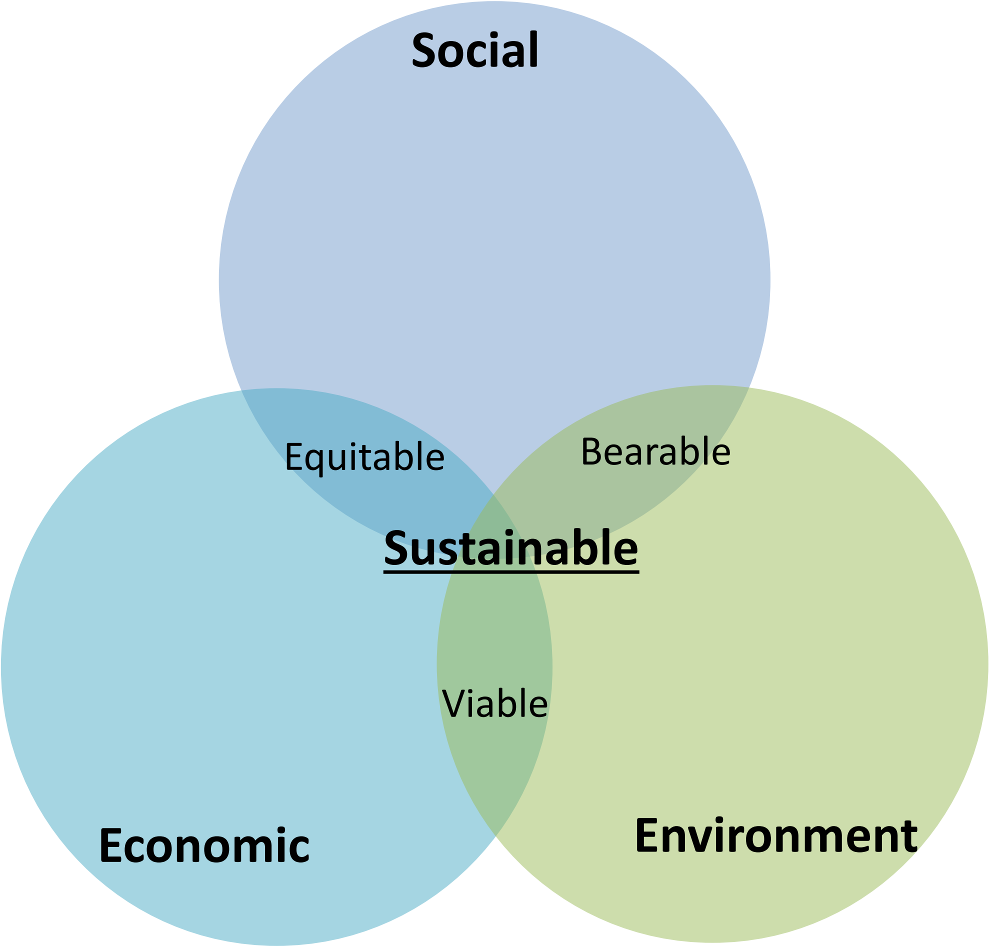
# Leveraging Mid-Infrared Milk Spectroscopy to Increase the Sustainability of Dairy Farms

**Frédéric Dehareng**[1], Octave Christophe[1], Tom Przybylski[1], Huzaifa Simon[1], Amélie Vanlierde[2] & Clément Grelet[1]

[1]*Quality and authentication of agricultural products Unit, CRA-W*
[2]*Animal production Unit, CRA-W*

ICAR Annual Conference 2025, NDDB Anand, Gujarat, India, 1st April 2025.


Social
Equitable
Bearable
Sustainable
Viable
Economic
Environment


If we want to understand and effectively manage sustainability, it requires a large amount of standardized data and measurements that accurately represent its complexity, diversity and evolution

… and ideally, these should not be too expensive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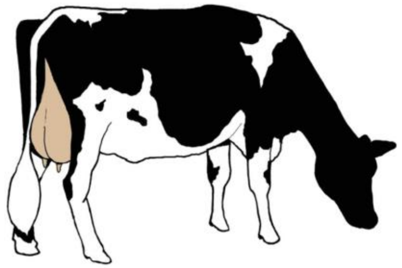
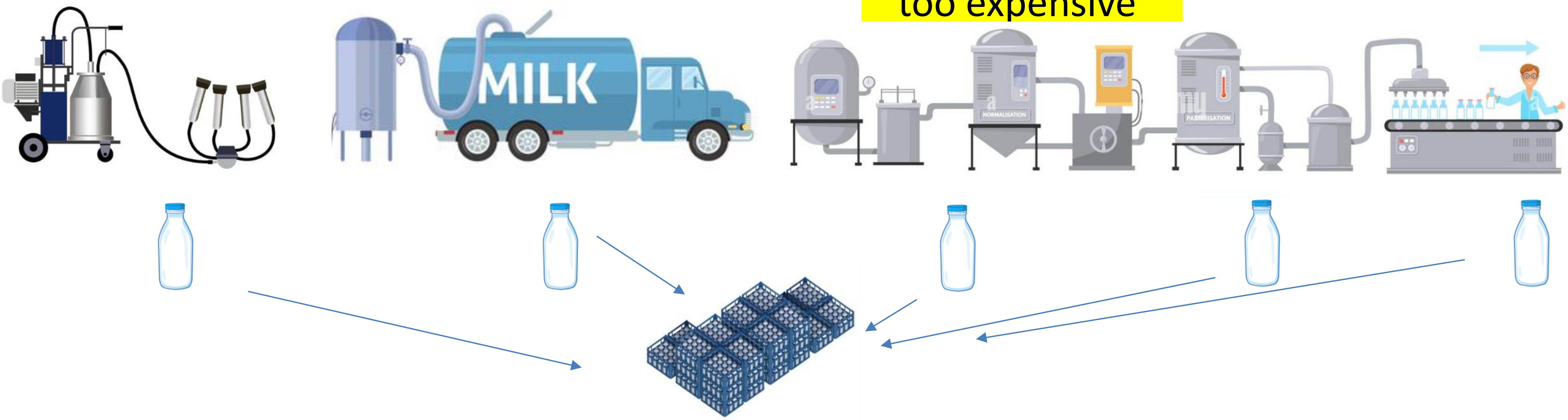
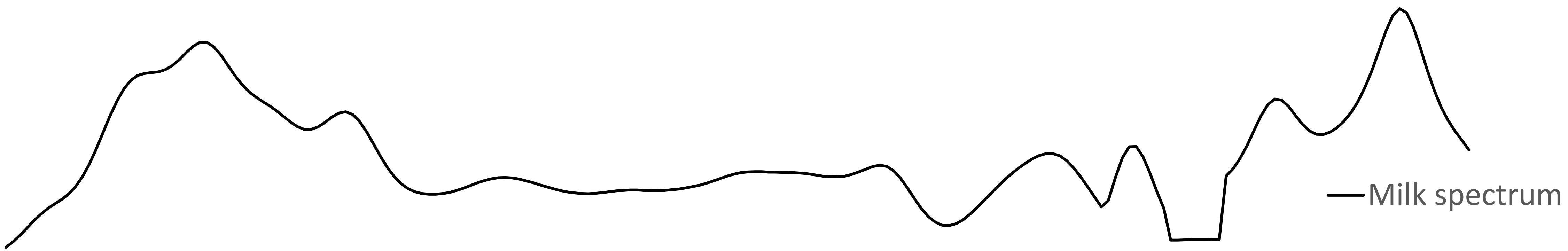
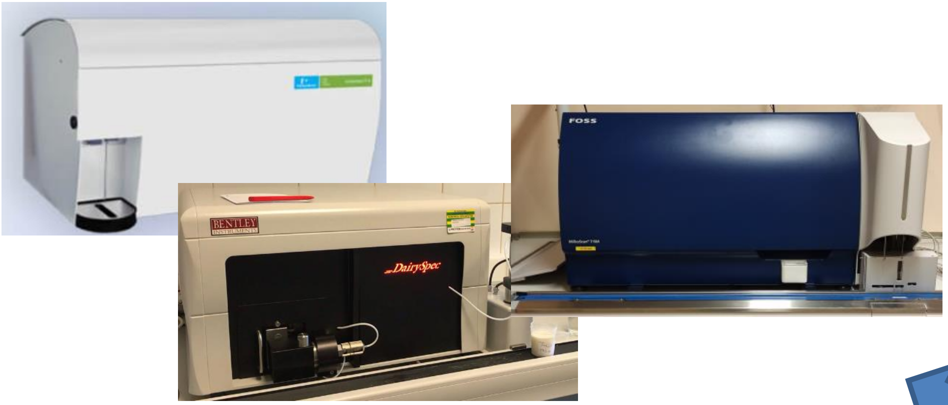


