Opportunities of exploiting MIR in dairy farming, much more than simple phenotyping through the prediction of major milk components

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[4]Comité du Lait, 4651 Battice – Belgium

FUTUROSPECTRE since 2008

Wallonie recherche CRA-W

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LIÈGE université Gembloux Agro-Bio Tech

H. Soyeurt
N. Gengler
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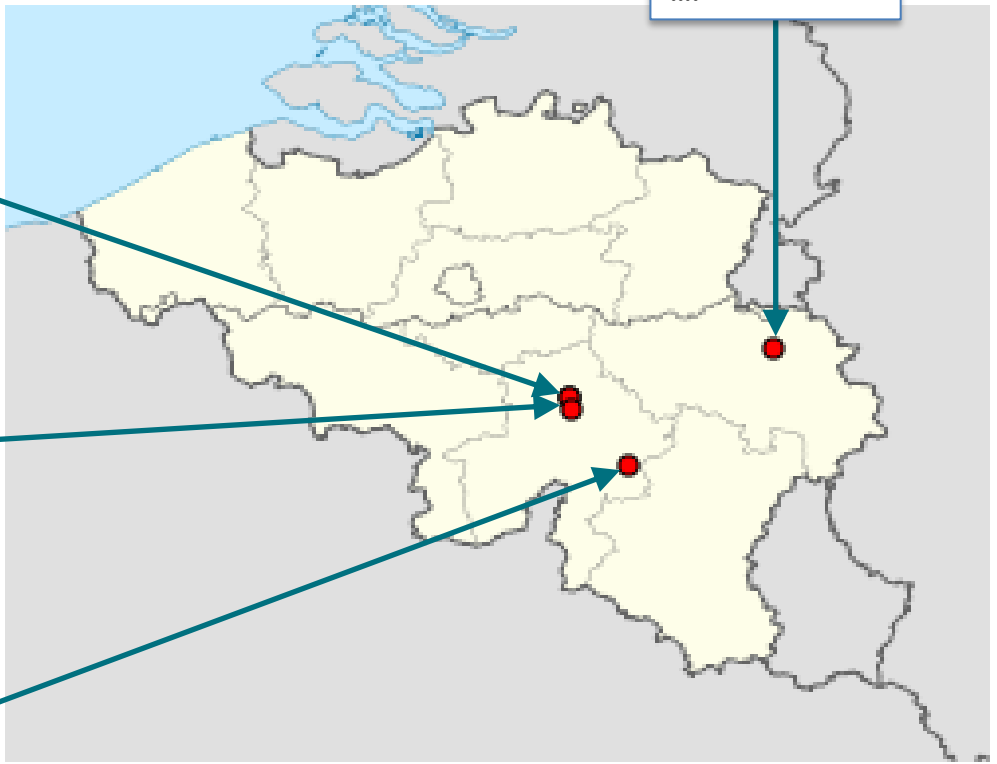
eleveo ensemble vers le avé

C. Bertozzi
C. Bastin
....

E. Piraux
D. Veselko
....

CdL comité du lait



Outline of Presentation

Milk recording and MIR spectrometry

Usefulness of (fine) milk composition

MIR spectrometry and novel milk composition based traits

Recent innovations in the use of milk MIR spectral data

Part I:
Reminder: Milk Recording and MIR Spectrometry

Reminder: Milk Recording

- Developed in the early 1900's
  - .....
  - France
    - Normandy (76) in 1907
  - Denmark
  - Germany
  - .....

Status in 1935

- Regular visits to farms by a technician (mostly)
  - Each week (experimental farms) to 4-6-8 weeks
  - Records quantity of milk and takes milk samples

Milk Recording (MR)

- Early picture
  - Shows why in French milk recording agents often not called “contrôleurs” but “peseurs”

ARS-USDA

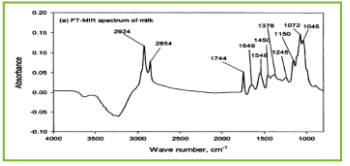
- Explains also
  - Tradition to express milk yields in kg (or lbs) of milk

MR today by

Predicting Milk Components

Milk samples
(milk payment, milk recording)

MIR spectrometry analysis



Raw data = MIR spectra

equations

Manufacturer's prediction

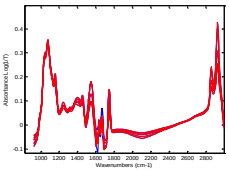
Quantification:

Fat, protein, urea, lactose….

Classical Use

MIR instrument

Raw information: Spectra



Manufacturer prediction equations:

- Fat% = $b_0 + \sum b_i(abs_i)$
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- Lact. = $b_0 + \sum b_i(abs_i)$

...

Classical predicted traits:

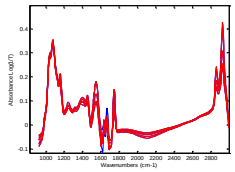
- Fat
- Proteins
- Urea
- Lactose

...

