Capitalizing on mid-infrared to improve nutritional and environmental quality of milk

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World Holstein Conference 2012 Congrès mondial Holstein

Holstein Canada

World Holstein Friesian Federation WHFF

Introduction

- Changes of consumer's perception
  - Improvement of the nutritional quality of food
  - Limitation of the environmental impact of food production and consumption
- Milk quality can be improved:
  - Nutritional quality:
    E.g., unsaturated fatty acids, calcium, lactoferrin
  - Environmental quality:
    E.g., milk production linked to urea, to methane

Introduction

- Acquisition of phenotypes needed!
- Development of practical tools:
  - Cheap: to be used on a large scale
  - Robust: to adapt to different breeds, sampling methods and dates…
  - Fast: more and more cows/farm
  - Reliable
- Use of mid-infrared spectrometry (MIR) on milk ⇨ promising technology

Part I: Usefulness of MIR spectrometry

MIR spectrometry

- Electromagnetic radiation
- Ranged between 1,000 and 5,000 cm^{-1}
- Used routinely by milk laboratories to quantify major milk components:
  - Fat, protein, lactose, urea…
- But: currently under-utilized technology

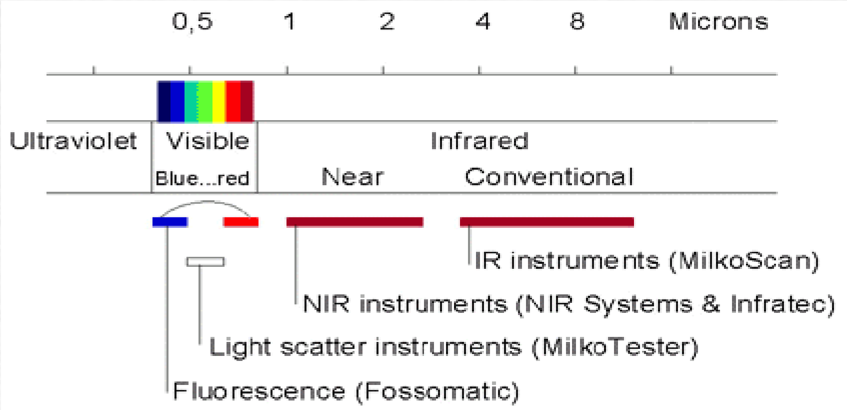


Figure 1 : Electromagnetic spectra (Foss, 2012)

MIR spectrometry

Milk samples

(milk payment, milk recording)

Every 2 or 3 days
Bulk milk samples
Managed by dairy companies

MIR spectrometry

Milk samples

(milk payment, milk recording)

Regularly (mostly 4 or 6 weeks)
Individual cows
Managed by milk recording organizations

MIR spectrometry

Milk samples

(milk payment, milk recording)

(Foss, 2008)

MIR analysis

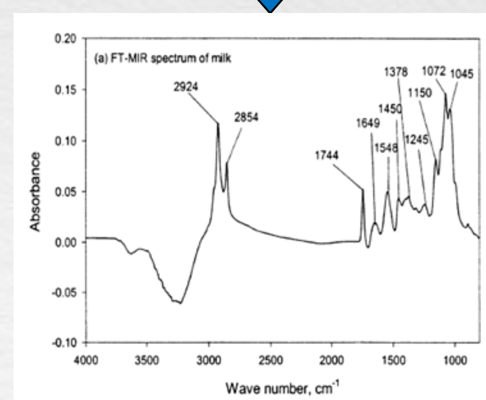
MIR spectrometry

Milk samples

(milk payment, milk recording)

(Foss, 2008)

MIR analysis



Raw data = MIR spectra

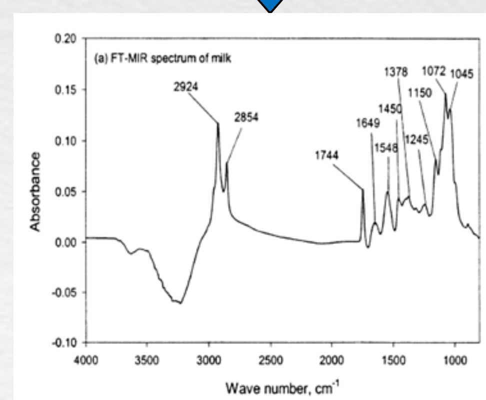
MIR spectrometry

Milk samples

(milk payment, milk recording)

(Foss, 2008)

MIR analysis



Raw data = MIR spectra

Calibration equations

Quantification:

fat

protein

lactose

…

MIR spectrometry

Milk samples

(milk payment, milk recording)

(Foss, 2008)

MIR analysis

Traditional data flow
(no MIR spectra stored)