… and ideally, these should not be too expensive





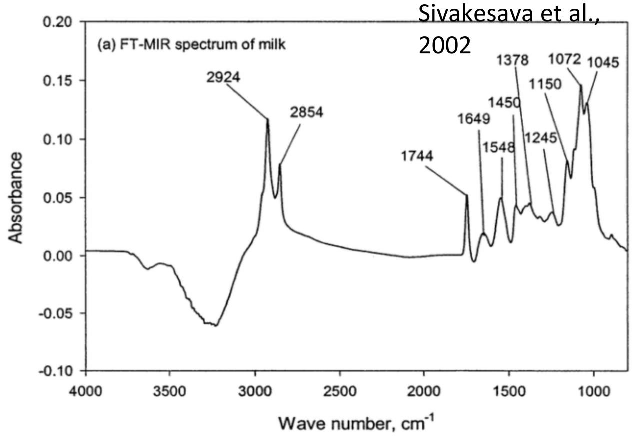

FT-IR Instruments




- Milk recording
- Milk payment
- During the process

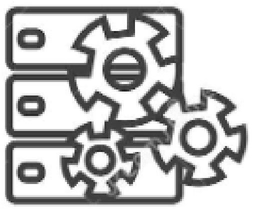
% Fat, Protein, lactose…

**and many more !**
**Milk is an excellent phenomics candidate**




Sivakesava et al., 2002

$$\begin{cases} a_{1,1}x_1 + a_{1,2}x_2 + \dots + a_{1,n}x_n = b_1 \\ a_{2,1}x_1 + a_{2,2}x_2 + \dots + a_{2,n}x_n = b_2 \\ \vdots \\ \vdots \\ a_{m,1}x_1 + a_{m,2}x_2 + \dots + a_{m,n}x_n = b_m \end{cases}$$



FT-MIR models

To estimate the quality of models -> Clustering based on RPD, RMSE and $R^2$

Contents lists available at ScienceDirect

Methods

journal homepage: www.elsevier.com/locate/ymeth

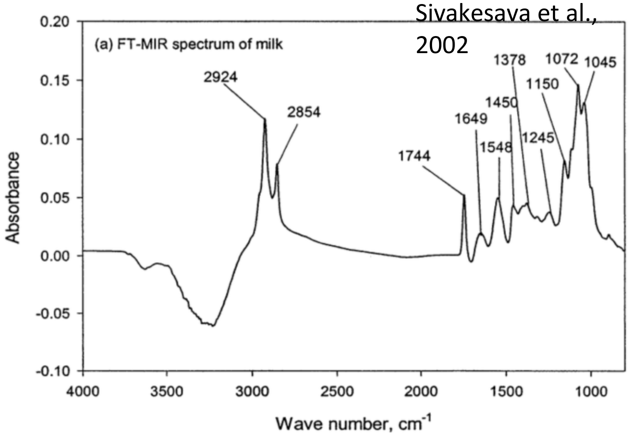
ELSEVIER


Large-scale phenotyping in dairy sector using milk MIR spectra: Key factors affecting the quality of predictions

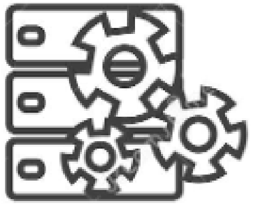
C. Grelet[a], P. Dardenne[a], H. Soyeurt[b], J.A. Fernandez[a], A. Vanlierde[a], F. Steevens[a], N. Gengler[b], F. Dehareng[a,*]

[a] Walloon Agricultural Research Center (CRA-W), 24 Chaussée de Namur, 5030 Gembloux, Belgium
[b] TERRA Teaching and Research Centre, Gembloux Agro-Bio Tech, University of Liège, 5030 Gembloux, Belgium

Sivakesava et al., 2002




$$
\begin{cases}
a_{1,1}x_1 + a_{1,2}x_2 + \dots + a_{1,n}x_n = b_1 \\
a_{2,1}x_1 + a_{2,2}x_2 + \dots + a_{2,n}x_n = b_2 \\
\vdots \\
\vdots \\
a_{m,1}x_1 + a_{m,2}x_2 + \dots + a_{m,n}x_n = b_m
\end{cases}
$$



FT-MIR models

To estimate the quality of models -> Clustering based on RPD, RMSE and $R^2$

| Model quality | RPDcv | Relative RMSEcv | $R^2$cv | Interpretation for application |
|---|---|---|---|---|
| 1 | + 6 | <5% | >0.97 | Any application |
| 2 | 4.2 - 6 | <10% | >0.94 | Quality control |
| 3 | 3 - 4.2 | <10% | >0.89 | Quantitative screening |
| 4 | 2 - 3 | <25% | >0.74 | Rought screening |
| 5 | 1.5 - 2 | <25% | >0.55 | Allows to compare groups, discriminate high or low values |
| 6 | 1.5 - 2 | >25% | >0.55 | Highly imprecise, can be used to detect extreme values |
| 7 | 0 - 1.5 | - | <0.55 | Not recommended |

Grelet et al., 2021

# Major components

e.g: FAT, PROT, LACTOSE…

| Model quality |
|---|
| 1 |

LEFIER ET AL.: JOURNAL OF AOAC INTERNATIONAL VOL. 79, NO. 3, 1996 711

FOOD COMPOSITION AND ADDITIVES

## Determination of Fat, Protein, and Lactose in Raw Milk by Fourier Transform Infrared Spectroscopy and by Analysis with a Conventional Filter-Based Milk Analyzer

DOMINIQUE LEFIER, REMY GRAPPIN, and SYLVIE POCHET
Institut National de la Recherche Agronomique, Station de Recherches en Technologie et Analyses Laitières, BP 89, 39801 Poligny Cedex, France

# Fatty acids

J. Dairy Sci. 94:1657–1667
doi:10.3168/jds.2010-3408


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

H. Soyeurt,*†[1,2] F. Dehareng,‡[1] N. Gengler,*† S. McParland,§ E. Wall,‡ D. P. Berry,§ M. Coffey,#
and P. Dardenne‡
*Animal Science Unit, Gembloux Agro-Bio Tech, University of Liège, 5030 Gembloux, Belgium
†National Funds for Scientific Research, 1000 Brussels, Belgium
‡Walloon Agricultural Research Centre, Valorisation of Agricultural Products, 5030 Gembloux, Belgium
§Teagasc Moorepark Dairy Production Research Centre, Fermoy, Co. Cork, Ireland
#Sustainable Livestock Systems Group, Scottish Agricultural College, Bush Estate, Penicuik, Midlothian, EH26 0PH, United Kingdom

