Latest developments of the use of mid-infrared spectral data in the north-western region of Europe: from OptiMIR to GplusE

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My Presentation Today

- Overview of activities and projects of our group and affiliated groups since 2005
  - Earlier developments (e.g. RobustMilk, GreenhouseMilk)
  - Mostly focus on recent (e.g. OptiMIR and GplusE)
- Focus on impact for industry and producers
- Before I start
  - Many thanks to numerous collaborators, without them this work would not be possible, especially the Walloon Agricultural Research Center (CRA-W)

Mid-Infrared as Technology

Also often called FTIR

- Mid-infrared (MIR) spectrometry is not new

  ➔ **Has been in use for a long time**

- But far away from the sight of the general industry and producers
- Use for all major milk components (except SCC)
  - Fat %
  - Protein %
  - Urea
  - Lactose
  - …

Major Milk Components (except SCC)

Milk samples

(milk payment, milk recording)

MIR analysis

"Black Box"

Quantification:

Fat %

Protein %

Urea

Lactose

First Steps to Extend Impact of MIR

- Around 2005 first ideas immerged in the European industry

  ➔ **Let's try to predict novel traits**

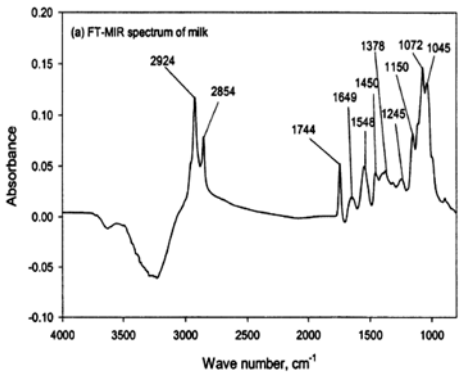
- Possible because hidden in the "black box" ➔ rather simple process of combining spectral data to get predictions!
- Based on prediction (often called calibration) equations

Major Milk Components (except SCC)

Milk samples

(milk payment, milk recording)

MIR analysis



Raw data = MIR spectra

Calibration equations

Quantification:

Fat %

Protein %

Urea

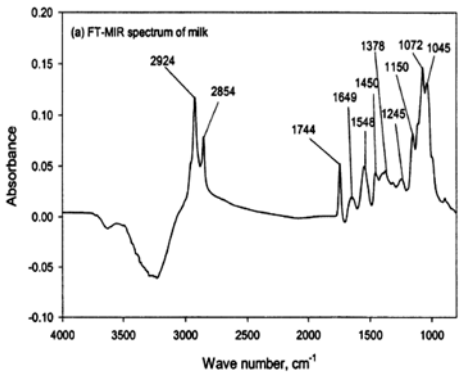
Lactose

Novel Traits ← Novel Calibrations

Milk samples

(milk payment, milk recording)

MIR analysis



Raw data = MIR spectra

Novel Calibration equations

Quantification:

Novel traits

Impulse from Local and EU Projects

- Best known: **RobustMilk** (www.robustmilk.eu)
  - "Innovative and Practical Breeding Tools for Improved Dairy Products from More Robust Dairy Cattle"
- Focusing on
  - **Milk quality** (fatty acids) and some **health related traits** (as lactoferrin and minerals)


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

Mid-infrared prediction of bovine milk fatty acid production systems, and countries

H. Soyeurt,*†[1,2] F. Dehareng,‡[1] N. Gengler,*† S. McParland,§ E. Wa and P. Dardenne‡
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†National Funds for Scientific Research, 1000 Brussels, Belgium
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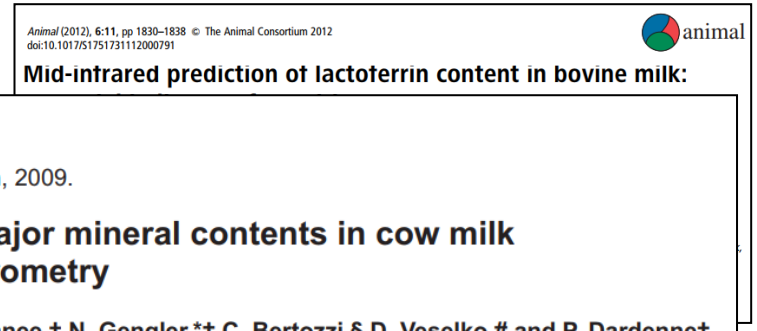
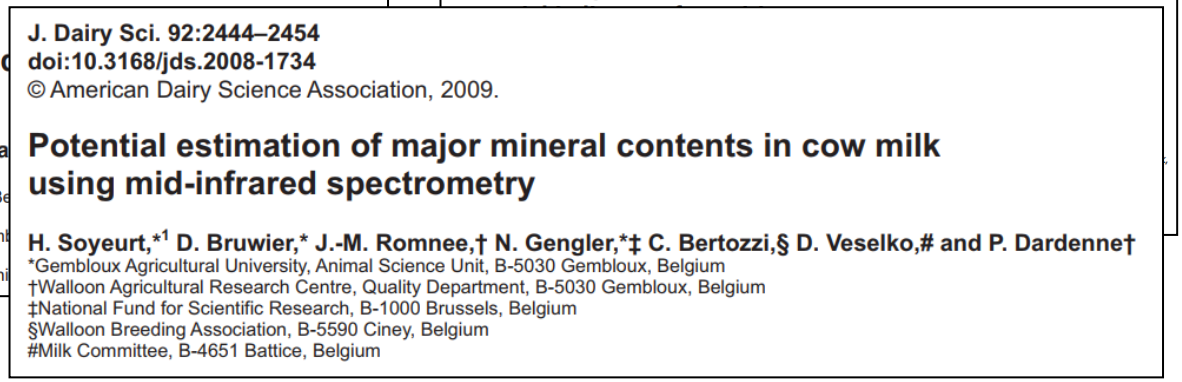
§Teagasc Moorepark Dairy Production Research Centre, Fermoy, Co. Cork, Ireland
#Sustainable Livestock Systems Group, Scottish Agricultural College, Bush Estate, Peni


Animal (2012), 6:11, pp 1830–1838 © The Animal Consortium 2012
doi:10.1017/S1751731112000791

Mid-infrared prediction of lactoferrin content in bovine milk:


