MIR spectrometry

Context …

Quota

Increase of feeding cost

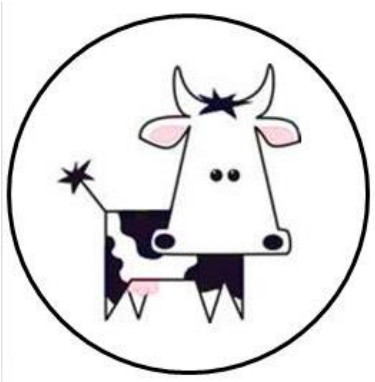
Environmental pressure



Variability of milk price

Milk composition is

- Part of economic outcome
- Mirror of the cow health



Optimize the production cost !!

Interest of developing decision tools from milk composition

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Milk MIR spectrometry

Milk analysis …

Milk sampling scheme

Milk recording

3.5% fat

Cow 1

3.8% fat

Cow 2

4.1% fat

Cow 3

DHI

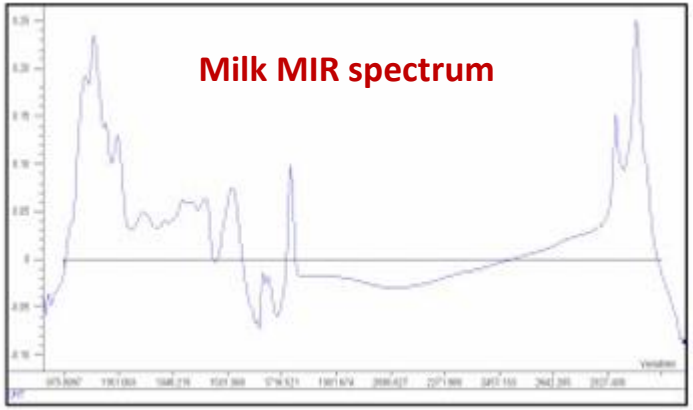
Milk payment

3.3% fat

Dairy industry

Milk analysis

%fat

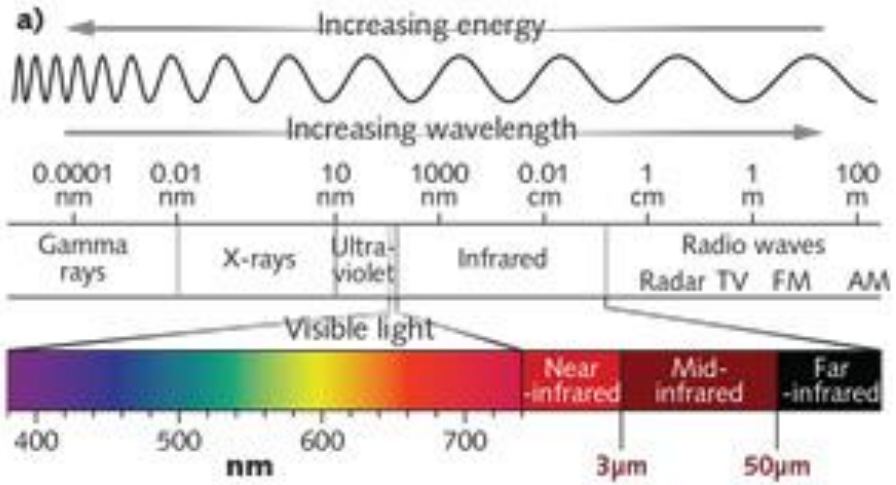


Milk recording
(± 4 weeks for each cow)

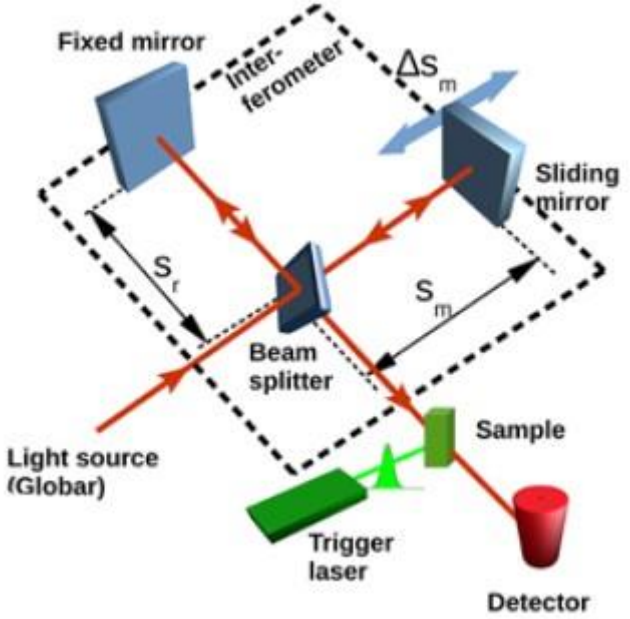
Milk payment
(± 3 days from bulk)

What is Mid-Infrared (MIR) spectrum ?

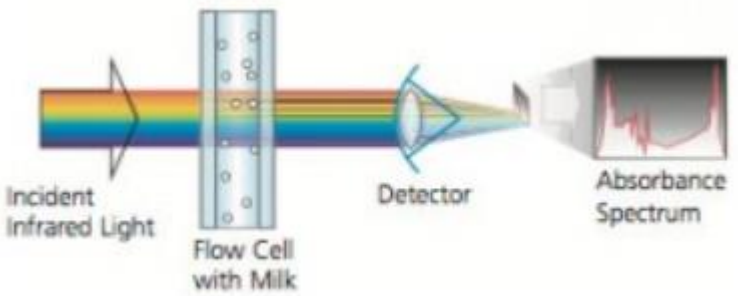
Electromagnetic radiation located between 3 and 50 µm