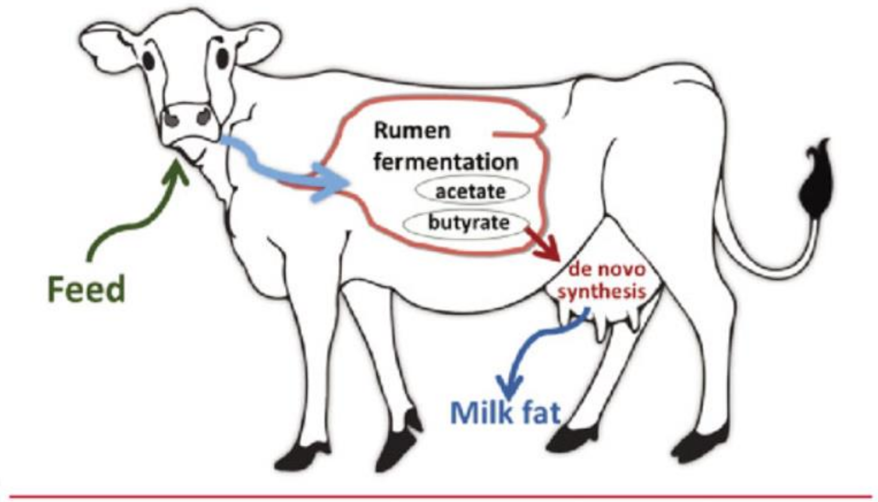
# Fatty acids

| Groups of models | | Predicted variable | Min | Max | Mean | SD | $R^2$cv | Relative RMSEcv | RPDcv | Model quality |
|---|---|---|---|---|---|---|---|---|---|---|
| Milk Fatty acids | CRA-W, Ulg, Teagasc, SRUC, FCEL, LKV-BW, LKV-NRW, LUKE, Valio, LKV-Austria | Milk C4 (g/dL) | 0.01 | 0.23 | 0.10 | 0.03 | 0.93 | 8% | 3.67 | 3 |
| | | Milk C6 (g/dL) | 0.01 | 0.16 | 0.07 | 0.02 | 0.91 | 9% | 3.32 | 3 |
| | | Milk C8 (g/dL) | 0.01 | 0.11 | 0.05 | 0.01 | 0.91 | 9% | 3.29 | 3 |
| | | Milk C10 (g/dL) | 0.02 | 0.32 | 0.11 | 0.04 | 0.91 | 9% | 3.37 | 3 |
| | | Milk C12 (g/dL) | 0.02 | 0.41 | 0.13 | 0.04 | 0.92 | 9% | 3.62 | 3 |
| | | Milk C14 (g/dL) | 0.05 | 1.20 | 0.45 | 0.13 | 0.93 | 7% | 3.88 | 3 |
| | | Milk C14_1 (g/dL) | 0.00 | 0.15 | 0.04 | 0.02 | 0.68 | 21% | 1.78 | 5 |
| | | Milk C16 (g/dL) | 0.12 | 3.32 | 1.20 | 0.40 | 0.94 | 8% | 4.18 | 3 |
| | | Milk C16_1c (g/dL) | 0.01 | 0.24 | 0.07 | 0.03 | 0.73 | 20% | 1.91 | 5 |
| | | Milk C17 (g/dL) | 0.00 | 0.09 | 0.03 | 0.01 | 0.80 | 13% | 2.24 | 4 |
| | | Milk C18 (g/dL) | 0.05 | 1.32 | 0.40 | 0.15 | 0.84 | 14% | 2.51 | 4 |
| | | Milk C18_1cis9 (g/dL) | 0.08 | 2.69 | 0.76 | 0.29 | 0.95 | 8% | 4.35 | 2 |
| | | Milk C18_2c9c12 (g/dL) | 0.00 | 0.17 | 0.06 | 0.02 | 0.72 | 19% | 1.91 | 5 |
| | | Milk C18_2c9t11 (g/dL) | 0.00 | 0.14 | 0.03 | 0.02 | 0.74 | 37% | 1.95 | 6 |
| | | Milk C18_3c9c12c15 (g/dL) | 0.00 | 0.09 | 0.02 | 0.01 | 0.68 | 22% | 1.77 | 5 |
| | | Milk Tot18_1cis (g/dL) | 0.09 | 2.77 | 0.82 | 0.31 | 0.95 | 8% | 4.58 | 2 |
| | | Milk Tot18_2 (g/dL) | 0.01 | 0.32 | 0.10 | 0.03 | 0.69 | 15% | 1.79 | 5 |
| | | Milk Total_C18_1 (g/dL) | 0.10 | 2.98 | 0.94 | 0.33 | 0.96 | 7% | 5.18 | 2 |
| | | Tot18_1trans (g/dL) | 0.01 | 0.57 | 0.13 | 0.06 | 0.79 | 21% | 2.17 | 4 |
| | | Milk Total_Trans (g/dL) | 0.02 | 0.75 | 0.16 | 0.08 | 0.80 | 19% | 2.26 | 4 |
| | | Milk isoanteiso FA (g/dL) | 0.02 | 0.28 | 0.09 | 0.03 | 0.75 | 14% | 2.00 | 5 |
| | | Milk Odd fatty acids (g/dL) | 0.03 | 0.50 | 0.16 | 0.04 | 0.83 | 10% | 2.41 | 4 |
| | | Milk omega3 (g/dL) | 0.00 | 0.11 | 0.03 | 0.01 | 0.66 | 22% | 1.73 | 5 |
| | | Milk omega6 (g/dL) | 0.01 | 0.33 | 0.10 | 0.03 | 0.72 | 14% | 1.89 | 5 |
| | | Milk SAT FA(g/dL) | 0.31 | 6.97 | 2.70 | 0.75 | 0.99 | 3% | 10.22 | 1 |
| | | Milk UNSAT (g/dL) | 0.14 | 3.86 | 1.25 | 0.39 | 0.97 | 5% | 5.75 | 2 |
| | | Milk MONO FA (g/dL) | 0.12 | 3.42 | 1.08 | 0.35 | 0.97 | 5% | 5.83 | 2 |
| | | Milk PUFA (g/dL) | 0.02 | 0.53 | 0.16 | 0.05 | 0.77 | 13% | 2.10 | 4 |
| | | Milk SCFA (g/dL) | 0.05 | 0.80 | 0.35 | 0.10 | 0.93 | 7% | 3.88 | 3 |
| | | Milk LCFA (g/dL) | 0.19 | 4.79 | 1.59 | 0.52 | 0.95 | 7% | 4.52 | 2 |
| | | Milk MCFA (g/dL) | 0.22 | 5.48 | 2.00 | 0.60 | 0.97 | 5% | 5.53 | 2 |

- Nutritional quality
- Physical properties
- Cow status biomarkers
- Milk typicity

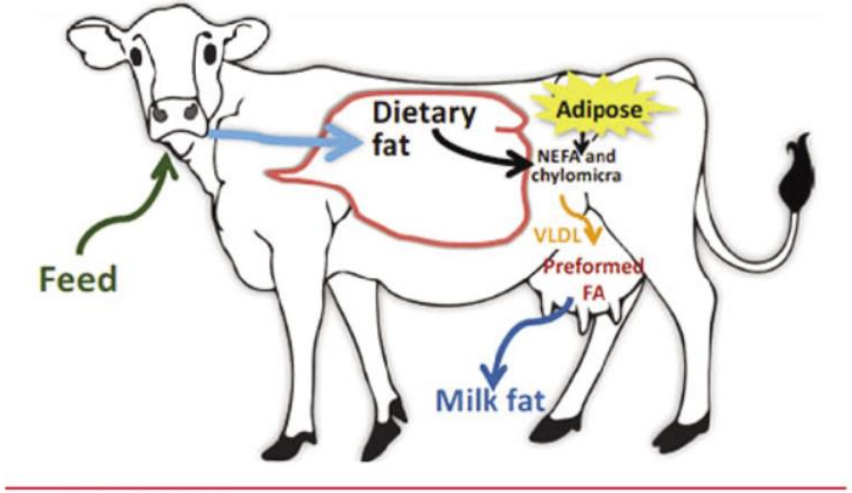
# Fatty acids

De novo Fatty acids synthesis




Source: Courtesy of M. Woolpert

Mixed and preformed Fatty acids synthesis




Source: Courtesy of M. Woolpert

- ➢ Nutritional quality
- ➢ Physical properties
- ➢ Cow status biomarkers
- ➢ Milk typicity