J. Dairy Sci. 92:2444–2454
doi:10.3168/jds.2008-1734

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

H. Soyeurt,*[1] D. Bruwier,* J.-M. Romnee,† N. Gengler,*‡ C. Bertozzi,§ D. Veselko,# and P. Dardenne†
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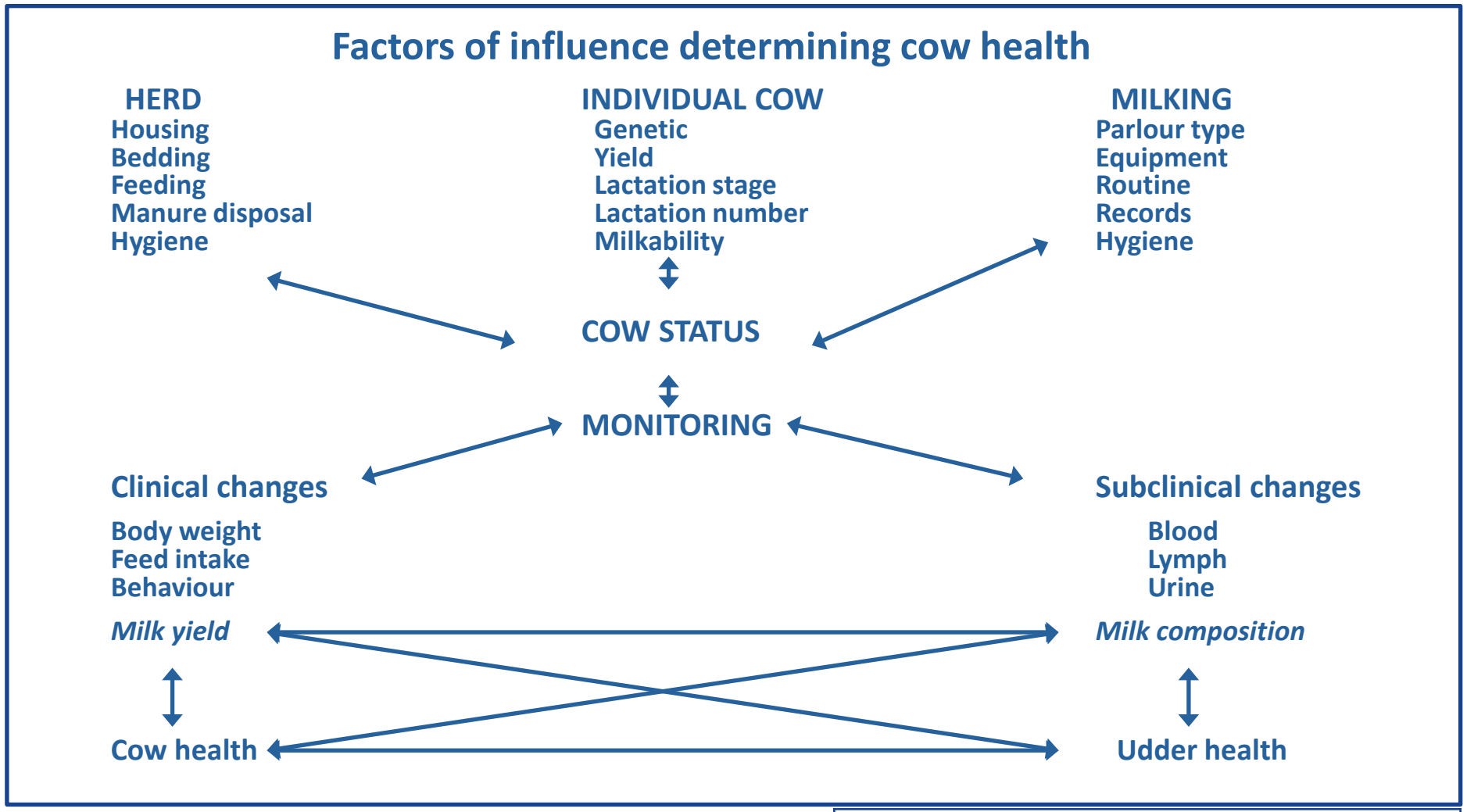
#Milk Committee, B-4651 Battice, Belgium

Impulse from Local and EU Projects

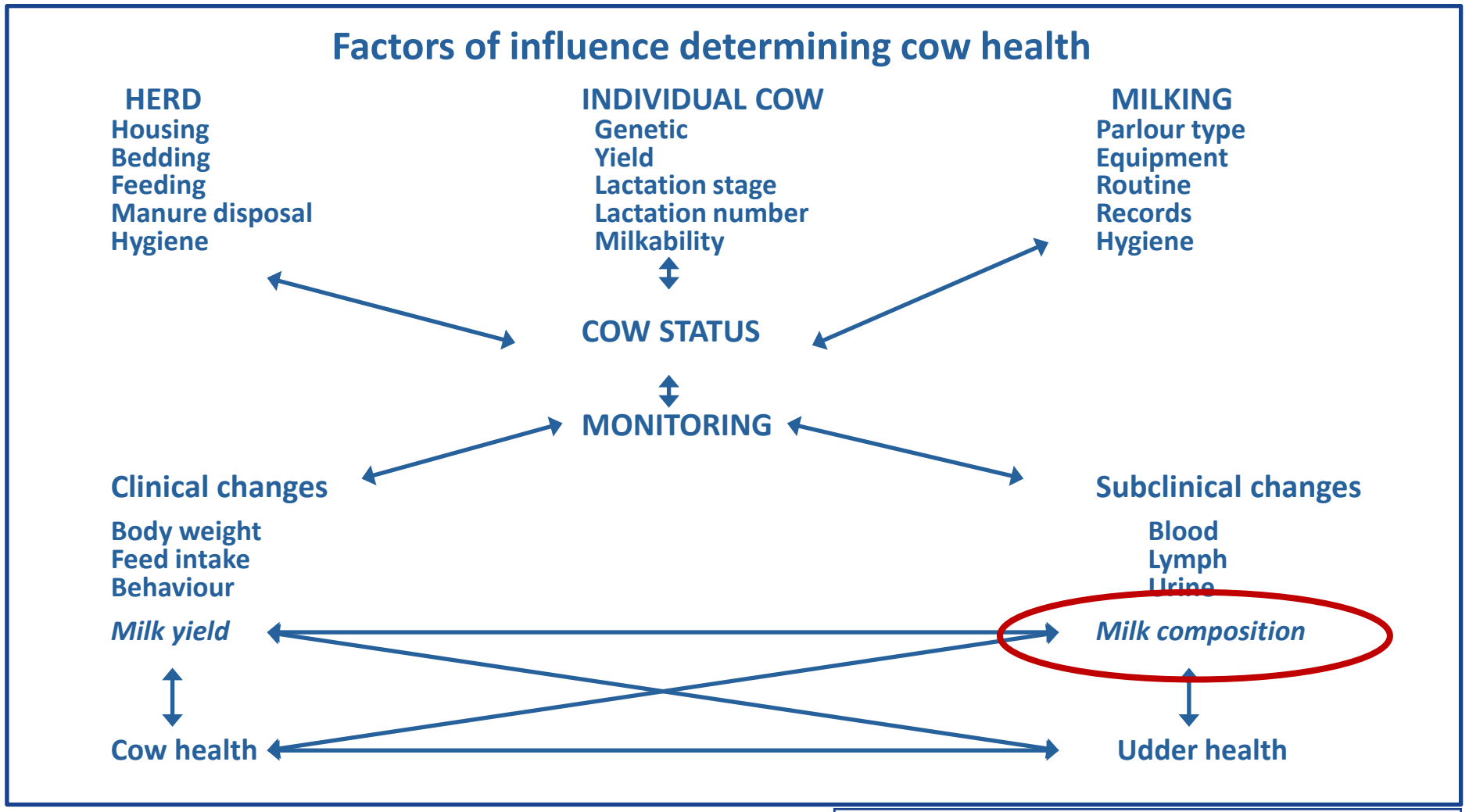
- Best known: **RobustMilk** (www.robustmilk.eu)
  - "Innovative and Practical Breeding Tools for Improved Dairy Products from More Robust Dairy Cattle"
- Focusing on
  - **Milk quality** (fatty acids) and some **health related traits** (as lactoferrin and minerals)
- Large impact as it showed
  - Basic validity of approach
  - Possibilities to used MIR for novel traits