Classical Use

MIR instrument

Raw information: Spectra



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Classical predicted traits:

- Fat
- Proteins
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...

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Extraction of the raw information

Novel Uses

← still based on "simple" calibrations

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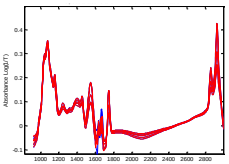
Raw information: Spectra



Standardized Spectra

More later

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New prediction equations:

- Equation 1 = $b_0 + \sum b_i(abs_i)$
- Equation 2 = $b_0 + \sum b_i(abs_i)$
- Equation 3 = $b_0 + \sum b_i(abs_i)$
- Equation 4 = $b_0 + \sum b_i(abs_i)$
- Equation 5 = $b_0 + \sum b_i(abs_i)$

...

New predicted traits:

- Prediction 1
- Prediction 2
- Prediction 3
- Prediction 4
- Prediction 5

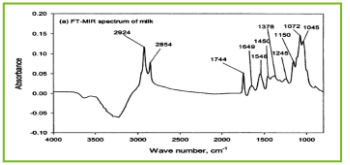
...

New MIR Predicted Phenotypes

New

Milk samples
(milk payment, milk recording)

MIR spectrometry analysis



Raw data = MIR spectra

New prediction equations

Quantification:

New: fatty acids, ….

Part II: Usefulness of (Fine) Milk Composition

Milk Composition

- Milk composition
  - Highly affected by feed and genetic background
- But also:
  - Health
  - And many other factors

⇨ very intense interaction
Blood circulation ⇔ Milk composition

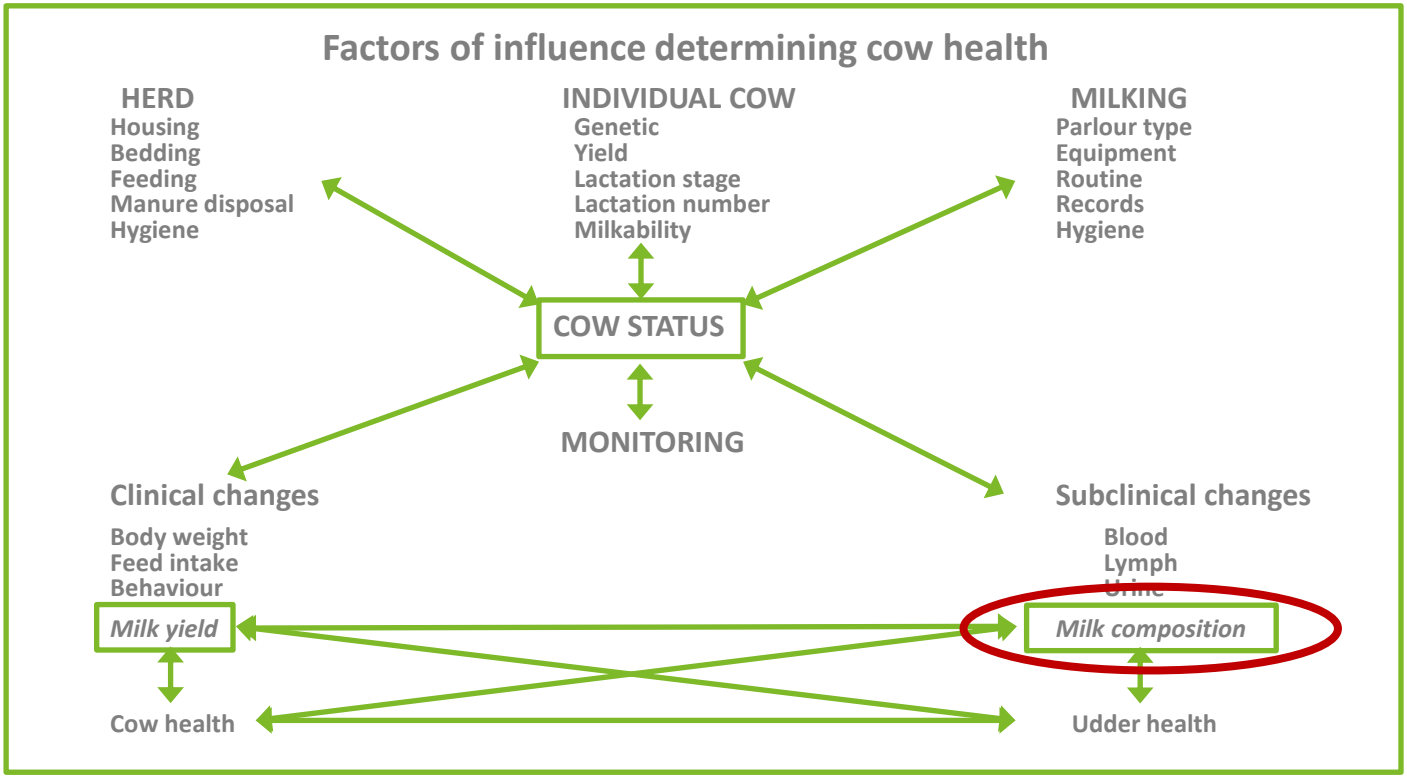
⇨ Concept of Biomarkers

Concept of Biomarkers

- Definition
  - "… objectively measured and evaluated … indicator of normal biological processes, pathogenic processes, or … responses to an … intervention"