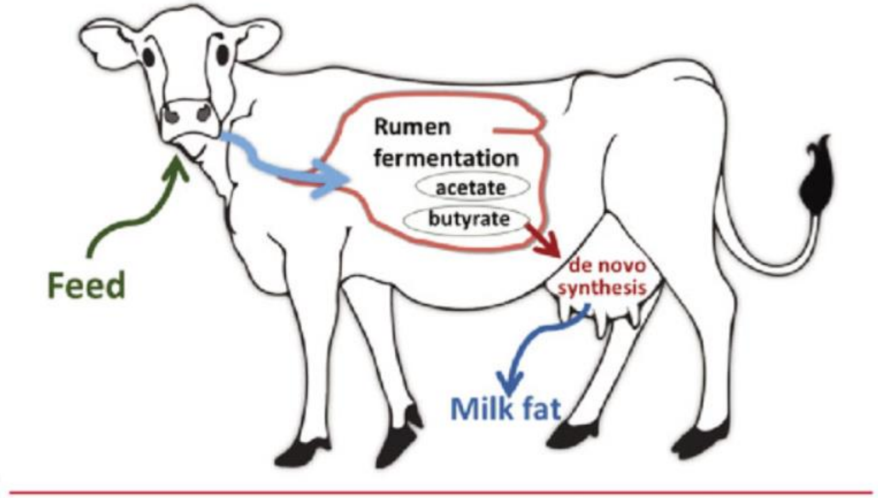
J. Dairy Sci. 107:9504–9515
https://doi.org/10.3168/jds.2024-25034


**Predicting subacute ruminal acidosis from milk mid-infrared estimated fatty acids and machine learning on Canadian commercial dairy herds**

F. Huot,[1,2,3] S. Claveau,[4] A. Bunel,[4] D. Warner,[5] D. E. Santschi,[5] R. Gervais,[1*] and E. R. Paquet[1,2,3*]
[1]Département des Sciences Animales, Université Laval, Québec, QC G1V 0A6, Canada
[2]Institut Intelligence et Données, Université Laval, Québec, QC G1V 0A6, Canada
[3]Centre de Recherche en Données Massives, Université Laval, Québec, QC G1V 0A6, Canada
[4]Agrinova, Alma, QC G8B 7S8, Canada
[5]Lactanet, Ste-Anne-de-Bellevue, QC H9X 3R4, Canada

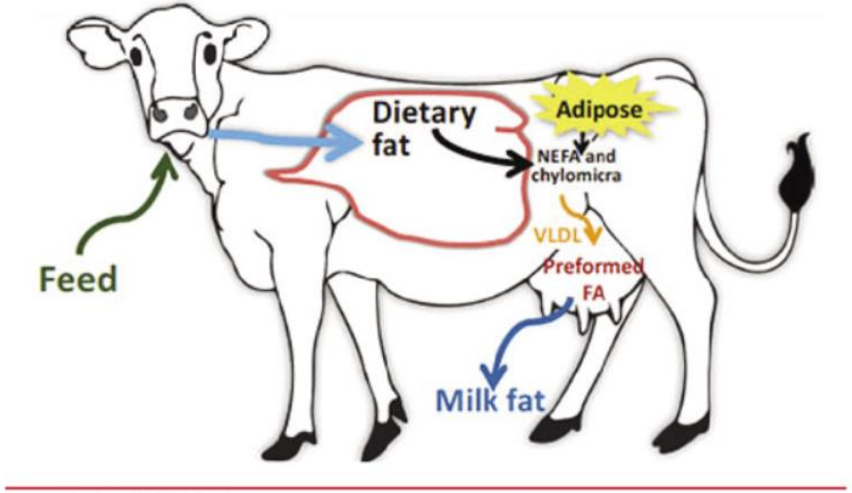
# Fatty acids

De novo Fatty acids synthesis




Source: Courtesy of M. Woolpert

Mixed and preformed Fatty acids synthesis




Source: Courtesy of M. Woolpert

- Nutritional quality
- Physical properties
- Cow status biomarkers
- Milk typicity

**Discrimination of the GRASS milk**

*animals* Soyeurt et al., 2022 MDPI

*Article*

**Prediction of Indirect Indicators of a Grass-Based Diet by Milk Fourier Transform Mid-Infrared Spectroscopy to Assess the Feeding Typologies of Dairy Farms**

Hélène Soyeurt [1,*], Cyprien Gerards [1], Charles Nickmilder [1], Jérôme Bindelle [1], Sébastien Franceschini [1], Frédéric Dehareng [2], Didier Veselko [3], Carlo Bertozzi [4], Nicolas Gengler [1], Antonino Marvuglia [5], Alper Bayram [5,6] and Anthony Tedde [1,7]

# Methane

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]

Journal of the Science of Food and Agriculture

SCI where science meets business

Research Article

**Improving robustness and accuracy of predicted daily methane emissions of dairy cows using milk mid-infrared spectra**

Amélie Vanlierde, Frédéric Dehareng, Nicolas Gengler, Eric Froidmont, Sinead McParland, Michael Kreuzer, Matthew Bell, Peter Lund, Cécile Martin, Björn Kuhla, Hélène Soyeurt

**Reference :**
**SF6 &**
**Respiratory chamber**

# Methane

Ref. analysis precision → Quality of the models

$$R^2_{max} = (SD_y^2 - SEL^2)/SD_y^2$$

animal
Volume 16, Issue 3, March 2022, 100469

Predicting enteric methane emission in lactating Holsteins based on reference methane data collected by the GreenFeed system

R. Liu [a b 1], D. Hailemariam [a 1], T. Yang [a], F. Miglior [c], F. Schenkel [c], Z. Wang [a], P. Stothard [a], S. Zhang [b], G. Plastow [a]

animal
Volume 18, Issue 7, July 2024, 101200

Combining short-term breath measurements to develop methane prediction equations from cow milk mid-infrared spectra

S. Fresco [a b], A. Vanlierde [c], D. Boichard [b], R. Lefebvre [b], M. Gaborit [d], R. Bore [e], S. Fritz [a b], N. Gengler [f], P. Martin [b]

**Reference : Greenfeed**

J. Dairy Sci. 107:978–991
https://doi.org/10.3168/jds.2023-23577
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**Predicting methane emissions of individual grazing dairy cows from spectral analyses of their milk samples**

S. McParland, M. Frizzarin, B. Lahart, M. Kennedy, L. Shalloo, M. Egan, K. Starsmore, and D. P. Berry*
Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy P61 P302, Co. Cork, Ireland

**Reference : Sniffers**


Smart Agricultural Technology 5 (2023) 100286

Contents lists available at ScienceDirect

Smart Agricultural Technology

journal homepage: www.journals.elsevier.com/smart-agricultural-technology

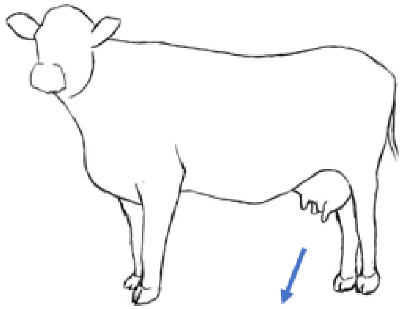
Is it possible to predict the methane emission intensity of Swedish dairy cows from milk spectra?

S. Mohamad Salleh [a,b,*], C. Kronqvist [a], E. Detmann [a,c], J. Karlsson [a,d], R. Danielsson [a]

# Nitrogen Efficiency

$$\text{N Use Efficiency (\%)} = \frac{N\ Out\ Milk}{N\ Intake} * 100$$

N Intake →
(recorded daily)