But Milk Composition Ideal Tool for More



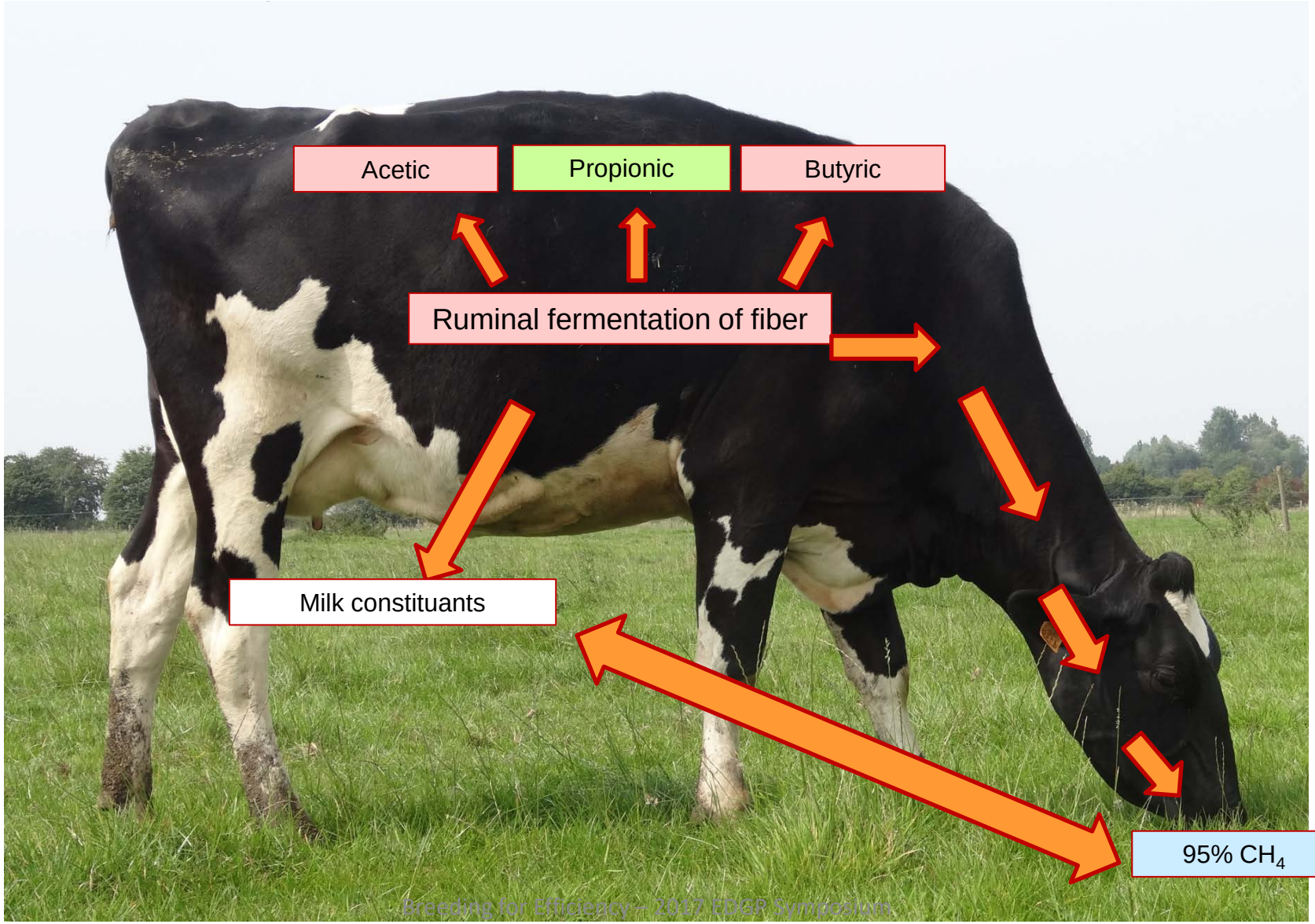
Hamann & Krömker 1997. Livest. Prod. Sci. 48: 201-208.

Metabolic Status ⬅ Subclinical Changes



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

Also: CH_4 ← Milk Composition



An Important Remark!