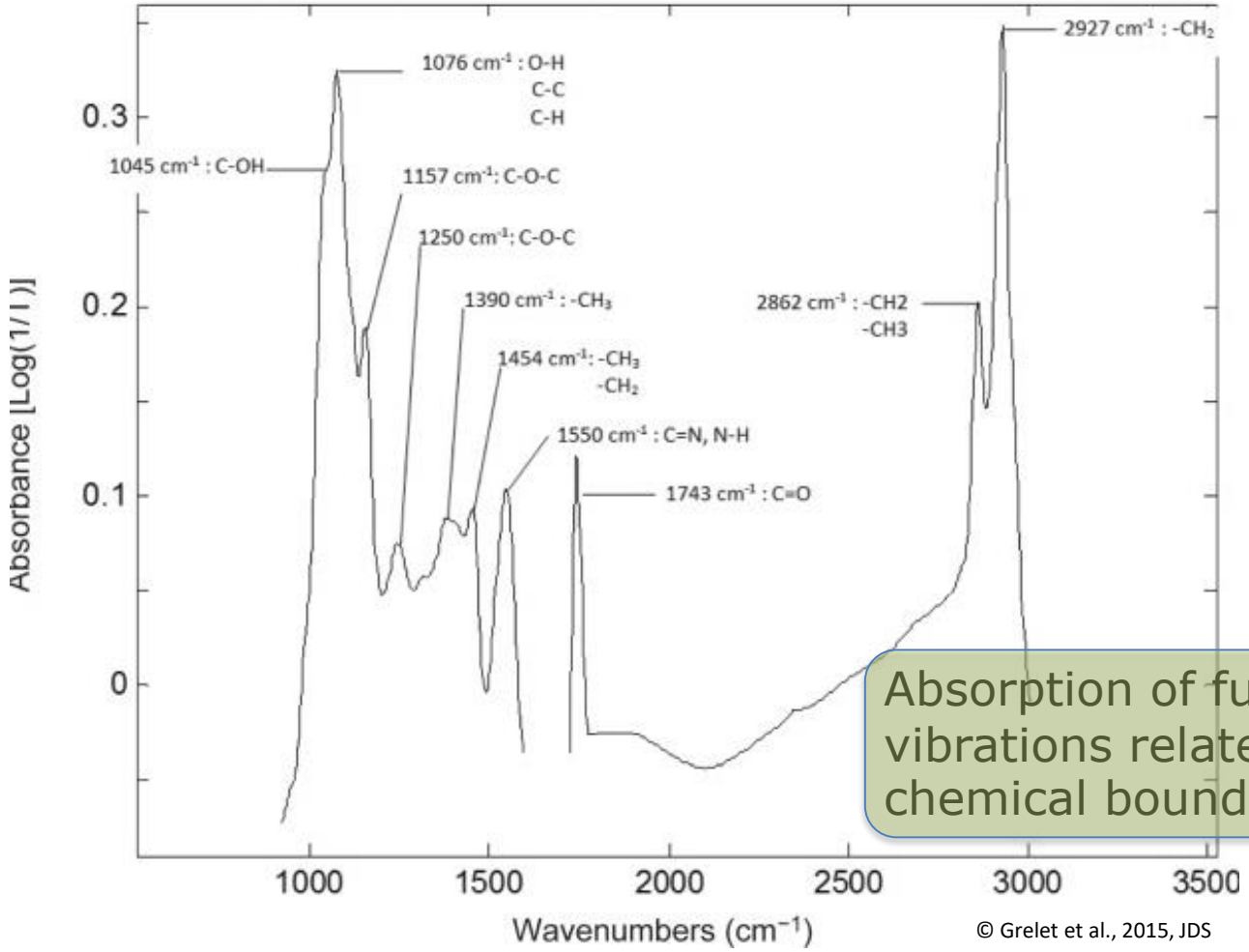
What is MIR spectrometry?



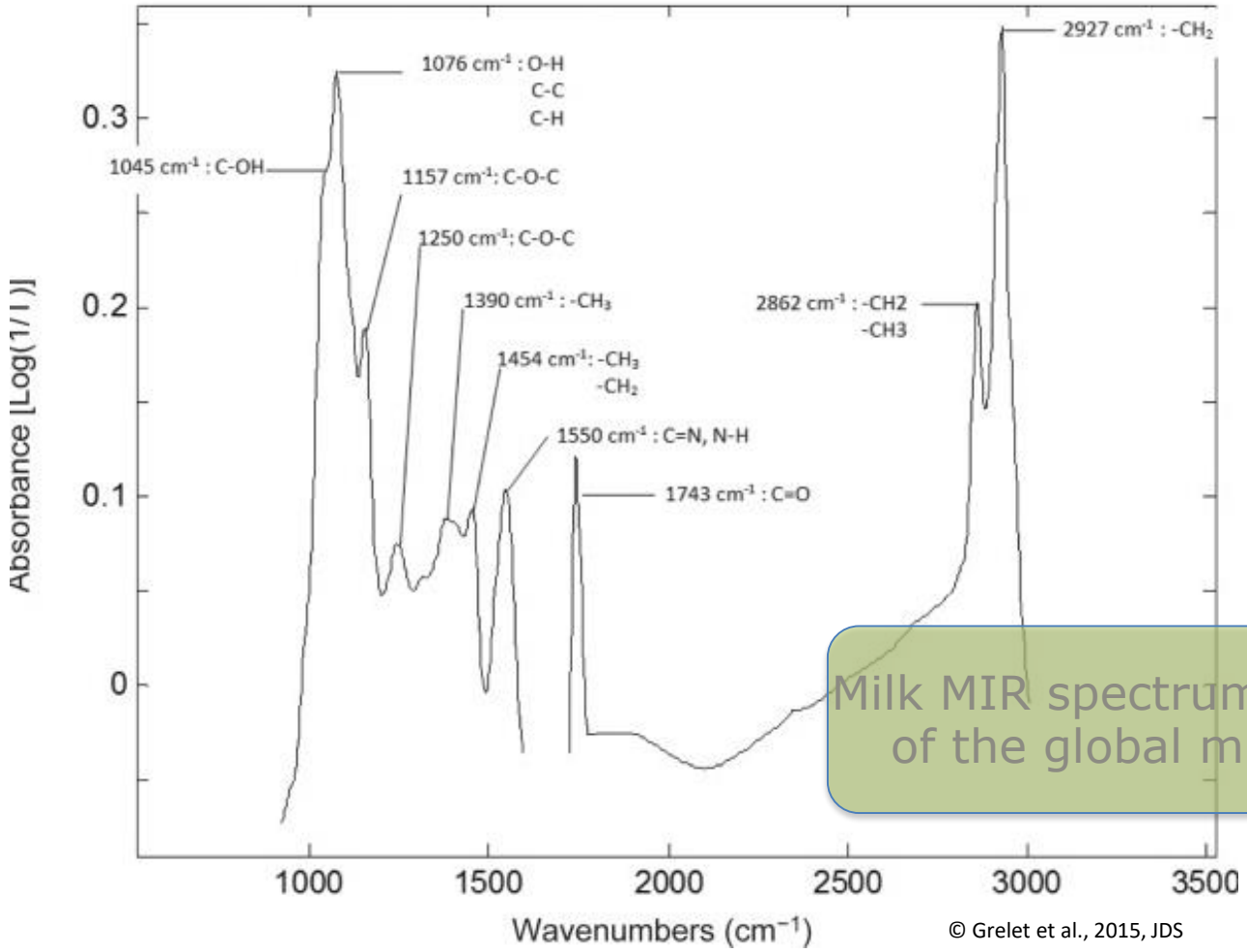
© Ritter et al., 2015, Frontiers in Molecular Biosciences



© Bentley instrument, 2019



Absorption of fundamental vibrations related to specific chemical bounds within a molecule



Milk MIR spectrum is representative of the global milk composition.