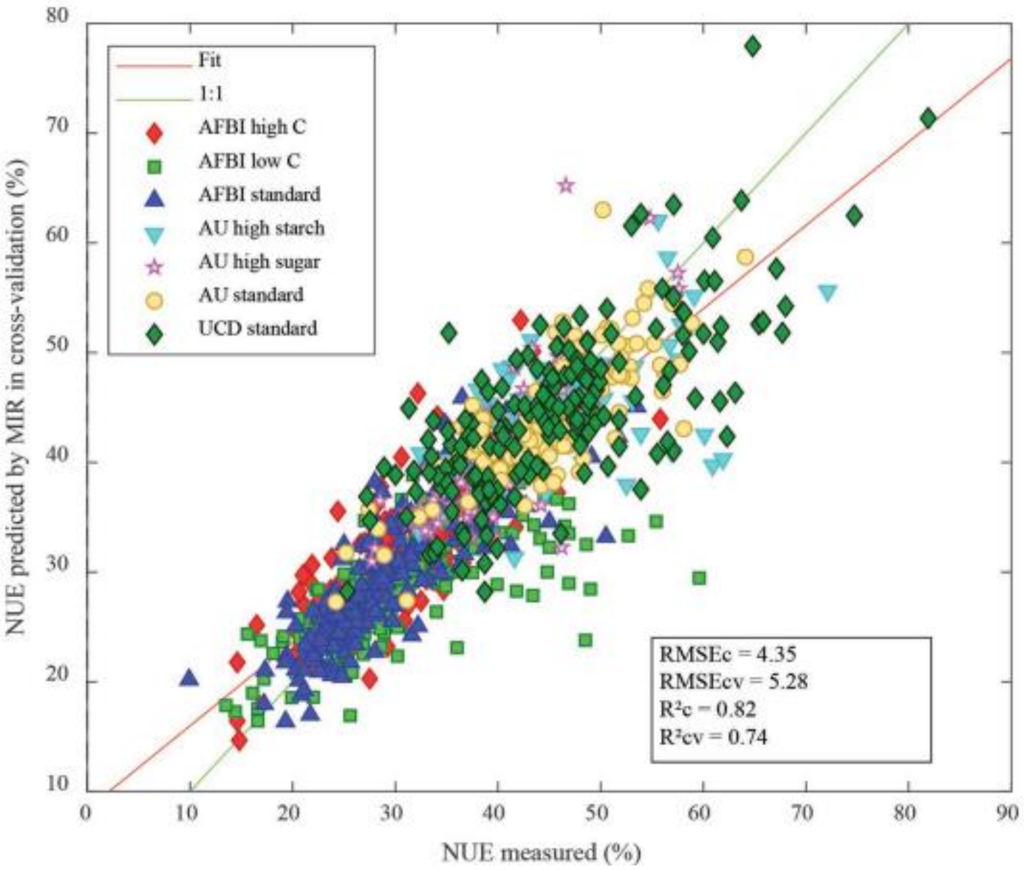
N Out Milk
(recorded twice weekly)

J. Dairy Sci. 103:4435–4445
https://doi.org/10.3168/jds.2019-17910


**Potential of milk mid-infrared spectra to predict nitrogen use efficiency of individual dairy cows in early lactation**

C. Grelet,[1] E. Froidmont,[1] L. Foldager,[2,3] M. Salavati,[4*] M. Hostens,[5] C. P. Ferris,[6] K. L. Ingvartsen,[2] M. A. Crowe,[7] M. T. Sorensen,[2] J. A. Fernandez Pierna,[1] A. Vanlierde,[1] N. Gengler,[8] GplusE Consortium,† and F. Dehareng[1]‡

Nitrogen use efficiency (NUE)



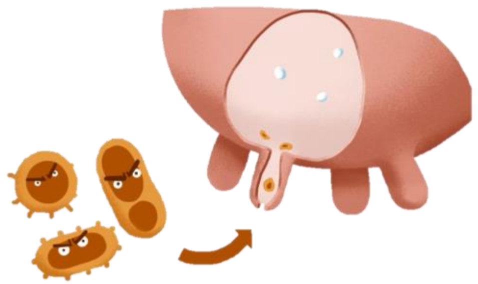

Grelet et al., J. Dairy Sci. 103:4435–4445 (2020)

| Model quality |
|---|
| 5 |

# Health status

## Mastitis

Reference → Elisa kits & fluorometric methods



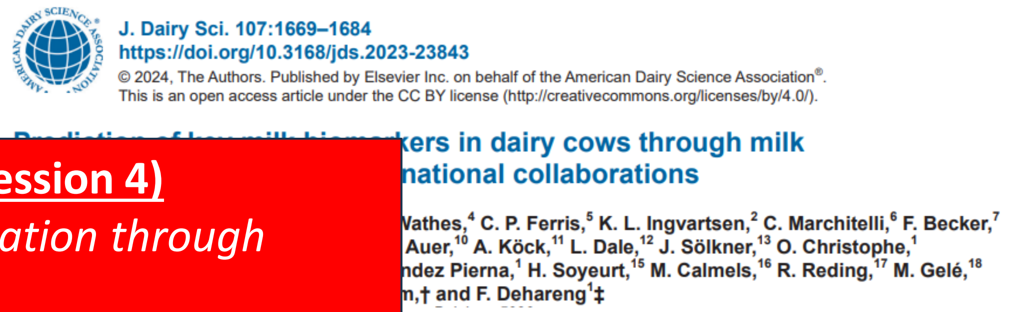
- Lactoferrin (Soyeurt et al., 2020)

| Groups of models | | Predicted variable | Min | Max | Mean | SD | R²cv | Relative RMSEcv | RPDcv | Model quality |
|---|---|---|---|---|---|---|---|---|---|---|
| Lactoferrin | EMR/CRA-W/ULG | Lactoferrin (mg/L) | 7 | 1248 | 299 | 222 | 0.66 | 44% | 1.71 | 6 |

- NAGase (quantitative & qualitative models; Grelet et al., 2024)

| Predicted variable | Min | Max | Mean | SD | R²v | Relative RMSEv | RPDv | Model quality |
|---|---|---|---|---|---|---|---|---|
| Milk NAGase (unit/L) | 0 | 25.10 | 1.91 | 1.61 | 0.68 | 50% | 1.98 | 6 |

| Method | Sensitivity | Specificity | Accuracy |
|---|---|---|---|
| Optimized PLS-DA | 85% | 88% | 88% |


J. Dairy Sci. 107:1669–1684
https://doi.org/10.3168/jds.2023-23843
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...kers in dairy cows through milk ...national collaborations

...Vathes,[4] C. P. Ferris,[5] K. L. Ingvartsen,[2] C. Marchitelli,[6] F. Becker,[7] ...Auer,[10] A. Köck,[11] L. Dale,[12] J. Sölkner,[13] O. Christophe,[1] ...ndez Pierna,[1] H. Soyeurt,[15] M. Calmels,[16] R. Reding,[17] M. Gelé,[18] ...m,† and F. Dehareng[1]‡

See the presentation of **Octave Christophe(Technical session 4)**
*Prediction of mastitis via mid infrared analysis of milk : Validation through experimental approach*

# Heat Stress

J. Dairy Sci. 108:1714–1729
https://doi.org/10.3168/jds.2024-25440


## Residual analysis for the identification of potential mid-infrared-derived biomarkers of heat stress in dairy cattle

**Pauline Lemal,[1]* Clément Grelet,[2] Frédéric Dehareng,[2] Hélène Soyeurt,[1] Martine Schroyen,[1] and Nicolas Gengler[1]**
[1]University of Liège, Gembloux Agro-Bio Tech (ULiège-GxABT), 5030 Gembloux, Belgium
[2]Walloon Agricultural Research Center (CRA-W), 5030 Gembloux, Belgium

- Good biomarkers : protein %, Mg concentration
- Genetic evaluation : interest for MUFA, C18:1 cis-9 or citrate variations

# Chronic stress

Interreg North-West Europe
HappyMoo
European Regional Development Fund

"stress is the non-specific response of the body to any demand made upon it" (Selye, 1976)