    (National Institutes of Health)

Milk Composition as Source of "Biomarkers" for Cow Status and Health



Hamann & Krömker 1997. Livest. Prod. Sci. 48: 201-208.

Milk Composition

- Milk composition
  - Highly affected by feeding and genetic background
- But also:
  - Health
  - And many other factors
- Very intense interaction:
  - Blood circulation ⟷ Milk production
- Therefore: milk composition could be used to monitor
  - Status and health (wellbeing)
- But also
  - Diet
  - Environmental impact
  - Quality of milk and milk products

Milk Composition

- Use of 5 major conventional components*
  - Fat content
  - Protein content
  - Somatic cell count**
  - Urea
  - Lactose

Milk payment + Milk recording

Certain milk recording plans

* Some variants between countries (e.g., in USA use of Solid-Non-Fat) or different definitions as "True protein" (e.g., France, USA) vs. others "Crude protein" (e.g., Belgium)

** Different from the other components (no content but counting of somatic cells), use of different technology

Major Components ⇔ Status

- Known for long time and available on a large scale
  ➔ Extensive research to establish usefulness

- Useful as indicators or proxies
  ➔ Status of the cow ?

- Abundant literature
- Here only most important findings

Somatic Cell Count (SCC)

- SCC not a typical component
  - Count of cells not a content of molecule(s) of interest
- From the beginning SCC developed as
  - Indicator or proxy for udder infection (mastitis)
  - Then entered payment systems
  - Difference to other components like fat content also in the used technology
- Inconvenience
  - Somatic cells are part of the udder defense strategy
  - Controversy ⇨are low SCC good or bad?
  - Need for novel (MIR based) biomarkers!

Use of Fat, Protein, Urea and Lactose

- Some examples of use of major milk components:
  - Fat content depression
    ⇨ Potential subacute ruminal acidosis (SARA)
  - High fat / protein ratio
    ⇨ Potential negative energy balance (and associated issues as ketosis …)
  - Urea and protein content
    ⇨Indicator of ruminal balance between protein and energy
  - Reduction in lactose content
    ⇨Indicator of mastitis
  - However, many authors also showed
    ⇨ Limitation in usefulness of major milk components
  - Need for novel (MIR based) biomarkers!

Fine Milk Composition

- Until recently ~ 5 major major components
- However
  - Milk is a very complex substance
  - Large number of constituents
  - Some major components themselves
    ⇨ complex groupings of minor constituents

Therefore:

⇨ many potential Biomarkers

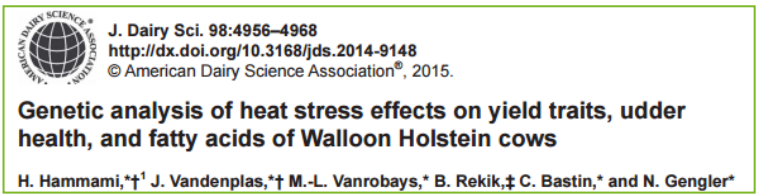
Fine Milk Composition

- Milk fat
  - Fatty acids (FA) mostly as triglycerides
  - Non-esterified fatty acids (NEFAs)
- Milk protein
  - Caseins
  - a-lactalbumins
  - b-lactoglobulins
  - Other minor proteins (e.g., lactoferrin)

- Other minor constituents
  - β-hydroxybutyrate (BHBA)
  - Acetone and acetoacetate
  - Minerals
  - Citrate
  - Vitamins
  - ….

Fine Milk Composition

- Therefore: complexity of fine milk composition very useful to assess indirectly (some examples):
  - Animal (health) status
    (e.g., ketosis using BHBA, acetone, acetoacetate and citrate)
  - Milk and milk product quality, technological properties
    (e.g., FA, caseins)
  - Udder health
    (e.g., lactoferrin, minerals)
  - And even, as shown by recent research, feeding behavior under heat stress
    (e.g., FA linked to body fat reserve mobilization)



Fine Milk Composition

- Therefore, complexity of fine milk composition very useful to assess indirectly (some examples):
  - Animal (health) status
  - Milk and milk product quality, technological properties
  - Udder health
  - Feeding behavior under heat stress
- But also: environmental impact traits:
  - Phosphorus efficiency
  - Nitrogen efficiency
  - Energy efficiency and Methane

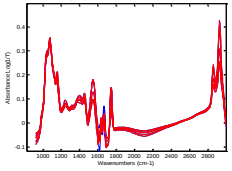
⇦ example link to FA

Part III:
MIR spectrometry and novel milk composition based traits

Classical Use

MIR instrument

Raw information: Spectra



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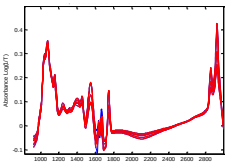

Standardized Spectra

More later

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New prediction equations:

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...