© Grelet et al., 2015, JDS

Different brands

Foss

© Foss website, 2019

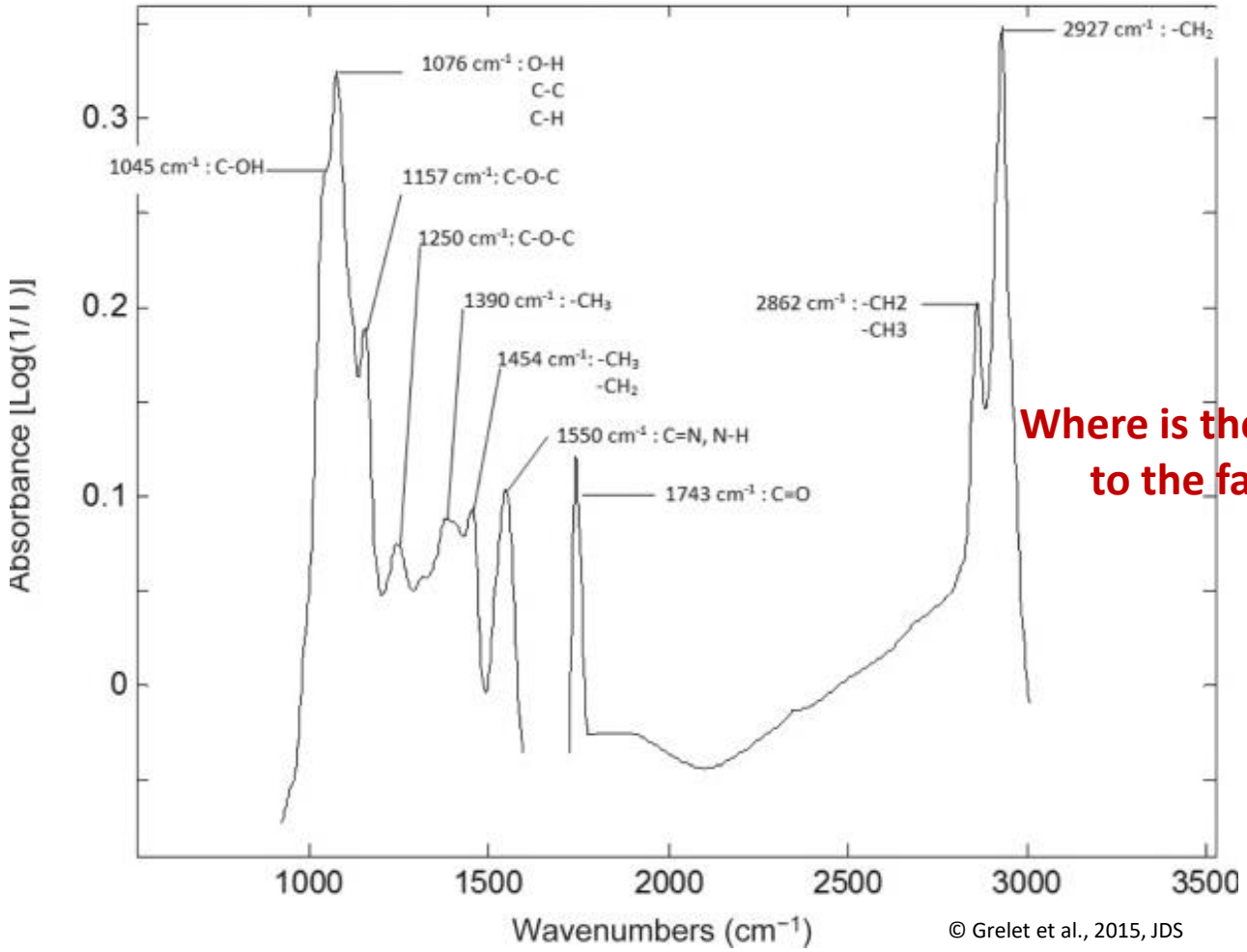
Bentley

© Bentley instrument website, 2019

Perten (Delta)

© Perten instrument website, 2019

- Different **resolutions**
- Different **spectral ranges**



Where is the information related to the fat quantification ?

© Grelet et al., 2015, JDS

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Milk MIR spectrometry

How to extract the interesting information …

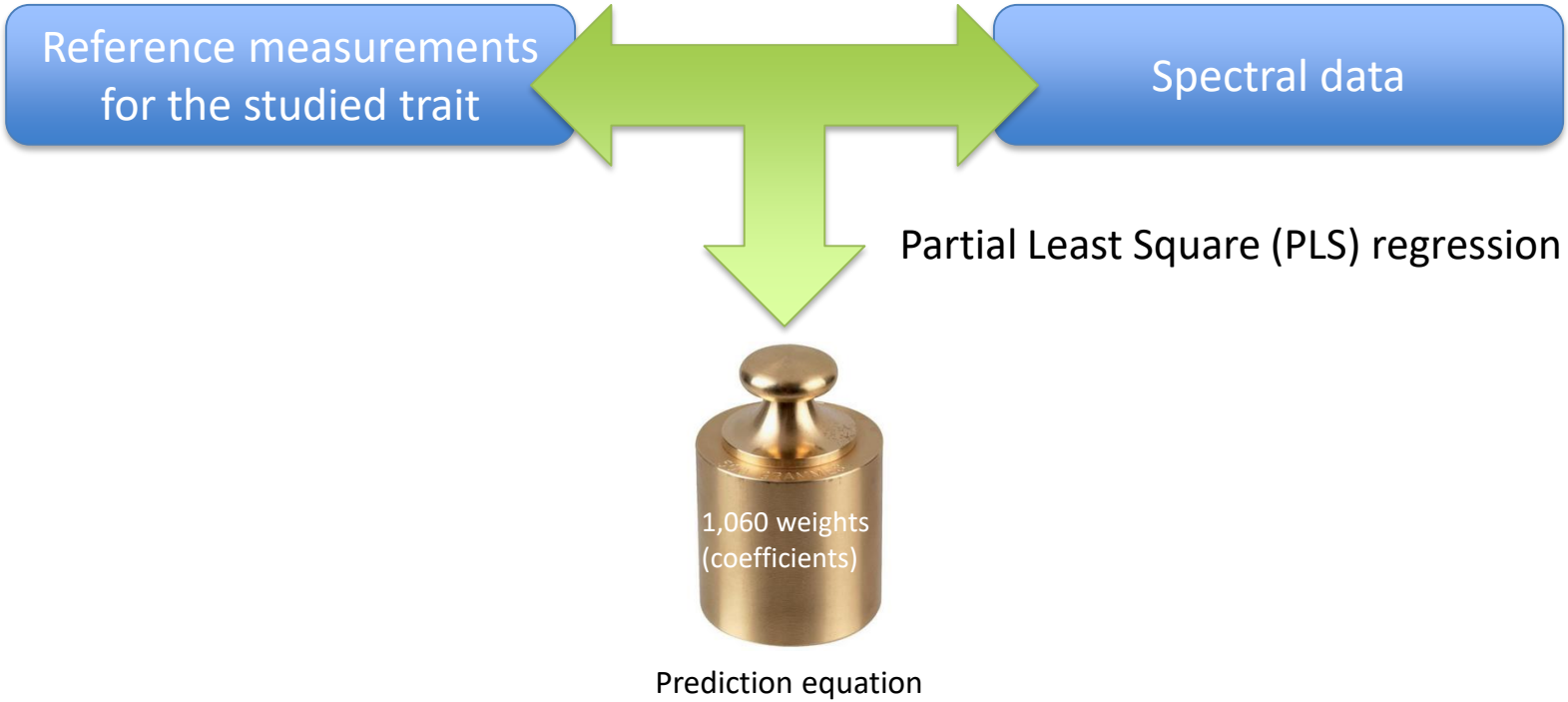
Milk analysis

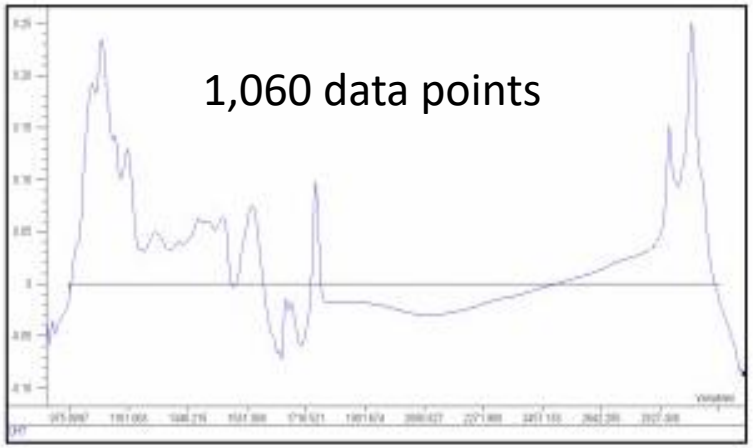
Milk recording
(± 4 weeks for each cow)