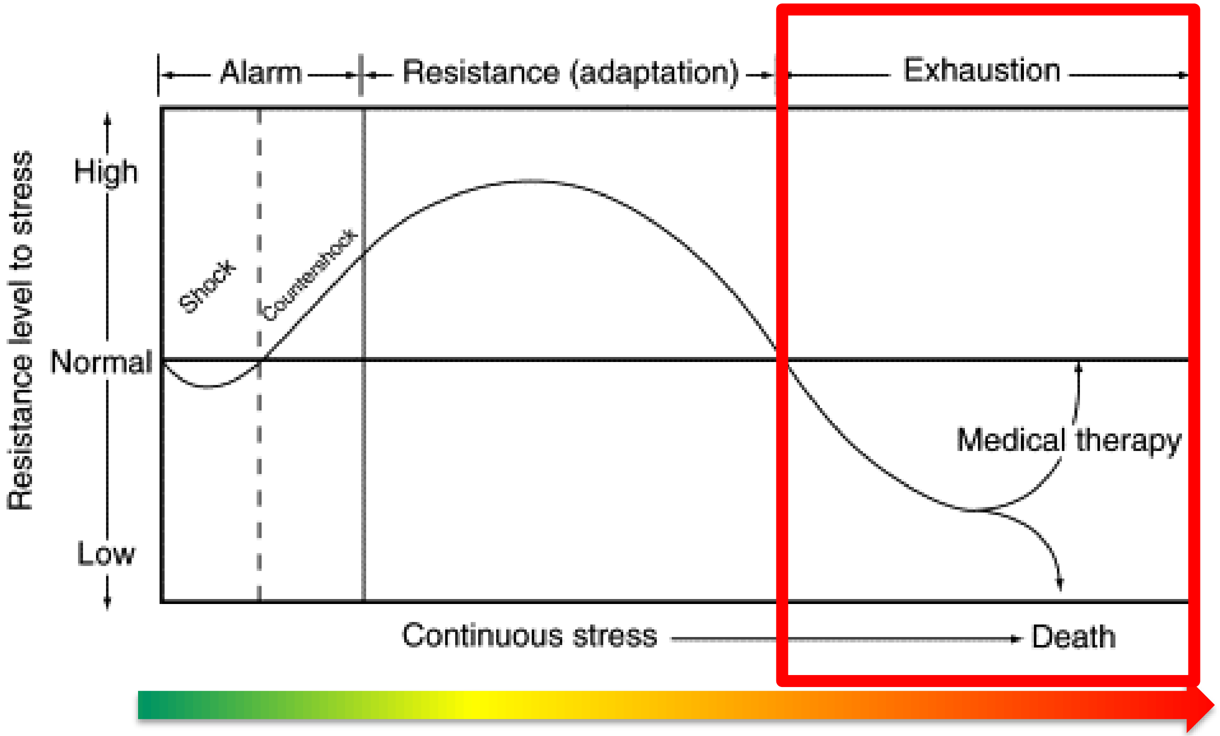



*Figure of General adaption syndrome (from A.C. Brown, C.I. Waslien, in Encyclopedia of Food Sciences and Nutrition (Second Edition), 2003)*

↗ susceptibility to metabolic, inflammatory and infectious diseases (Moberg et al., 1980;

↗ fertility troubles 008)

↘ grow

↘ weight

↘ milk pro al., 2018)

**No consensus in literature regarding chronic stress biomarkers**

**↘ production and economics of farms**

**↘ welfare of cows**

**↘ societal perception of dairy production**

See the presentation of **Clément Grelet (Technical session 4)**
*Possibilities of rapid MIR analysis of milk to provide information on cow's welfare*

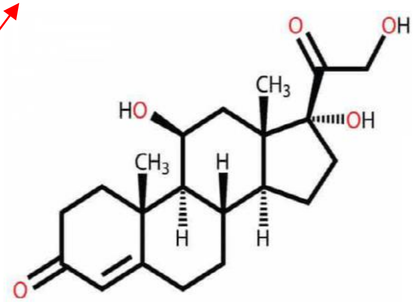
# Chronic stress


animal
Volume 16, Issue 5, May 2022, 100502


## Identification of chronic stress biomarkers in dairy cows

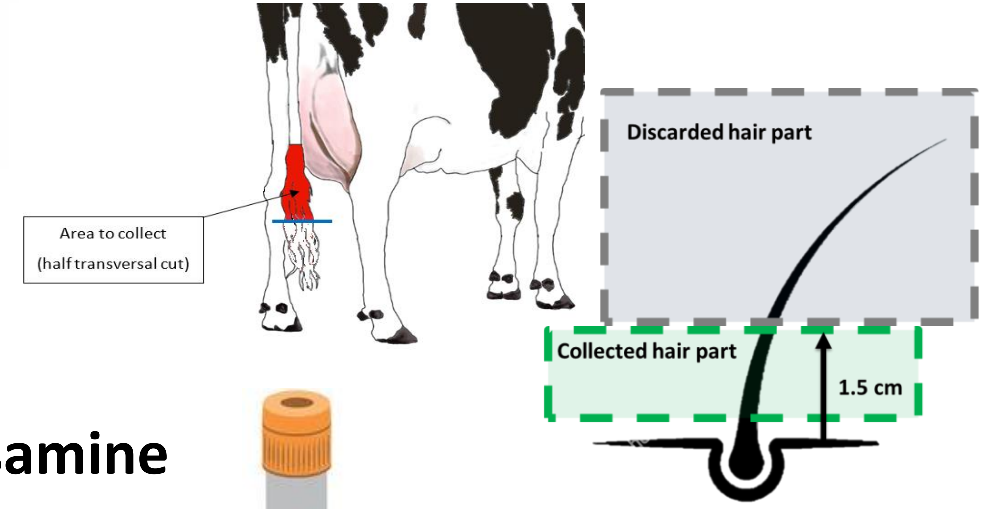

C. Grelet [a], V. Vanden Dries [a], J. Leblois [b], J. Wavreille [a], L. Mirabito [c], H. Soyeurt [d], S. Franceschini [d], N. Gengler [d], Y. Brostaux [d], HappyMoo Consortium [e 1], F. Dehareng [a]


# Hair cortisol

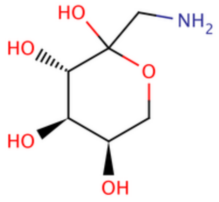



Gold standard chronic stress biomarker

(Comin et al., 2013; Burnett et al., 2015; Heimbürge et al., 2019; Vesel et al., 2020; Tallo-Parra et al., 2017b).




# Blood fructosamine

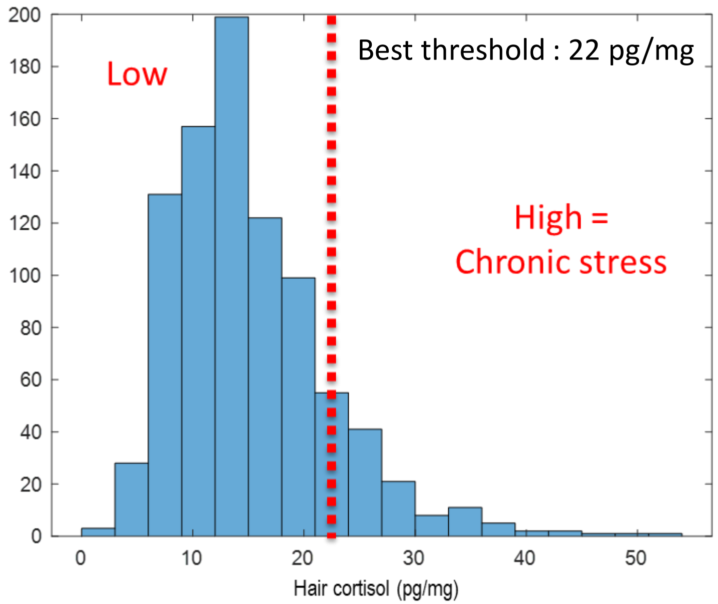



**See the presentation of <u>Clément Grelet (Technical session 4)</u>**
*Possibilities of rapid MIR analysis of milk to provide information on cow's welfare*

# Chronic stress

## <u>Cortisol discriminant models</u>

## Hair cortisol




### Cross validation

| | Low cortisol | High cortisol | | Sensibility | Specificity | Accuracy |
|---|---|---|---|---|---|---|
| Predicted Low | 719 | 73 | | | 81% | 77% |
| Predicted High | 172 | 107 | | 59.4% | | |
| | **891** | **180** | **1071** | | | |

### External-Herd-Validation

| | Low cortisol | High cortisol | | Sensibility | Specificity | Accuracy |
|---|---|---|---|---|---|---|
| Predicted Low | 656 | 71 | | | 74% | 71% |
| Predicted High | 235 | 109 | | 60.6% | | |
| | **891** | **180** | **1071** | | | |