New predicted traits:

- Prediction 1
- Prediction 2
- Prediction 3
- Prediction 4
- Prediction 5

...

Examples of Applications

Milk quality

Estimating Fatty Acid Content in Cow Milk Using Mid-Infrared Spectrometry

H. Soyeurt,*†1,2 P. Dardenne,‡ F. Deh
P. Mayeres,*#3 and N. Gengler*†3

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

H. Soyeurt,*†1 D. Bruwier,* J.-

Prediction of individual milk proteins including free amino acids in bovine milk using mid-infrared spectroscopy and their correlations with milk processing characteristics

A. McDermott,*† G. Visentin,*† M. De Marchi,† D. P. Berry,* M. A. Fenelon,‡ P. M. O'Connor,‡ O. A. Kenny,‡ and S. McParland*

Technological properties

Prediction of coagulation properties, titratable acidity, and pH of bovine milk using mid-infrared spectroscopy

M. De Marchi,*1 C. C. Fagan,† C. P. O'Donnell,† A. Cecchinato,* R. Dal Zotto,* M. Cassandro,* M. Penasa,* and G. Bittante*

Cow phenotypes

Potential use of milk mid-infrared spectra to predict individual methane emission of dairy cows

F. Dehareng†,
A. Vanlierde†

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

H. Soyeurt†,‡,
F. Dehareng§, H
M. Coffey#, L.

The potential of Fourier transform infrared spectroscopy of milk samples to predict energy intake and efficiency in dairy cows†

S. McParland

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,*† C.
F. G. Colinet,†

Prediction and validation of residual feed intake and dry matter intake in Danish lactating dairy cows using mid-infrared spectroscopy of milk

N. Shetty,† P. L

Assessing the effect of pregnancy stage on milk composition of dairy cows using mid-infrared spectra

A. Lainé,* C. Bastin,*†1 C. Grelet,† H. Hammami,* F. G. Colinet,* L. M. Dale,*2 A. Gillon,‡ J. Vandenplas,*§3 F. Dehareng,† and N. Gengler*†4

Outliers, detection of contaminants

Use of a multivariate moving window PCA for the untargeted detection of contaminants in agro-food products, as exemplified by the detection of melamine levels in milk using vibrational spectroscopy

J.A. Fernández Pierna, D. Vincke, V. Baeten, C. Grelet, F. Dehareng, P. Dardenne *

Milk origin determination

PDO PGI

Building of prediction models by using Mid-Infrared spectroscopy and fatty acid profile to discriminate the geographical origin of sheep milk

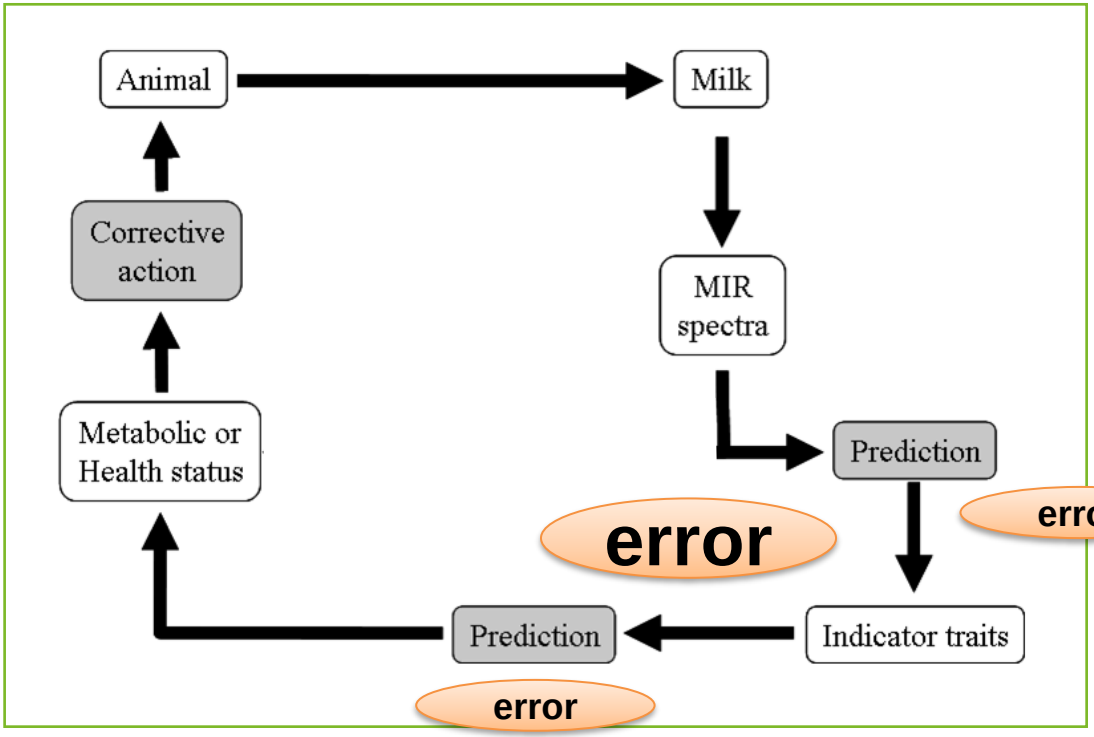
Marco Caredda [a], Margherita Addis [a], Ignazio Ibba [b], Riccardo Leardi [c], Maria Francesca Scintu [a], Giovanni Piredda [a], Gavino Sanna [d,*]