Milk payment
(± 3 days from bulk)

Prediction equation

How to build a prediction equation



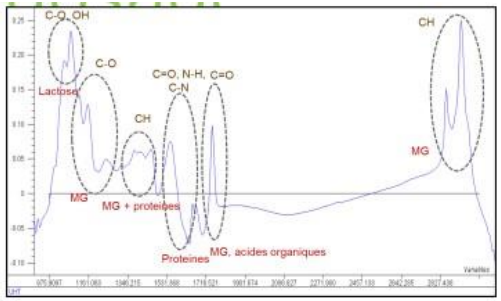


Spectra with unknown reference measurements

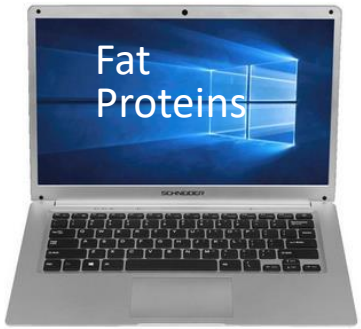
Prediction equation

More than 17 millions of test day records

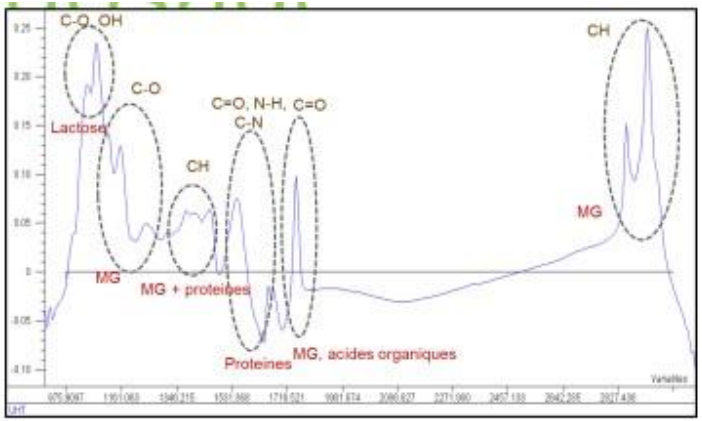
Prediction for new spectra



Prediction equation



- Before 2005, only equations related to **fat** and **proteins** were implemented in all milk laboratories
- In some others, equations were available also for **lactose** and **urea**
- **Walloon research team** composed by Gembloux Agro-Bio Tech, Walloon Research Centre, Comité du Lait and Walloon Breeding Association (Awé) through FuturoSpectre decided to **extend the use of milk MIR spectral data**
- In 2005, they were the **first to record the spectral data for DHI application**



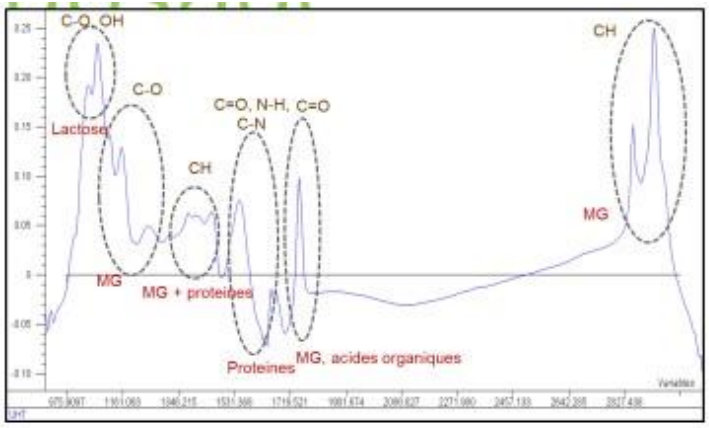
Prediction equation

Journal of Dairy Science
Volume 94, Issue 4, April 2011, Pages 1657–1667

Mid-infrared prediction of bovine milk fatty acids across multiple breeds, production systems, and countries

H. Soyeurt, F. Dehareng, N. Gengler, S. McParland, E. Wall, D.P. Berry, M. Coffey, P. Dardenne
Show more

http://dx.doi.org/10.3168/jds.2010-3408



Prediction equation

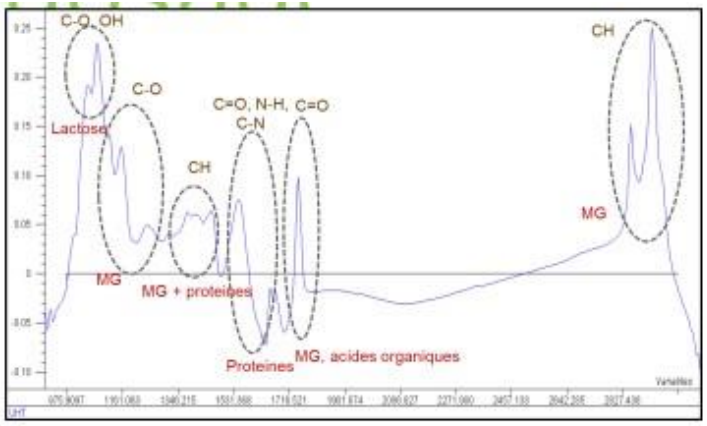
Journal of Dairy Science
Volume 92, Issue 6, June 2009, Pages 2444–2454

Research-article

Potential estimation of major mineral contents in cow milk using mid-infrared spectrometry

H. Soyeurt, D. Bruwier, J.-M. Romnee, N. Gengler, C. Bertozzi, D. Veselko, P. Dardenne
Show more

http://dx.doi.org/10.3168/jds.2008-1734



Prediction equation

animal, Volume 6, Issue 11

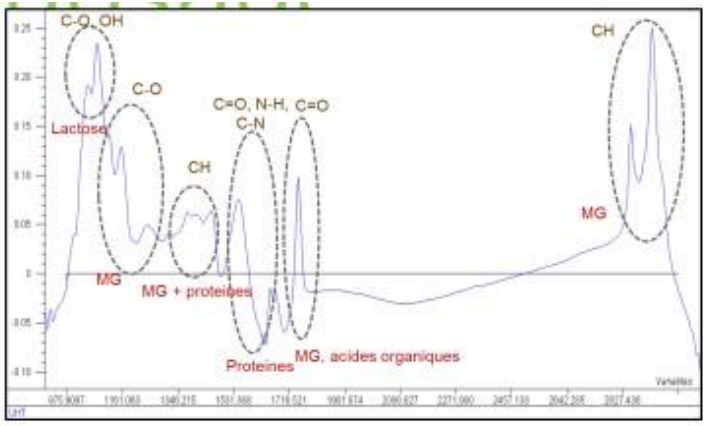
November 2012, pp. 1830-1838

Mid-infrared prediction of lactoferrin content in bovine milk: potential indicator of mastitis