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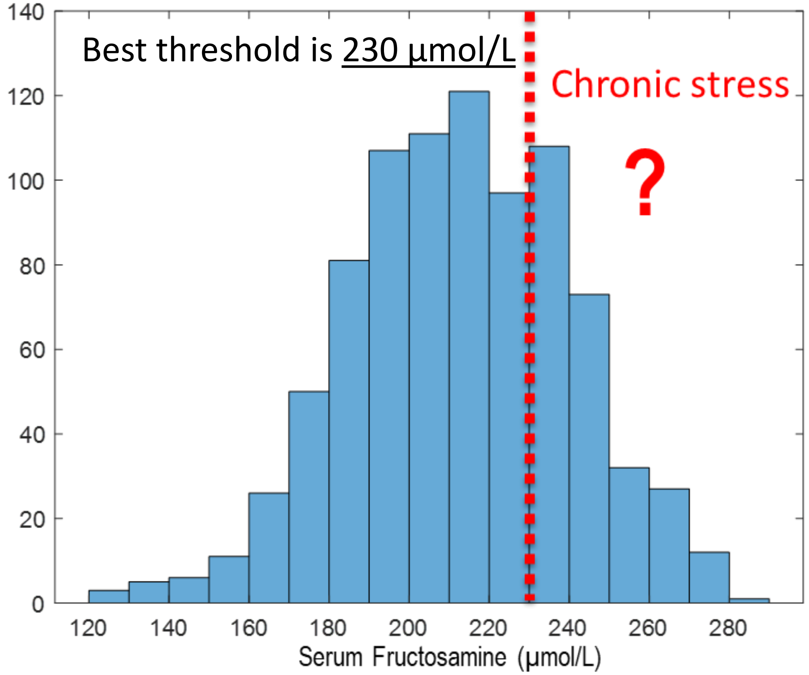
# Chronic stress

## Blood fructosamine




## Blood fructosamine model

### Cross validation

| | Low fructosamine | High fructosamine | | Sensibility | Specificity | Accuracy |
|---|---|---|---|---|---|---|
| Predicted Low | 513 | 58 | | | 75% | 75% |
| Predicted High | 175 | 194 | | 77.0% | | |
| | **688** | **252** | **940** | | | |

### External-Herd-Validation

| | Low fructosamine | High fructosamine | | Sensibility | Specificity | Accuracy |
|---|---|---|---|---|---|---|
| Predicted Low | 467 | 77 | | | 67.9% | 68.3% |
| Predicted High | 221 | 175 | | 69.4% | | |
| | **688** | **252** | **940** | | | |

## And many other models…

- related to the prediction of milk taste (lipolysis or free fatty acids)
- for predicting the ability to be processed into dairy products (ability to be transformed into cheese, butter, yogurt, etc.)
- in relation to the quality of the processed product (e.g., spreadability of butter)
- for protein composition
- and many others, the list is long


If we want to understand and effectively manage sustainability, it requires a large amount of standardized data and measurements that accurately represent its complexity, diversity and evolution

… and ideally, these should not be too expensive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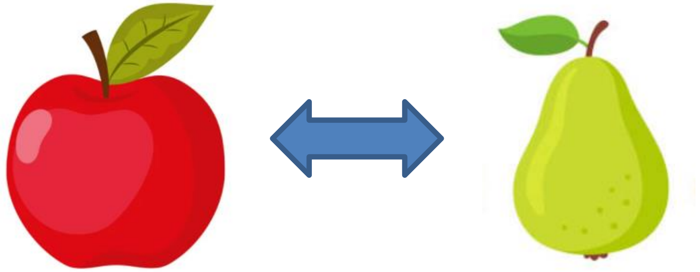
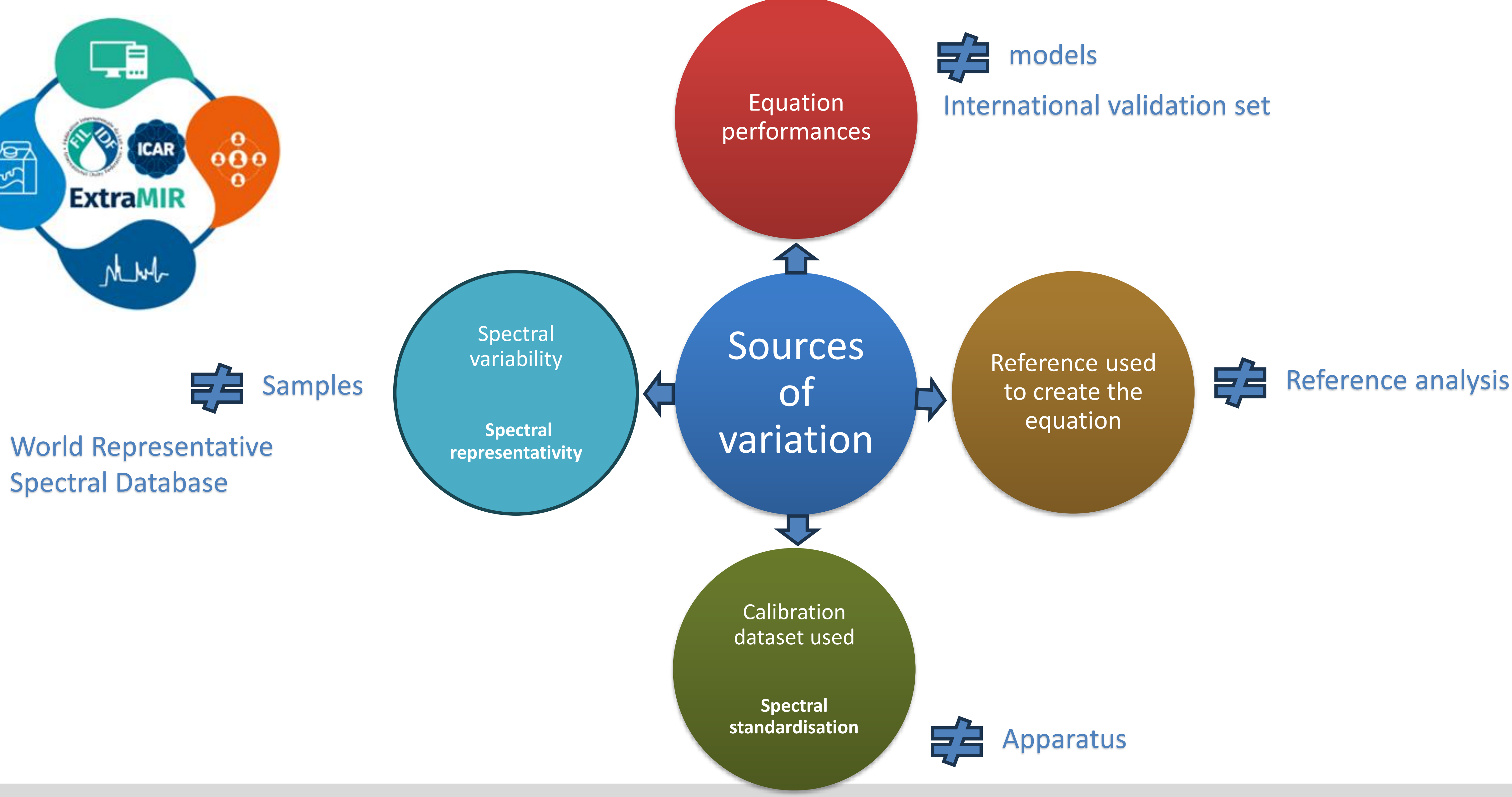
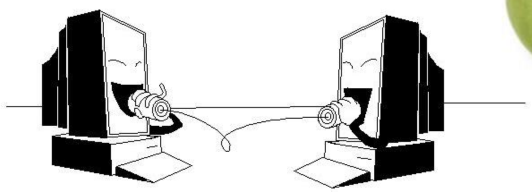


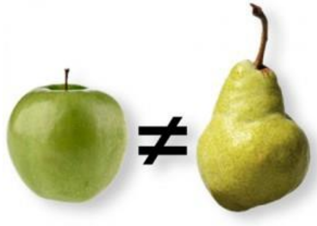

Equation performances
≠ models
International validation set
Sources of variation
Spectral variability
Spectral representativity
≠ Samples
World Representative Spectral Database
Reference used to create the equation
≠ Reference analysis
Calibration dataset used
Spectral standardisation
≠ Apparatus

# Objective and importance of MIR spectral standardization

### Harmonization of spectra across instruments, labs, countries, continents

- Sharing of model
- Sharing of data (costly reference)