Part IV: Recent innovations in the use of milk MIR spectral data

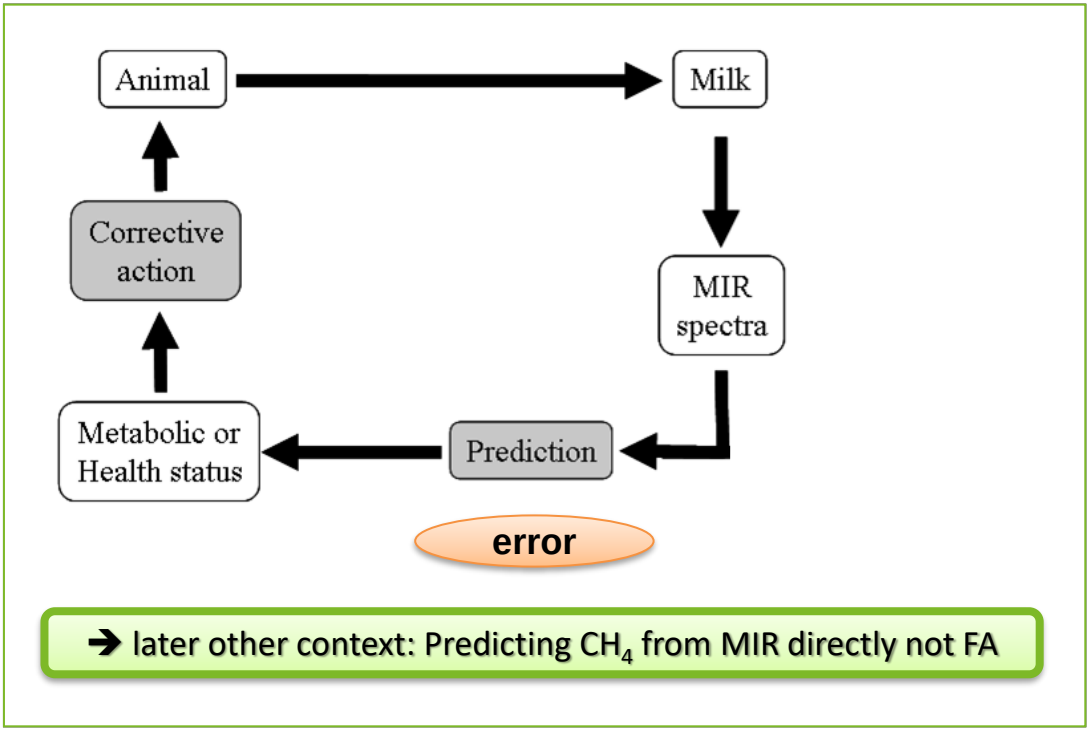
1st Innovation:

Direct Prediction of Traits of Interest from MIR Spectra

MIR ⇨ Components ⇨ Trait of Interest



Directly: MIR ⇨ Trait of Interest



➔ later other context: Predicting CH_4 from MIR directly not FA

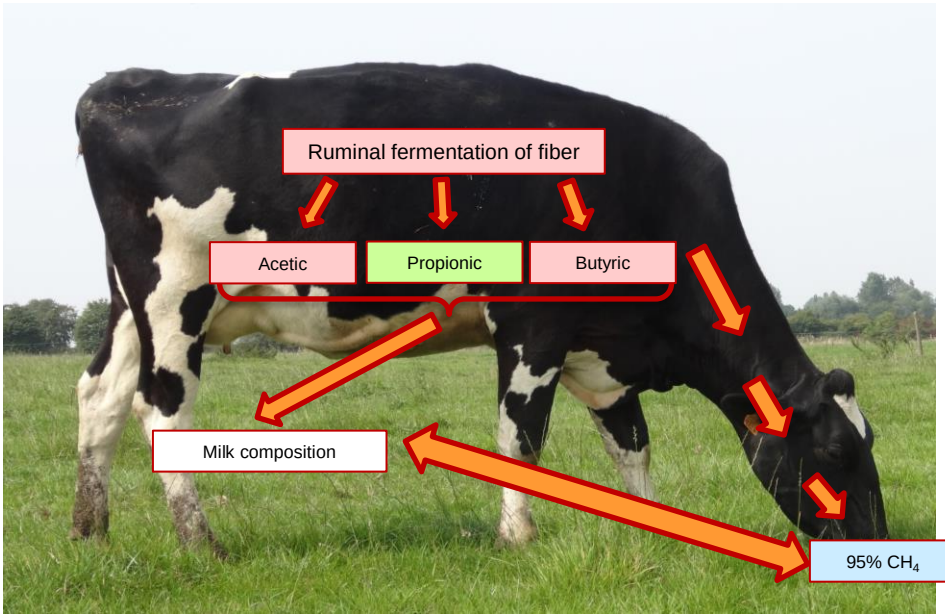
2nd Innovation:

Adjusting calibrations for longitudinal traits: example CH_4

Context – Measuring CH_4

- CH_4 ← large scale phenotyping
  - Difficult, time consuming, expensive
  - Proxies ?
- Use of a milk mid-infrared (MIR) spectra based proxy
  - Was illustrated as being a real opportunity

CH_4 ←→ Milk Composition

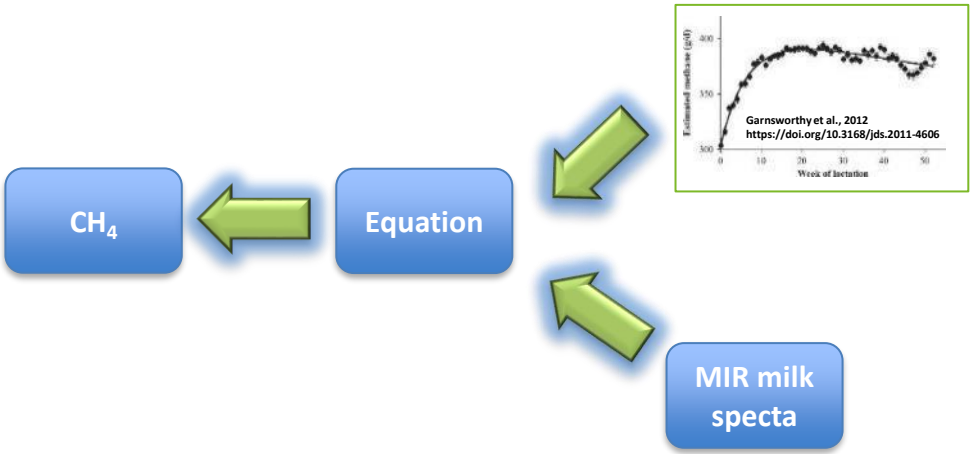


CH_4 Equation – First Ideas

MIR CH_4 Equation (1st innovation)

CH_4 Equation ←Calibration MIR x Lact. curve

➔ Lactation Stage Dependent



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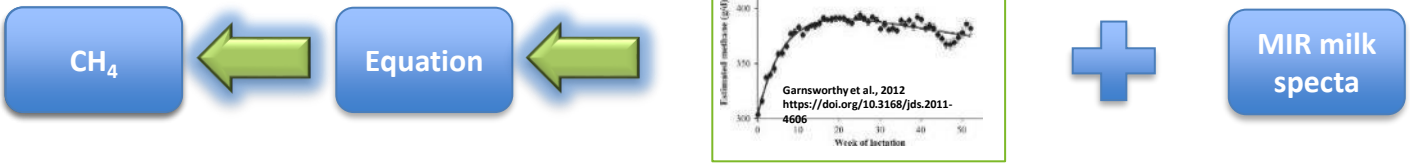