- Spectrometers MIR data potentially unstable
- As long as clearly defined compound

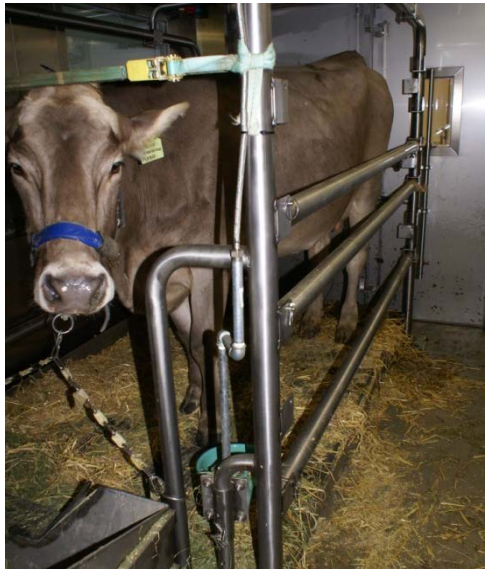
  ➔ **possible to correct post-calibration**
- Using reference milk with known composition
- As done in routine for fat%, protein%,…

- However if the target becomes a status or a non-milk phenotype (as CH_4)

  ➔ **impossible to correct post-calibration**

Important Issue ← Different Machines

For each CH_4 measurement



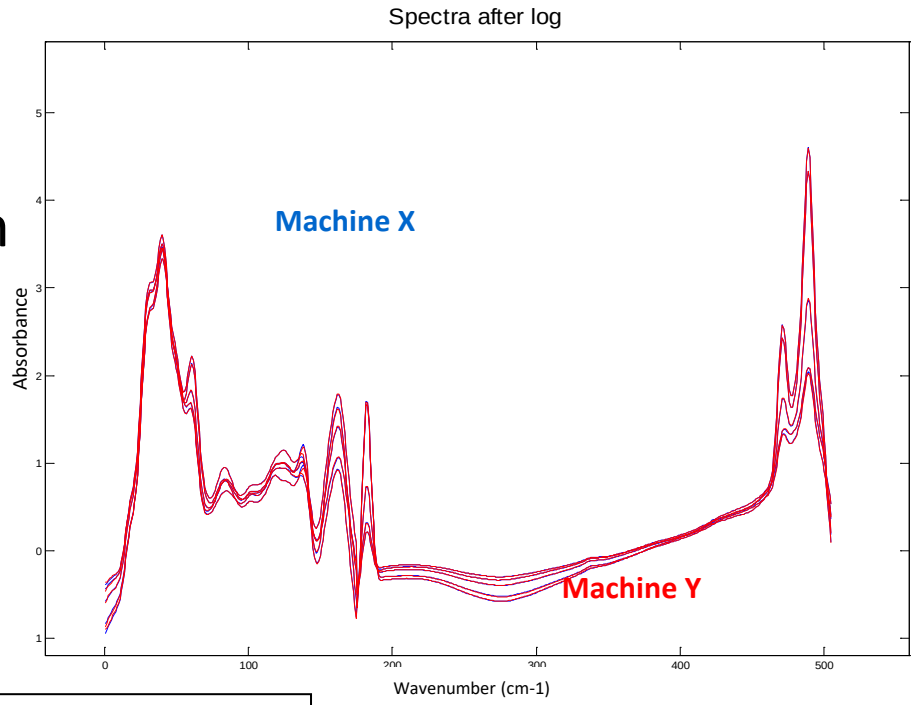
Standardization

→

OptiMIR

Wallonie recherche CRA-W

Milk MIR spectra



J. Dairy Sci. 100:1–12
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]
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‡Walloon Breeding Association, B-5590 Ciney, Belgium

From January 2011 to September 2015

www.optimir.eu

WITH THE SUPPORT OF

Partners


EUROPEAN PARTNERSHIP
11 milk recording organizations
6 research centres and universities
1 laboratory
awe
FRANCE CONSEIL ÉLEVAGE
cra-w
gembloux agro bio tech
INSTITUT DE L'ÉLEVAGE
NMR
Clasel
SRUC
AGRICULTURES & TERRITOIRES
OXYGEN CONSEIL ÉLEVAGE
LKV
LKV Baden-Württemberg
ICBF.com
CONVIS

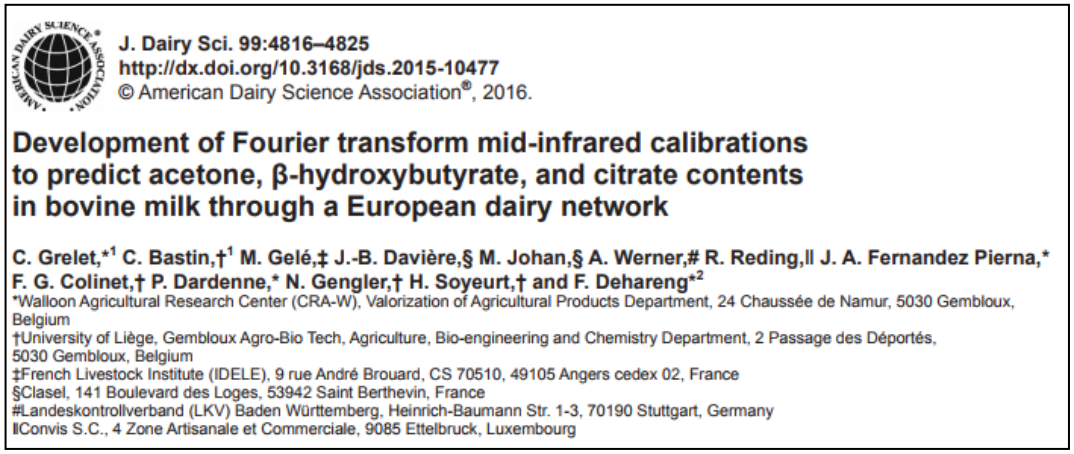
OptiMIR

- Important project
  ➔large scale DHI industry collaboration in NW Europe
- Created a forum of exchange of knowledge and know-how for industry and science
- For industry:
  - Acquisition of MIR spectral data
    ➔ knowing their spectrometers
  - Storing MIR data (and not loosing it)
  - Doing MIR “standardization”
  - Applying MIR equations
  - Reporting results

➔ **Creation of the European Milk Recording (EMR) group**

OptiMIR Research

- Several innovative aspects (as direct use of MIR data)
- Also facilitator for exchange and data consolidation
  - For some traits consolidated into the OptiMIR research database (e.g., for Ketosis related biomarkers, like BHB, citrate, …)



J. Dairy Sci. 99:4816–4825
http://dx.doi.org/10.3168/jds.2015-10477

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,† and F. Dehareng*[2]
*Walloon Agricultural Research Center (CRA-W), Valorization of Agricultural Products Department, 24 Chaussée de Namur, 5030 Gembloux, Belgium
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‡French Livestock Institute (IDELE), 9 rue André Brouard, CS 70510, 49105 Angers cedex 02, France
§Clasel, 141 Boulevard des Loges, 53942 Saint Berthevin, France
#Landeskontrollverband (LKV) Baden Württemberg, Heinrich-Baumann Str. 1-3, 70190 Stuttgart, Germany
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  - For other traits facilitator of contacts, harmonization of MIR and reference data and exchange (e.g. as for methane)