### Harmonization of spectra across time

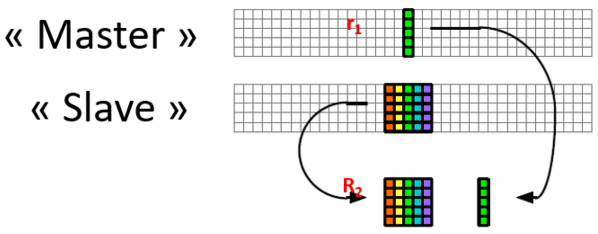
- Useability of models in time
- Stability of predictions

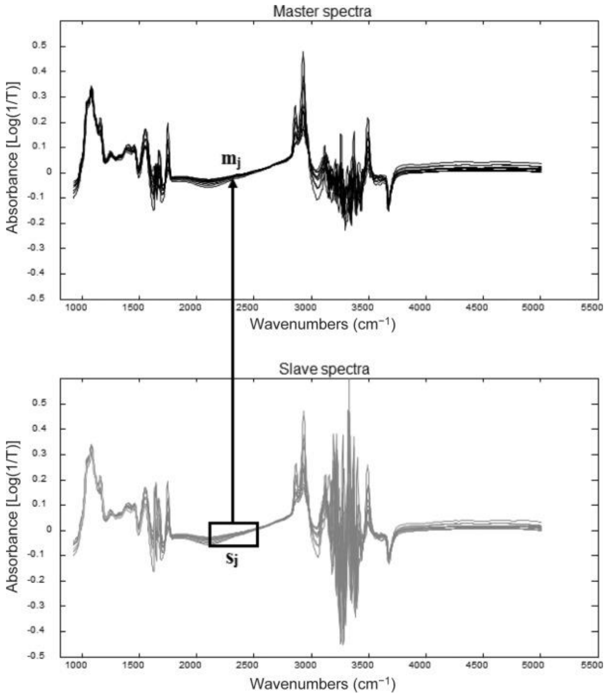
### Harmonization of historical database

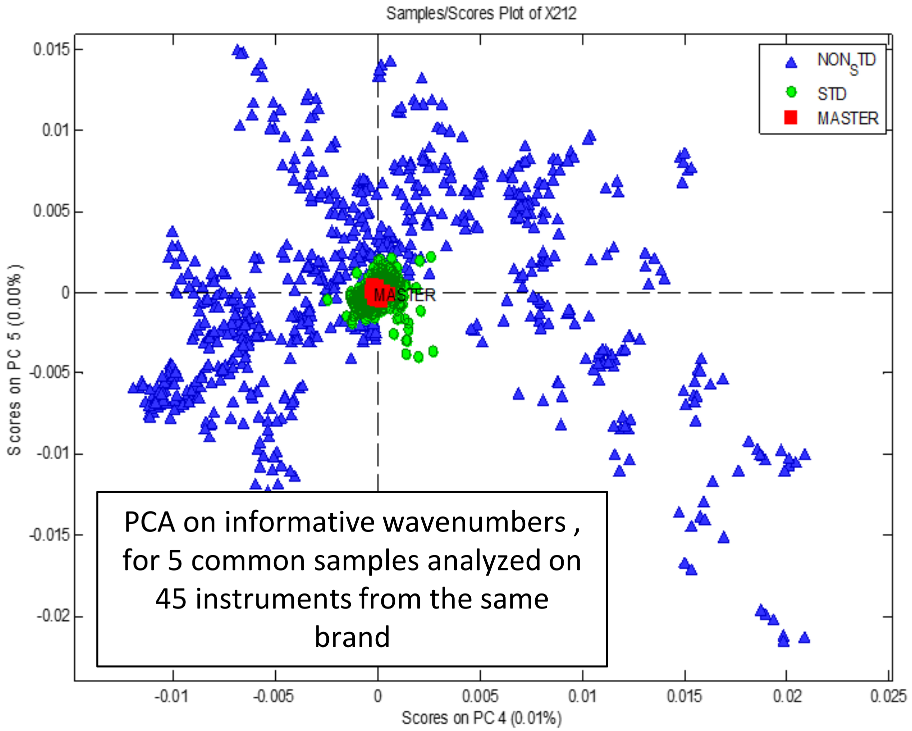
- Use of new models on historical spectra
- Power of big data
- Genetic evaluation

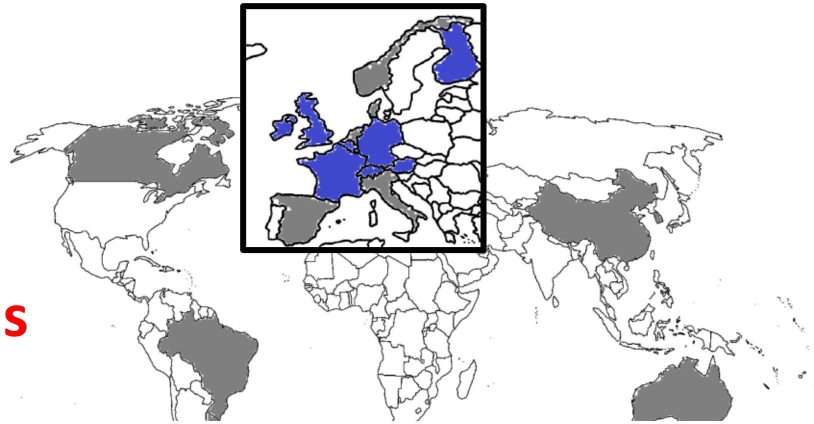
# Standardization of MIR instruments

**PIECE-WISE DIRECT STANDARDIZATION (PDS)**



**40 Labs**
**112 Apparatus**


J. Dairy Sci. 100:7910–7921
https://doi.org/10.3168/jds.2017-12720



**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]

## Creation of historical spectral Database

Since 2008

Wallonie

Futurospectre DB

≈ 7.000.000 individual spectra

≈ 5.750.000 bulk spectra

Since 2023

Interreg Co-funded by the European Union
North-West Europe
HoliCow

HOLICOW

North-West Europe

≈ 60.000.000 individual spectra

**As all our models are built with standardized spectra, meaning they are directly compatible with these databases. This allows for many predictions to be directly accessible and potentially comparable to each other!**


If we want to **understand and effectively manage** sustainability, it requires a large amount of standardized data and measurements that accurately represent its complexity, diversity and evolution

… and ideally, these should not be too expensive

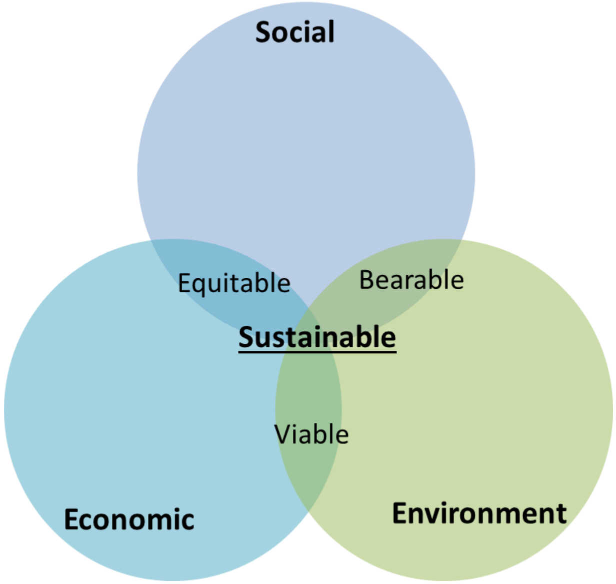

WALLeSmart

Interreg North-West Europe Co-funded by the European Union

HoliCow

DECiDE

# Take home messages




- If you are thinking about improving the sustainability of your dairy farms, think big and global! The factors and interrelations are numerous and complex to understand
- Milk is an excellent phenomics candidate !
- A multitude of parameters can be predicted based on its composition
- Anticipate! Unfortunately, spectral standardisation is not retroactive
- Collaborate as much as possible! By this way, you can share data (often very expensive), and create common models more robust

# Many thanks

To our collaborators and supports !