H. Soyeurt [a1] [a2], C. Bastin [a1], F. G. Colinet [a1], V. M.-R. Arnould [a1] [a3], D. P. Berry [a4], E. Wall [a5], F. Dehareng [a6], H. N. Nguyen [a6], P. Dardenne [a6], J. Schefers [a7], J. Vandenplas [a1] [a2], K. Weigel [a7], M. Coffey [a5], L. Théron [a8], J. Detilleux [a8], E. Reding [a9], N. Gengler [a1] [a2] and S. McParland [a4]

DOI: http://dx.doi.org/10.1017/S1751731112000791

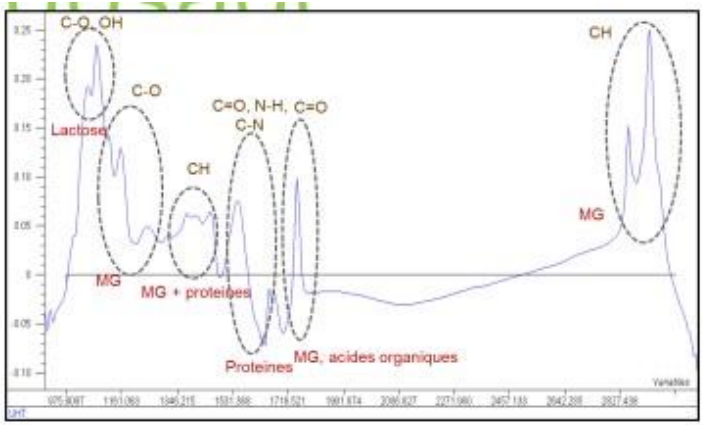
Published online: 01 April 2012



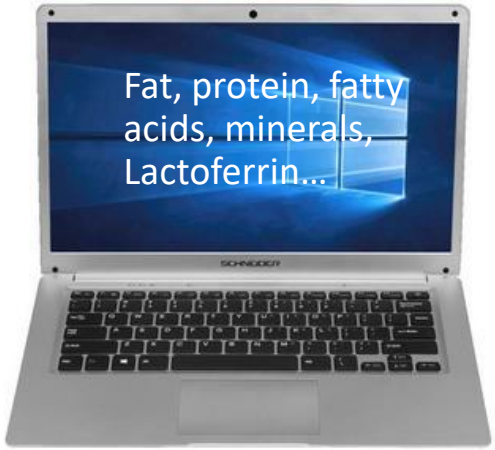
Prediction equation

If you **increase** the number of **prediction equations**, you can **increase** the number of **phenotypes** based on the **same** raw **spectra**

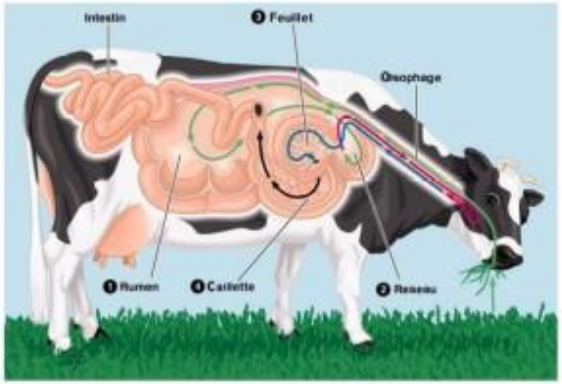
More than just a prediction related to milk composition



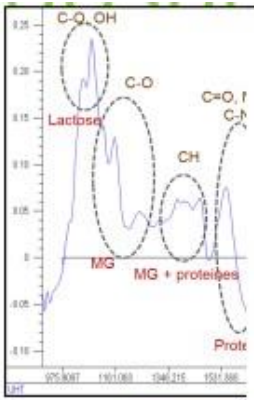
Prediction equation



Indirect links with **cow** metabolic **status**



More than just a prediction related to milk composition



Journal of Dairy Science

Volume 99, Issue 6, June 2016, Pages 4816–4825

Development of Fourier transform mid-infrared calibrations to predict acetone, β-hydroxybutyrate, and citrate contents in bovine milk through a European dairy network

C. Grelet*, †, 1, C. Bastin†, 1, M. Gelé‡, J.-B. Davière§, M. Johan§, A. Werner#, R. Reding†, J.A. Fernandez Pierna*, F.G. Colinet†, P. Dardenne*, N. Gengler†, H. Soyeurt†, F. Dehareng*

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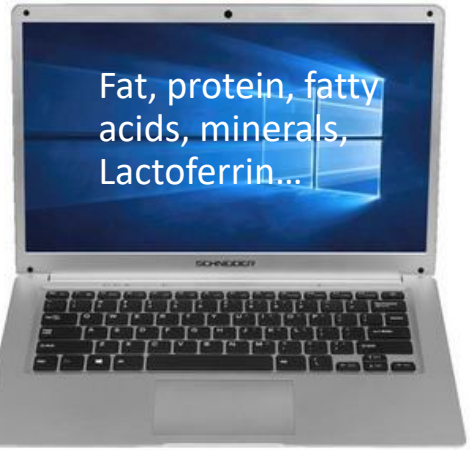
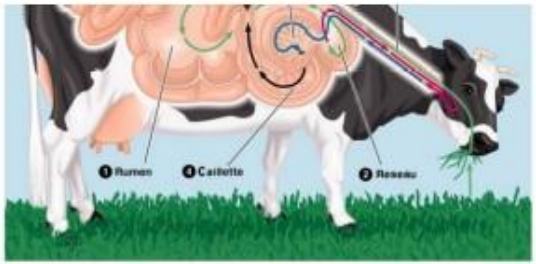
http://dx.doi.org/10.3168/jds.2015-10477