➔ **For CH_4 also very important GreenHouseMilk and Methagene**

CH_4 - SF_6 equation

- Research supported by local and international projects (e.g., GreenHouseMilk)
- Prediction of daily CH_4 from milk MIR spectra
  - Based on SF_6 references
  - From Belgium and Ireland

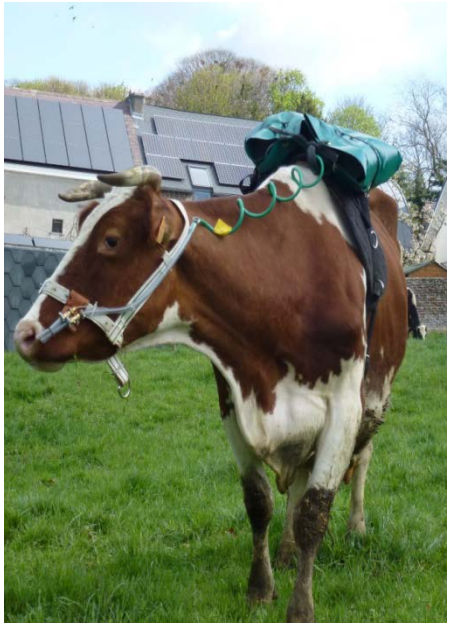
N	SD	R^2c	R^2cv	SEC	SECV
532	129	0.74	0.70	66	70

CSIRO PUBLISHING

Animal Production Science, 2016, **56**, 258–264
http://dx.doi.org/10.1071/AN15590

Milk mid-infrared spectra enable prediction of lactation-stage-dependent methane emissions of dairy cattle within routine population-scale milk recording schemes

Amélie Vanlierde[A,], Marie-Laure Vanrobays[B,G,*], Nicolas Gengler[B], Pierre Dardenne[A], Eric Froidmont[C], Hélène Soyeurt[B], Sinead McParland[D], Eva Lewis[D], Matthew H. Deighton[D,E], Michaël Mathot[F] and Frédéric Dehareng[A]*



Evolution of CH_4 equations ← Chambers

- "Open initiative" ← New members

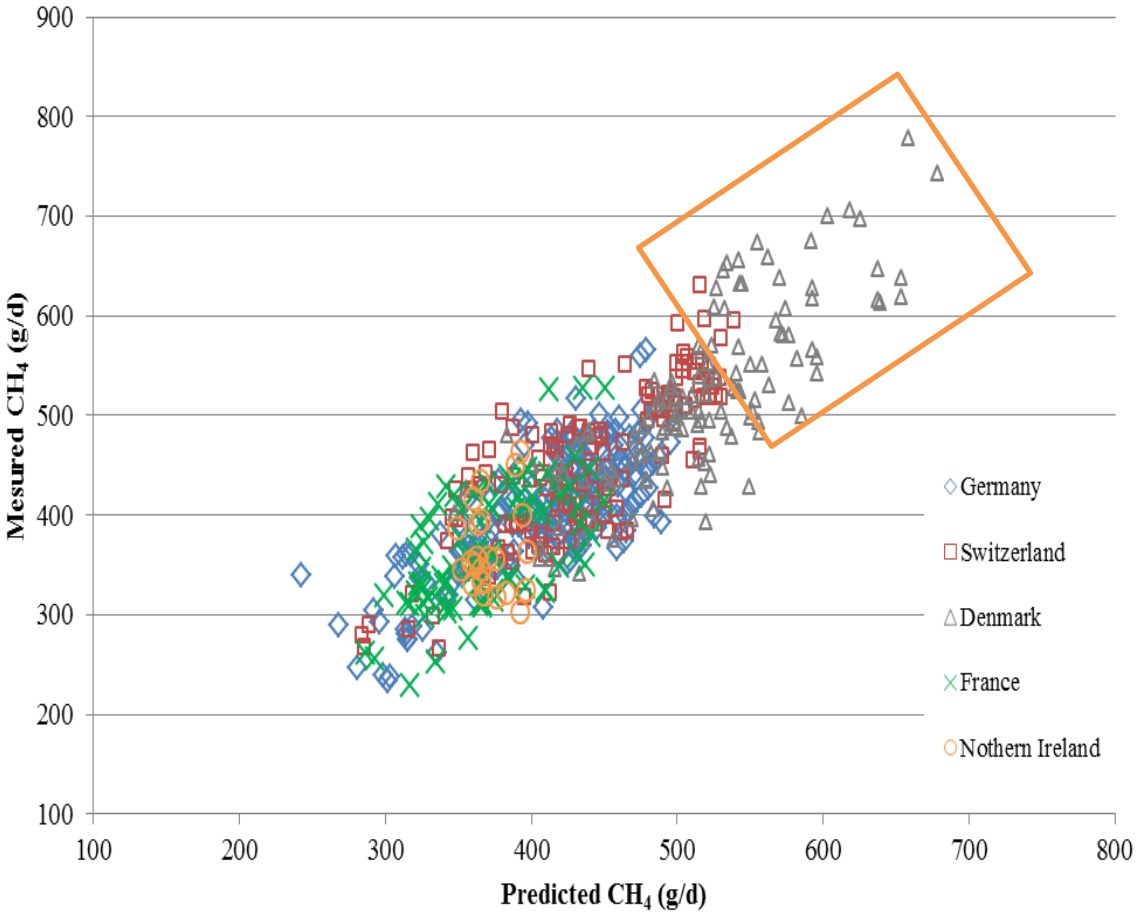
  Starting collaboration with Australia, potentially Canada

  – Through many contacts and projects as Methagene and GplusE
    - MIR and CH_4 data to be added in calibration
  – Get MIR equation and updates
- Evolution from SF_6 to respiration chambers
  – Independent datasets
  – Gold standard reference technique
- Confront the statistics with the SF_6 version

Data sets

Results

Measured CH_4 emissions in function of the predicted CH_4



N	SD	R^2c	R^2cv	SEC	SECV
586	87	0.69	0.63	48	53

→ Only Danish data in this area

→ Less variability in this CH_4 range

→ Less accuracy in predictions

→ Need of more data in this CH_4 range

Genotype plus Environment
Integration for a more sustainable dairy production system