J. Dairy Sci. 98:5740–5747
http://dx.doi.org/10.3168/jds.2014-8436

***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,* and N. Gengler†[2]

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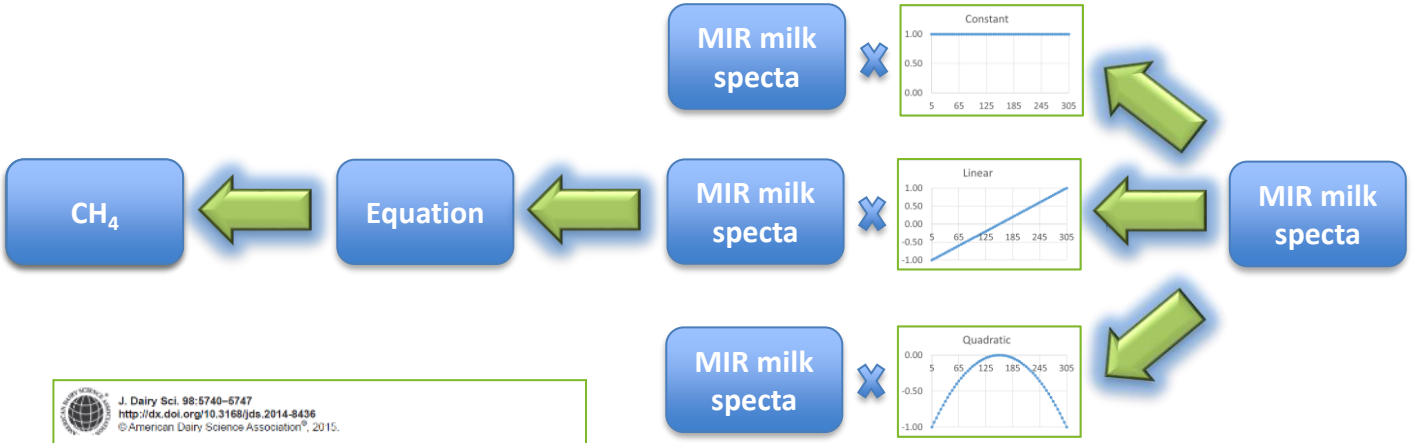

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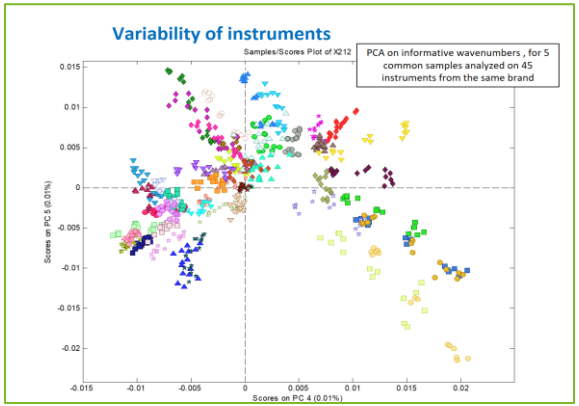
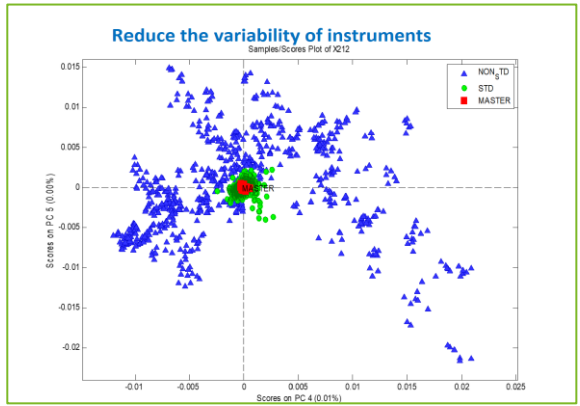
3rd Innovation (less in the NIRS world) :

Standardizing Spectra….

Standardization of MIR Spectra….





J. Dairy Sci. 98:2150–2160
http://dx.doi.org/10.3168/jds.2014-8764
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Standardization of milk mid-infrared spectra from a European dairy network

C. Grelet,[1] J. A. Fernández Pierna,[1] P. Dardenne, V. Baeten, and F. Dehareng[2]
Walloon Agricultural Research Center, Valorisation of Agricultural Products Department, 24 Chaussée de Namur, 5030 Gembloux, Belgium

J. Dairy Sci. 100:7910–7921
https://doi.org/10.3168/jds.2017-12720
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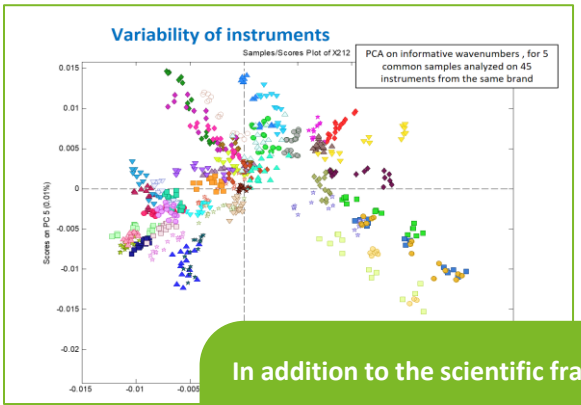
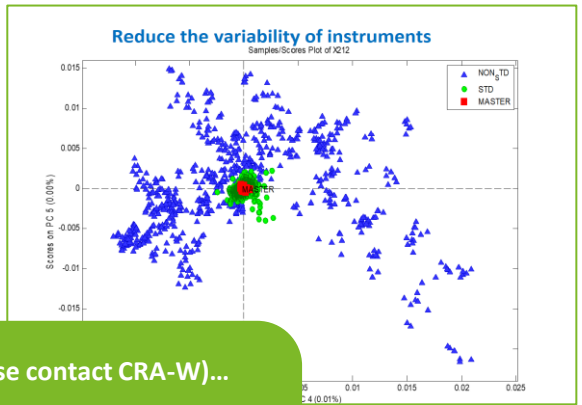
Standardization of milk mid-infrared spectrometers for the transfer and use of multiple models