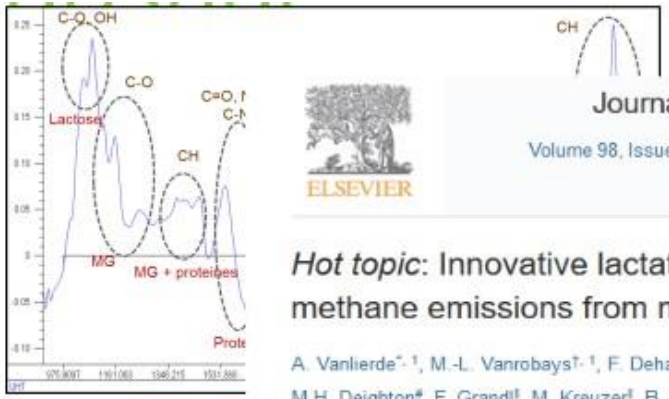
Get rights and content





Energy balance
Acidosis

More than just a prediction related to milk composition



Journal of Dairy Science
Volume 98, Issue 8, August 2015, Pages 5740–5747

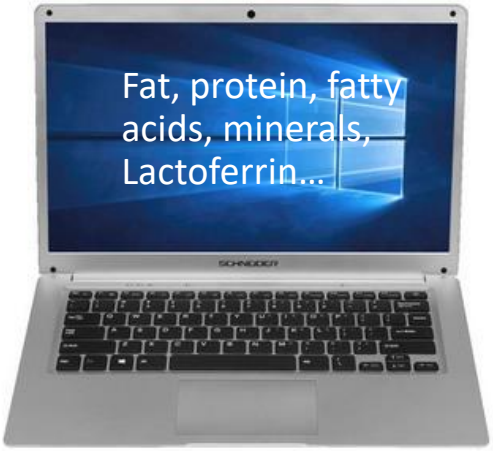
Hot topic: Innovative lactation-stage-dependent prediction of methane emissions from milk mid-infrared spectra

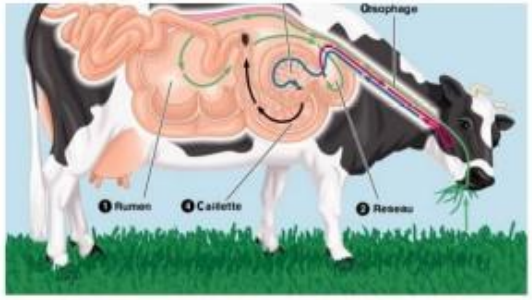
A. Vanlierde[*,1], M.-L. Vanrobays[†,1], F. Dehareng[*], E. Froidmont[‡], H. Soyeurt[†], S. McParland[§], E. Lewis[§], M.H. Deighton[#], F. Grandl[‖], M. Kreuzer[‖], B. Gredler[¶], P. Dardenne[*], N. Gengler[†]

Show more

http://dx.doi.org/10.3168/jds.2014-8436

Get rights and content





Energy balance
Acidosis
Methane …

Increasing the use of MIR

- Other developments
  - Cheese making properties
  - Detection of abnormal milk
  - …
- Obtaining MIR spectral data is **computationally easy**
- Allowing the developments of **management and breeding** tools thanks to its **high throughput**

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Milk MIR spectrometry

Need to have high quality predictions …

Obtaining of reliable predictions

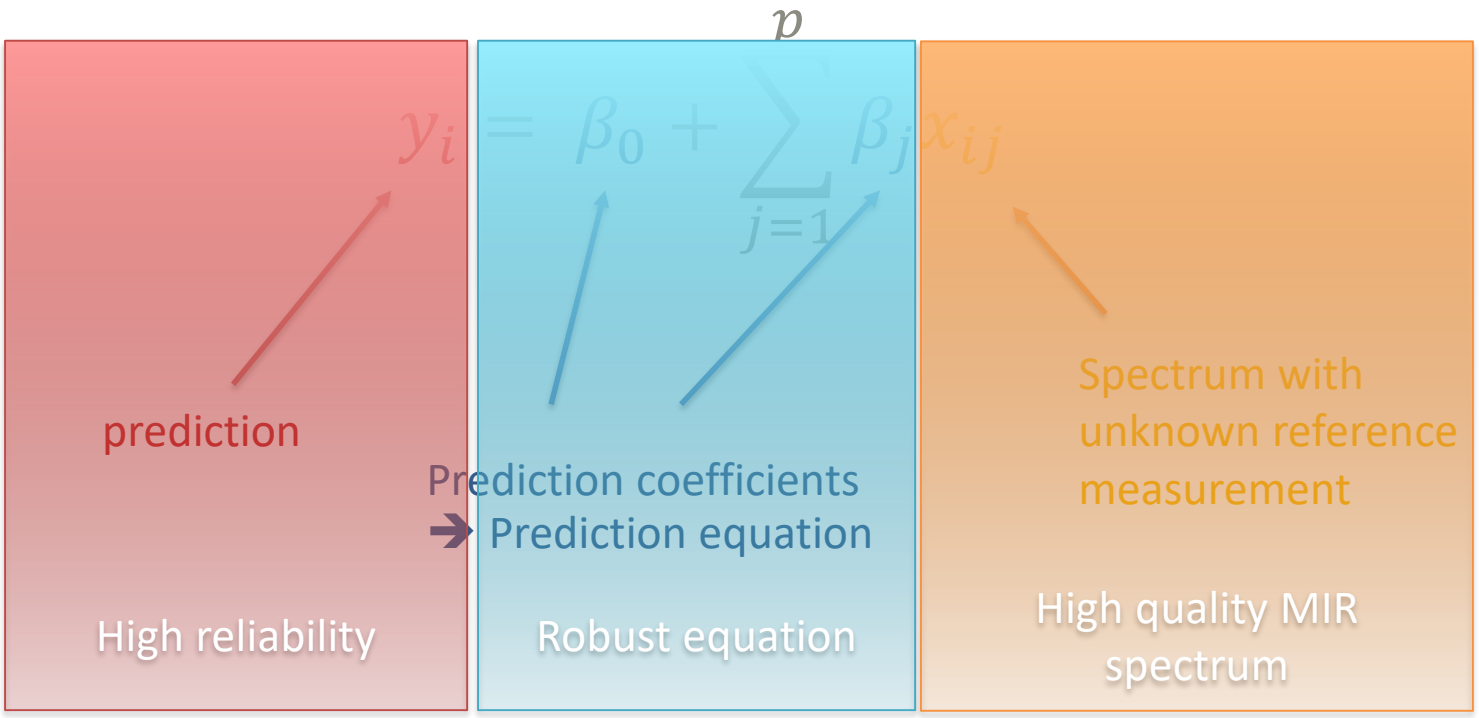
$$y_i = \beta_0 + \sum_{j=1}^{p} \beta_j x_{ij}$$