- European project focusing on biomarkers for sustainable dairy cattle breeding and management (see www.gpluse.eu)
  - Lead partner UCD, Dublin, Ireland
    + BE, DE, DK, NL, IT, UK + USA + China
    associated to industry (CRV, QLIP, AWE, EMR)

1. Objective: more classical work on energy balance and RFI and DMI

MIR Prediction of Feed Related Phenotypes

	Predictor traits	n	#LV	R^2cv	RMSECV
Energy balance (Mcal/d)	MIR	1069	15	0.43	5.1
Energy balance (Mcal/d)	**MIR, DIM, FPCM**	1098	12	**0.51**	4.8
RFI (kg/d)	MIR	1115	14	0.46	2.9
RFI (kg/d)	MIR, DIM, FPCM	1097	14	**0.53**	2.7
DMI (kg/d)	MIR	1052	14	0.47	3.2
DMI (kg/d)	MIR, DIM, FPCM	1098	8	**0.59**	2.9

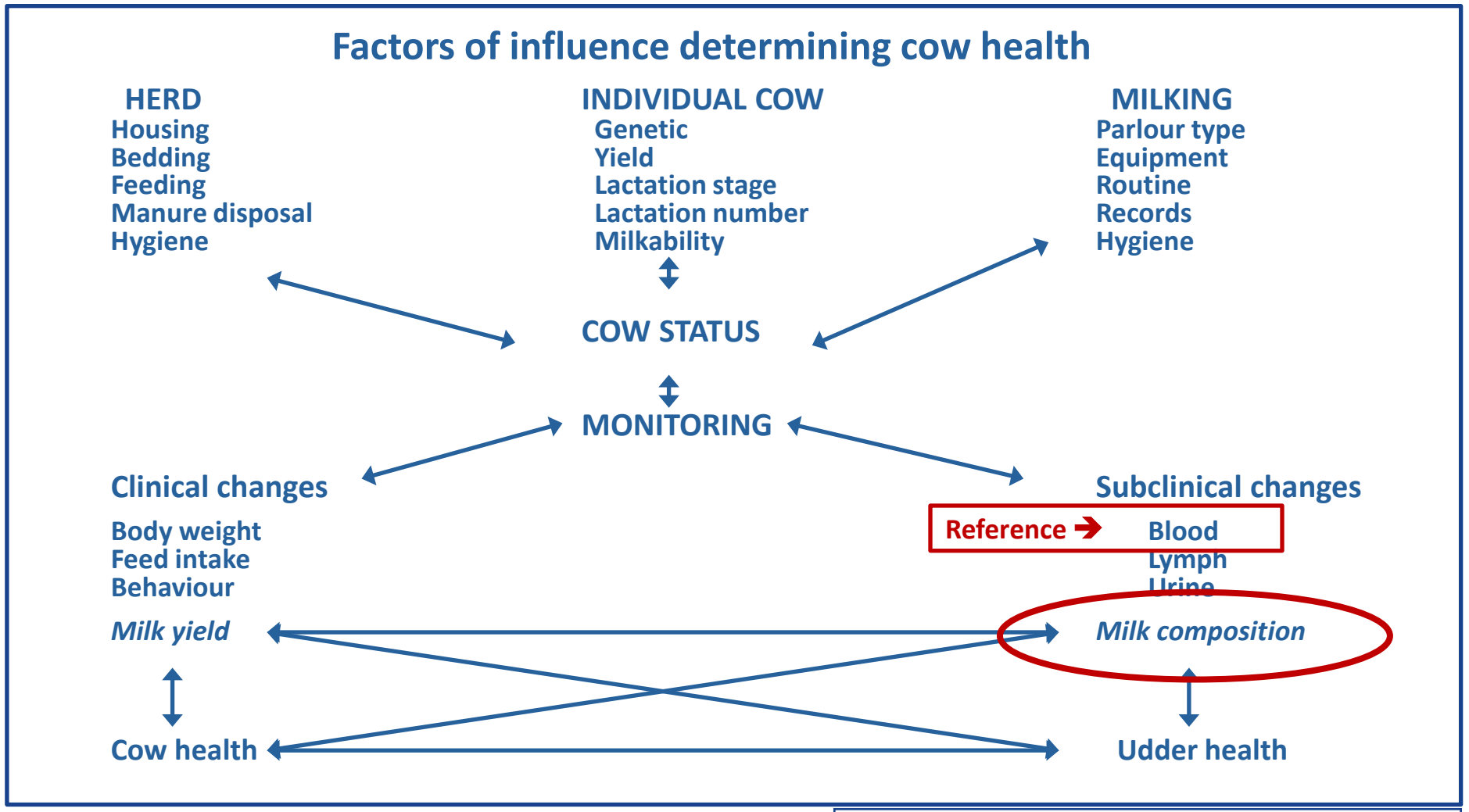
Grelet et al., ICAR 2017

Only 131 cows → need for broader collaboration

- European project focusing on biomarkers for sustainable dairy cattle breeding and management (see www.gpluse.eu)