C. Grelet,* J. A. Fernández Pierna,* P. Dardenne,* H. Soyeurt,† A. Vanlierde,* F. Colinet,† C. Bastin,‡ N. Gengler,† V. Baeten,* and F. Dehareng*[1]
*Valorization of Agricultural Products Department, Walloon Agricultural Research Center, 5030 Gembloux, Belgium
†Agriculture, Bio-Engineering, and Chemistry Department, University of Liège, Gembloux Agro-Bio Tech, 5030 Gembloux, Belgium
‡Walloon Breeding Association, B-5590 Ciney, Belgium

Standardization of MIR Spectra….



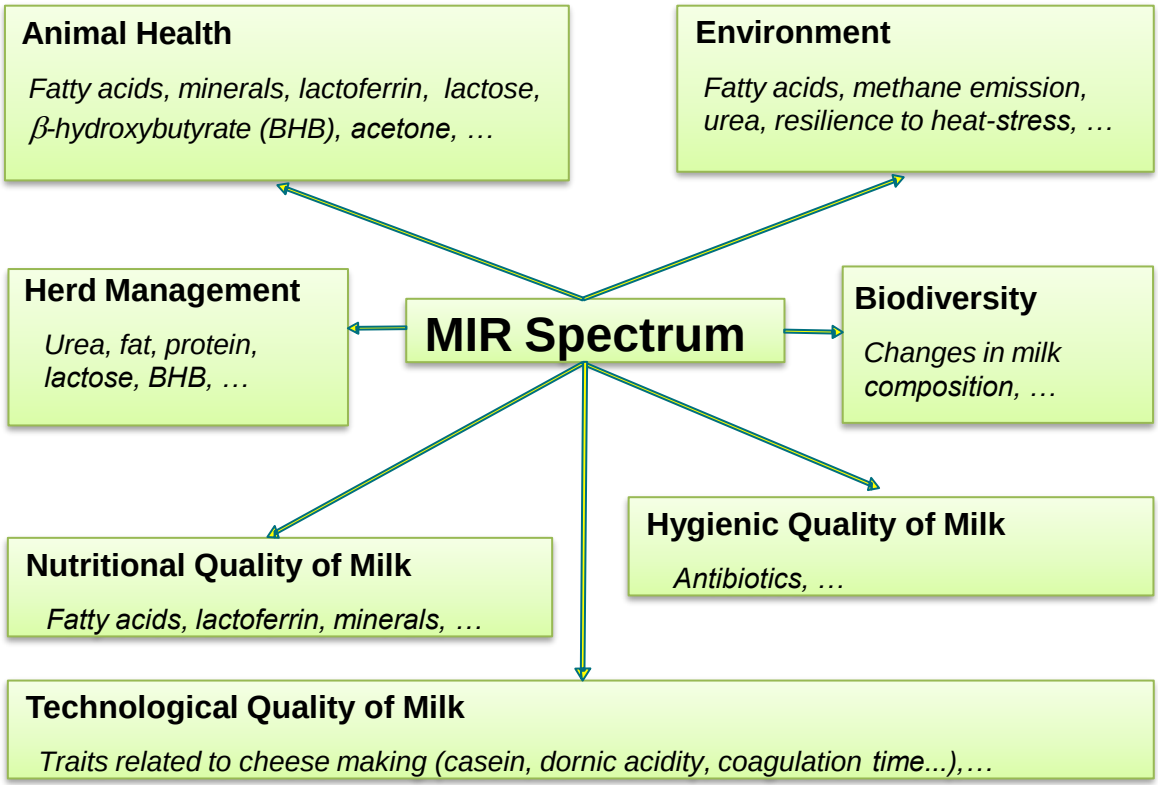


In addition to the scientific framework (please contact CRA-W)…

Commercial services were started by EMR (European Milk Recording)

please visit: www.milkrecording.eu

Conclusions



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ROBUSTMILK

GPLUSE Genotype plus Environment Integration for a more sustainable dairy production system

GREENHOUSE MILK

OptiWIR

Interreg North-West Europe HappyMoo

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- And thanks to our many (international) partners!

Thank you!

Any questions?

Do not hesitate to drop me an e-mail :
nicolas.gengler@uliege.be