prediction

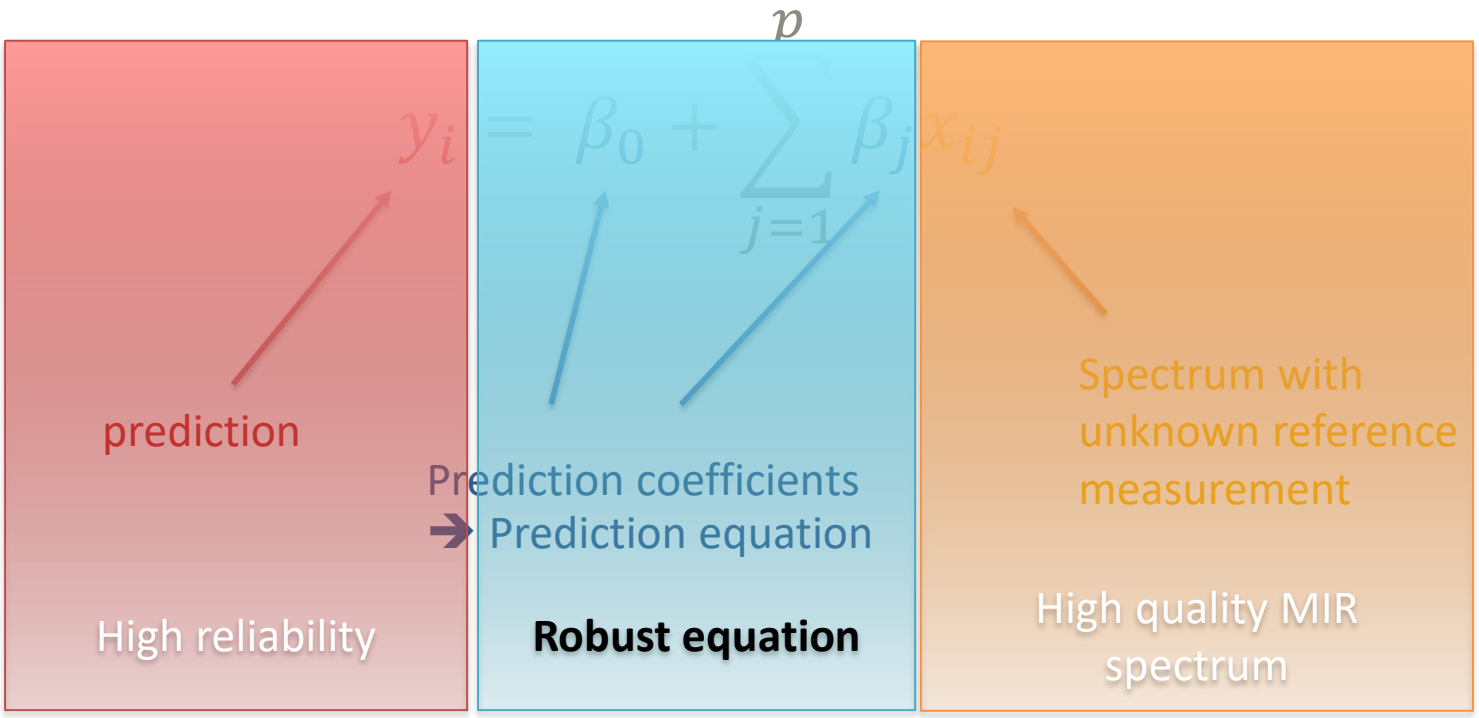
Prediction coefficients
➔ Prediction equation

Spectrum with unknown reference measurement

Obtaining of reliable predictions



Obtaining of reliable predictions



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Milk MIR spectrometry

Need to have robust prediction equations …

How to build a robust prediction equation

- Structure of the **calibration set** to estimate the coefficients
  - reference data used to estimate the coefficients of the established prediction equations

- **Accuracy** of the prediction
  - estimated from one or several sets of independent samples.

Structure of calibration set

- **Representative** of the dairy cattle population where the prediction equation will be applied

- Covering the **maximum variability** to avoid extrapolation
  - If a part of the variability of the spectral data and/or the studied trait is missing, this leads to extrapolate the prediction
  - Increasing the chance to decrease the expected accuracy

Accuracy of the prediction

- **Independent** validation set
  - Not always satisfy due to practical or financial issues
  - Repeated measurements per animal, herd, season …
- The cross-validation can overestimate the prediction accuracy if the independency is not verified
- So, it is always required to **know the methodology used to estimate the accuracy** of a prediction given by an equation.

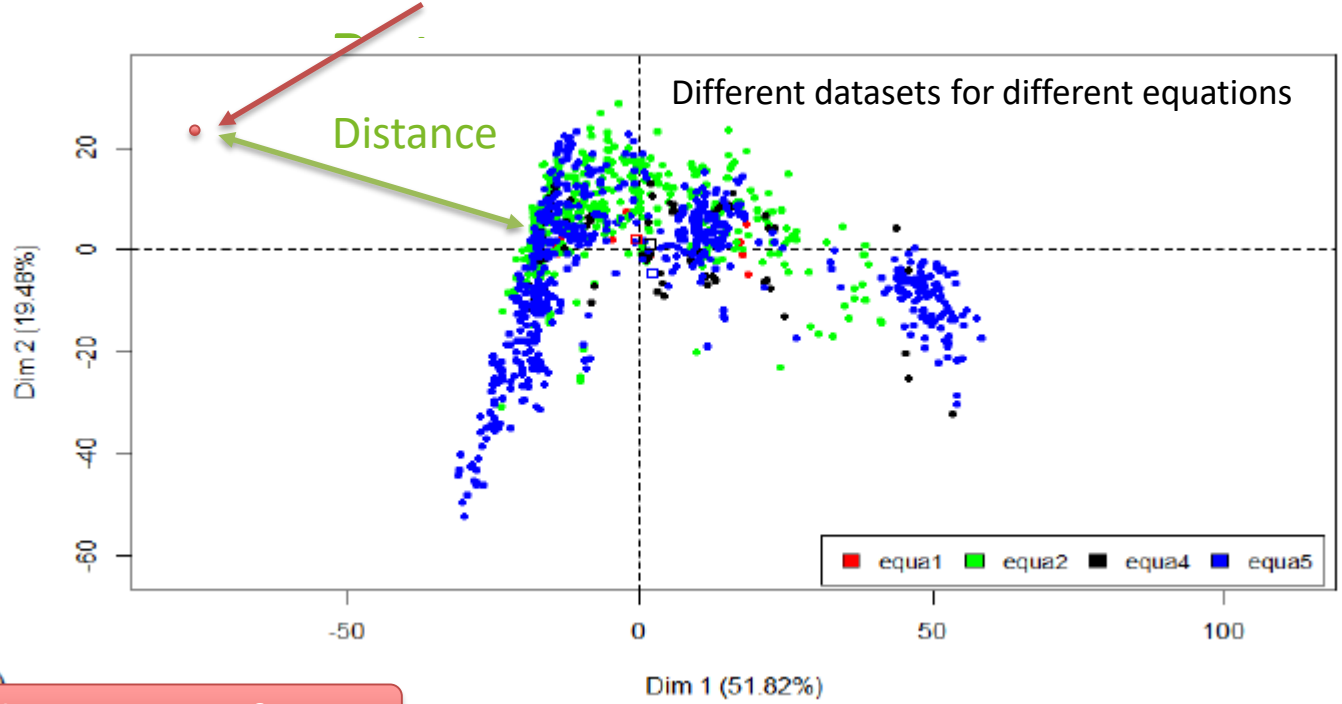
How to build a robust prediction equation