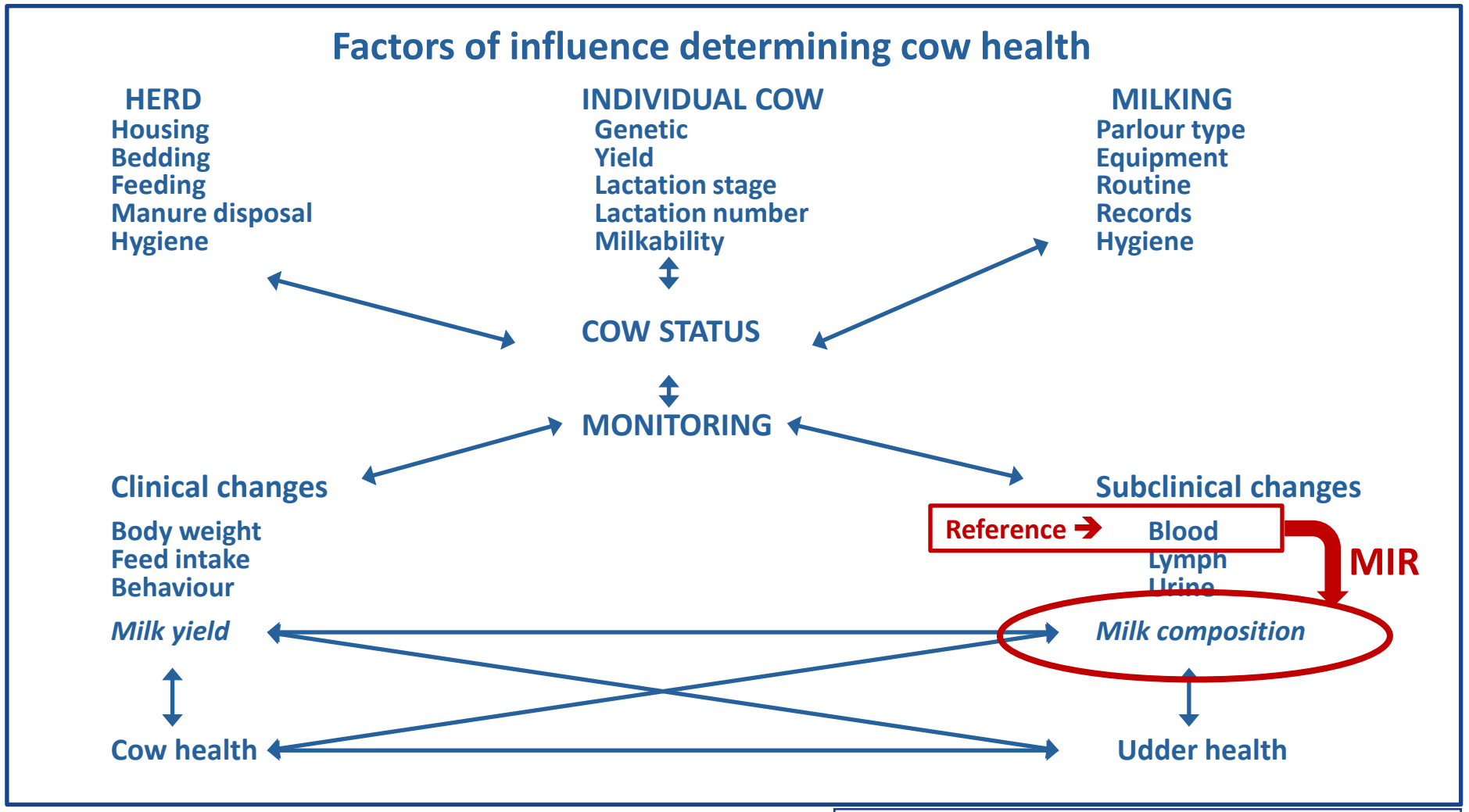
2. Objective shown here:
   making blood based biomarkers useful
   - Creating “health” clusters
   - Predicting membership of clusters from milk MIR data

Blood Based Biomarkers as Reference



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

Blood Based ➔ Milk MIR Predicted



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

Creating Health Clusters

Phenotypes of interest (Grelet et al., ICAR 2017)

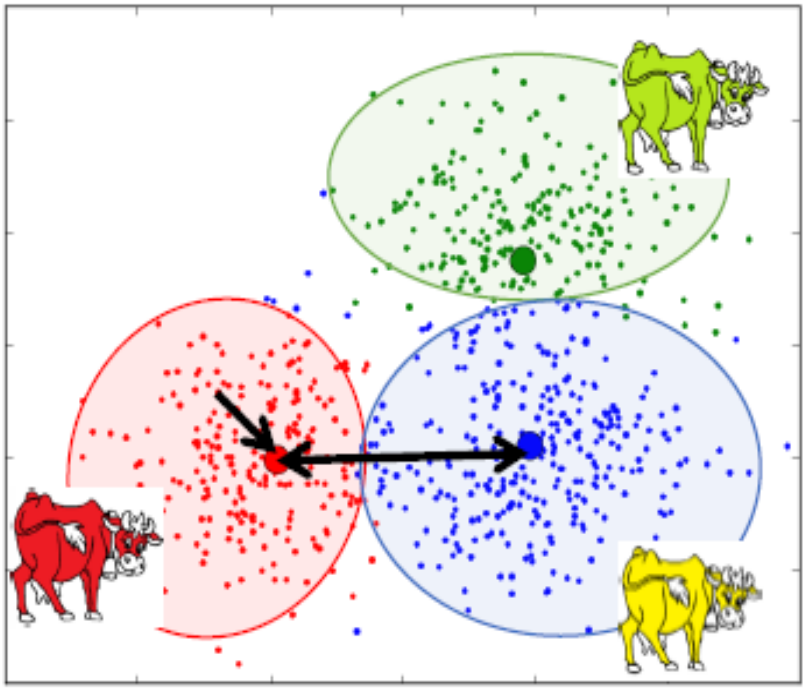
Blood metabolites and hormones are usefull when used togheter

→ Clusters:

- Combination of the blood metabolites and hormones into 3 groups of cow status

K-means nearest neighbour clustering

K=3

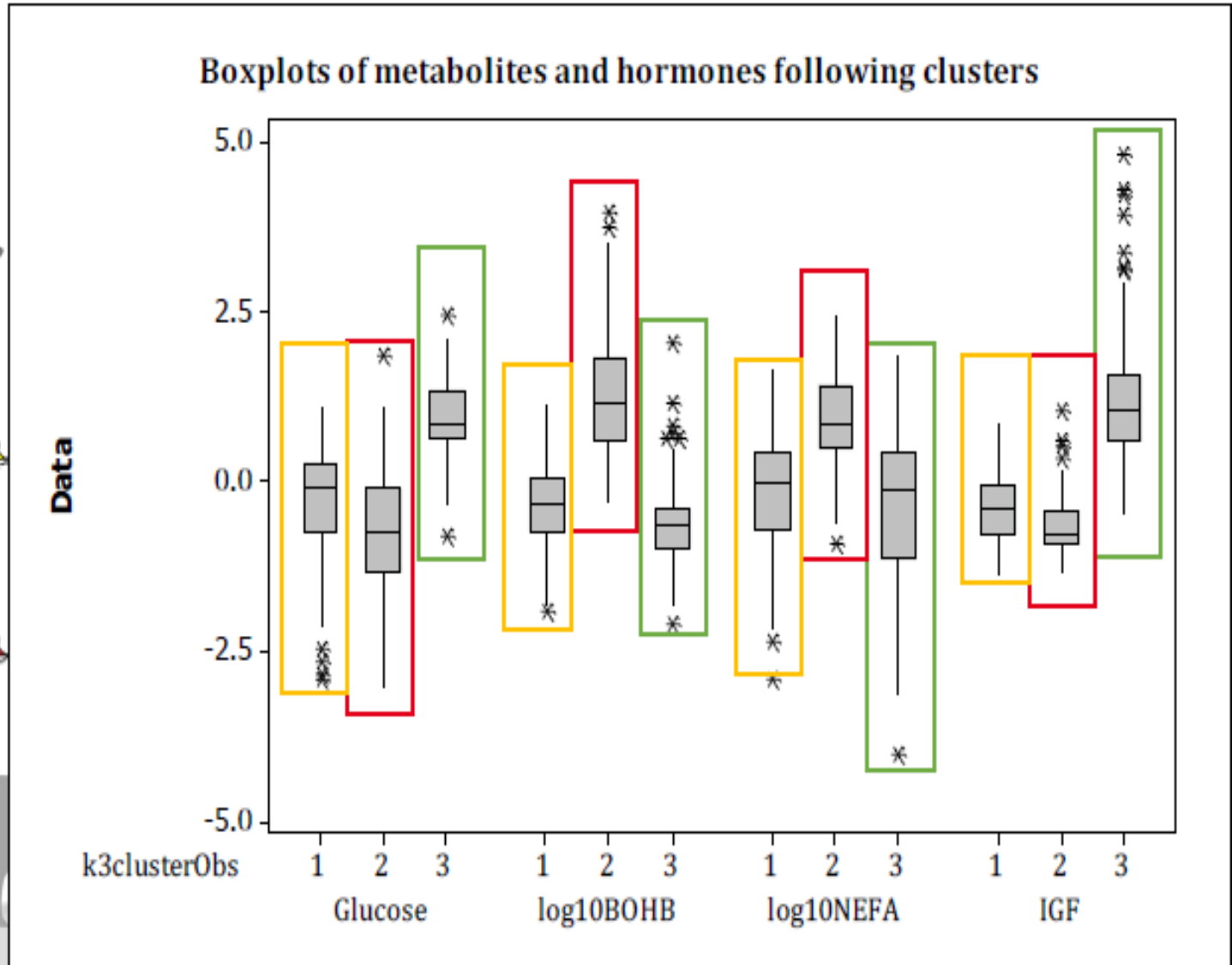


Creating Health Clusters

3 : healthy cows

1 : intermediate cows

2: imbalanced cows



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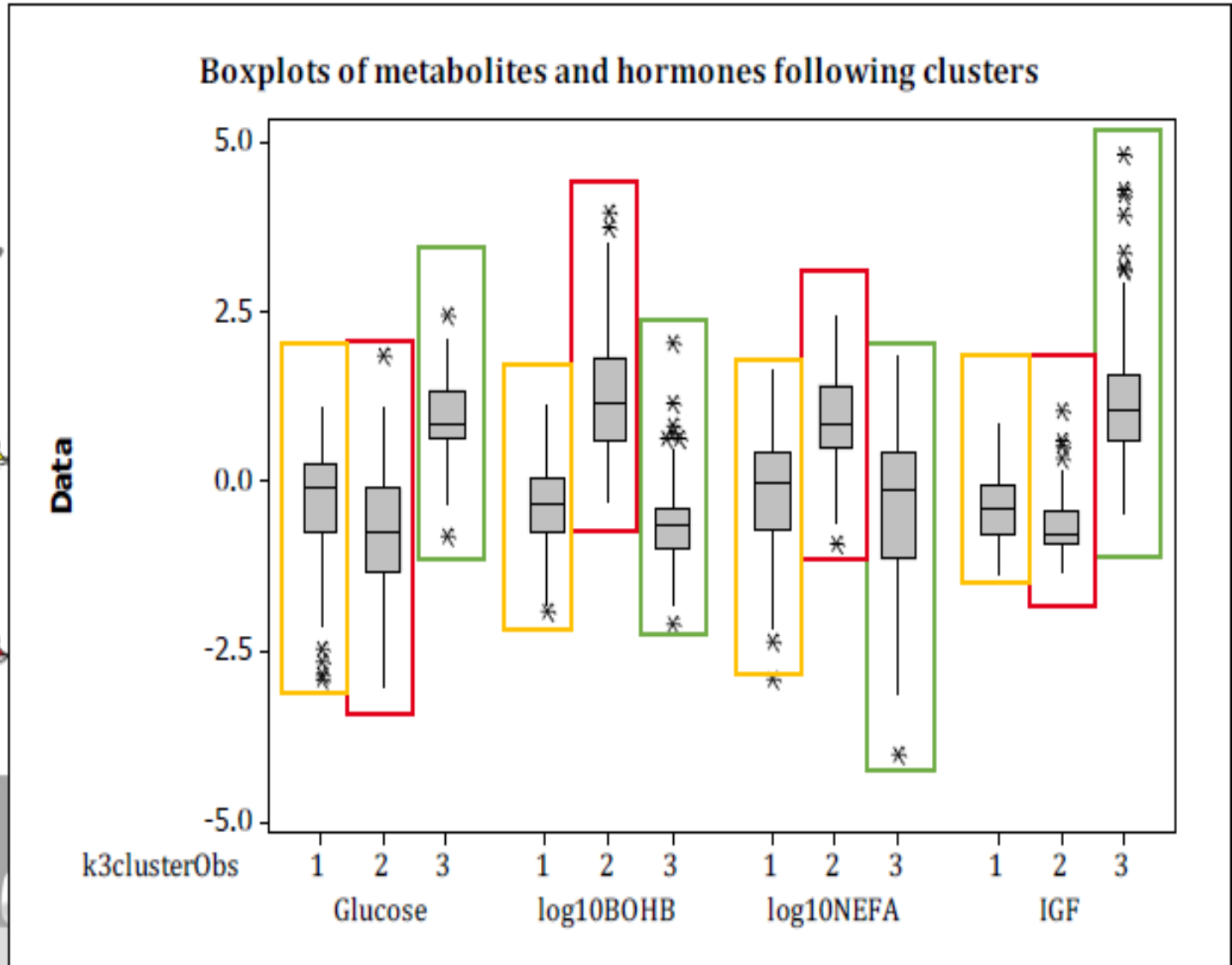

Predicting Health Clusters from MIR Data

	Healthy-or-Intermediate	Imbalanced		Sens	Spec	Glob acc.
Predicted Healthy or Intermediate	246	23		70%	86%	82%
Predicted Imbalanced	41	54				
	287	77	364			

Sensitivity= true positives/(true positive + false negative)
Specificity= true negatives/(true negative + false positives)

Grelet et al., ICAR 2017

Only 354 cows → need for broader collaboration

Conclusion

- In the era of novel phenotypes….

collaboration is imperial

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Thank you for your attention!

Acknowledgments and Disclaimer

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