- Structure of the **calibration set** to estimate the coefficients

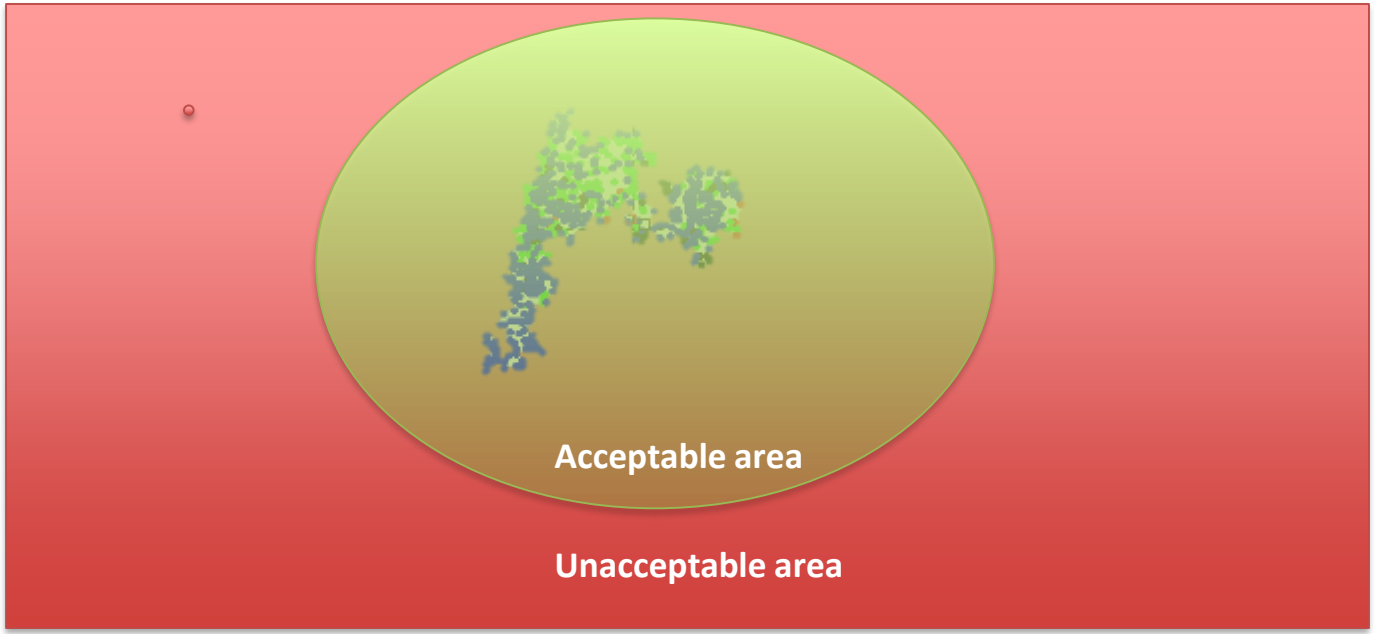
The elements available for the milk laboratories are often too limited to assess the robustness of a prediction equation

- **Accuracy** of the prediction
  - estimated from one or several sets of independent samples.

Can I make a prediction from this spectrum ?



No, because too far


Acceptable area
Unacceptable area

Limitation

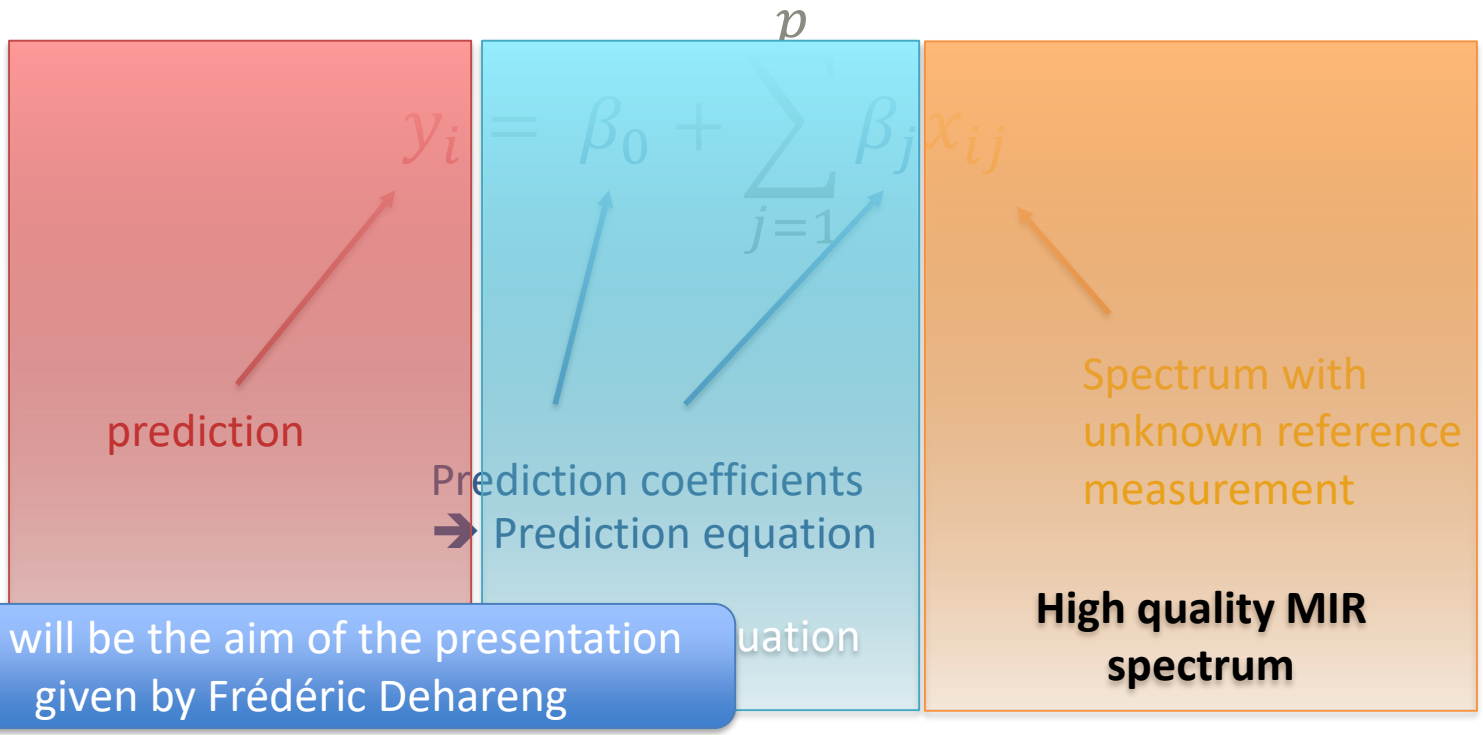
- Need to limit the spectral extrapolation
- Need to assess the structure of the calibration set
  - Standardized Mahalanobis distance
    - Distance lower than 3 reduced the risk of making a spectral extrapolation
  - Distance correlation
  - …

This work is not done currently ➔ Some extrapolation can be made without knowing that ➔ biased prediction

Limitations

- Covering as much as possible the variability of the studied trait is **expensive**
  - Interest to create international network to develop equations
    - Decreasing the research costs
    - Sharing knowledge
    - Limiting the existence of different equations for the same trait with variable accuracy

Obtaining of reliable predictions



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Milk MIR spectrometry

Conclusions …

Conclusions

- **High interest** for using milk MIR spectrometry to develop management and breeding tools
- Technology **already implemented** in all milk laboratories
- Establish a **guide of good practises** to ensure a high quality of predictions
  - International Committee for Animal Recording (ICAR)
  - International dairy federation (IDF)
- **Promoting international collaborations** for the development of prediction equations

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Milk mid-infrared spectrometry: Take information from light

Soyeurt H.

hsoyeurt@uliege.be

Thank you for your attention