Quantification:

fat

protein

lactose

…

MIR spectrometry

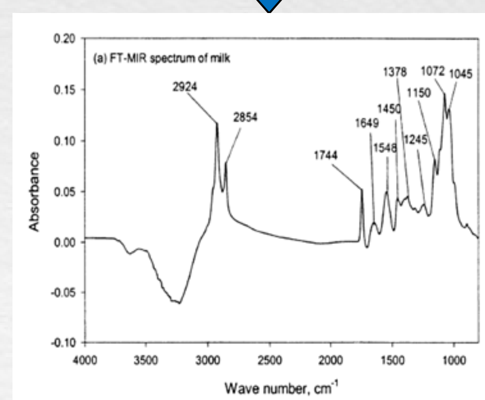
Milk samples

(milk payment, milk recording)

(Foss, 2008)

MIR analysis

New components require new equations



Stored MIR spectra

Calibration equations

Quantification:

fat

protein

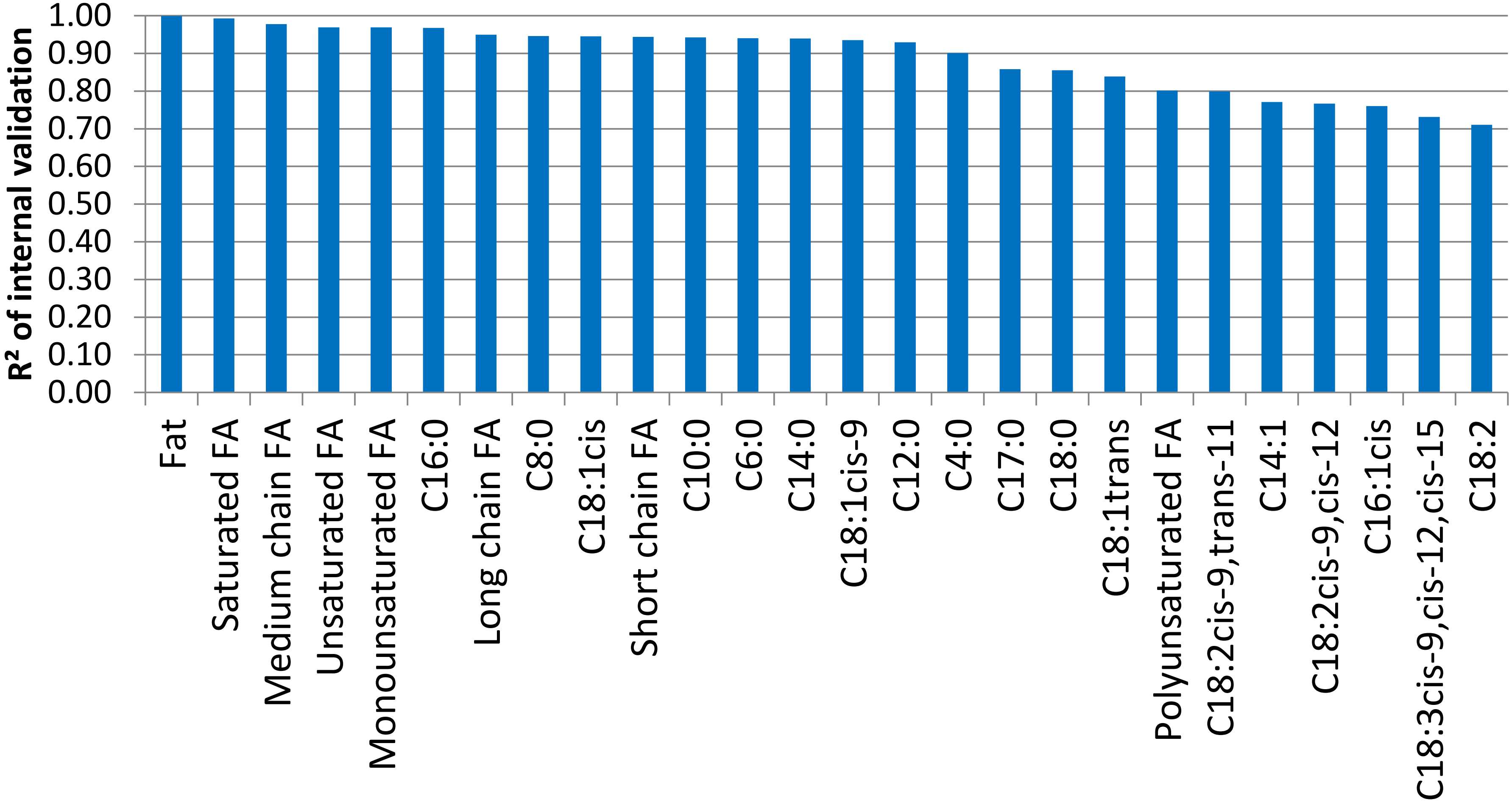
lactose

…

MIR calibration equations: Nutritional quality

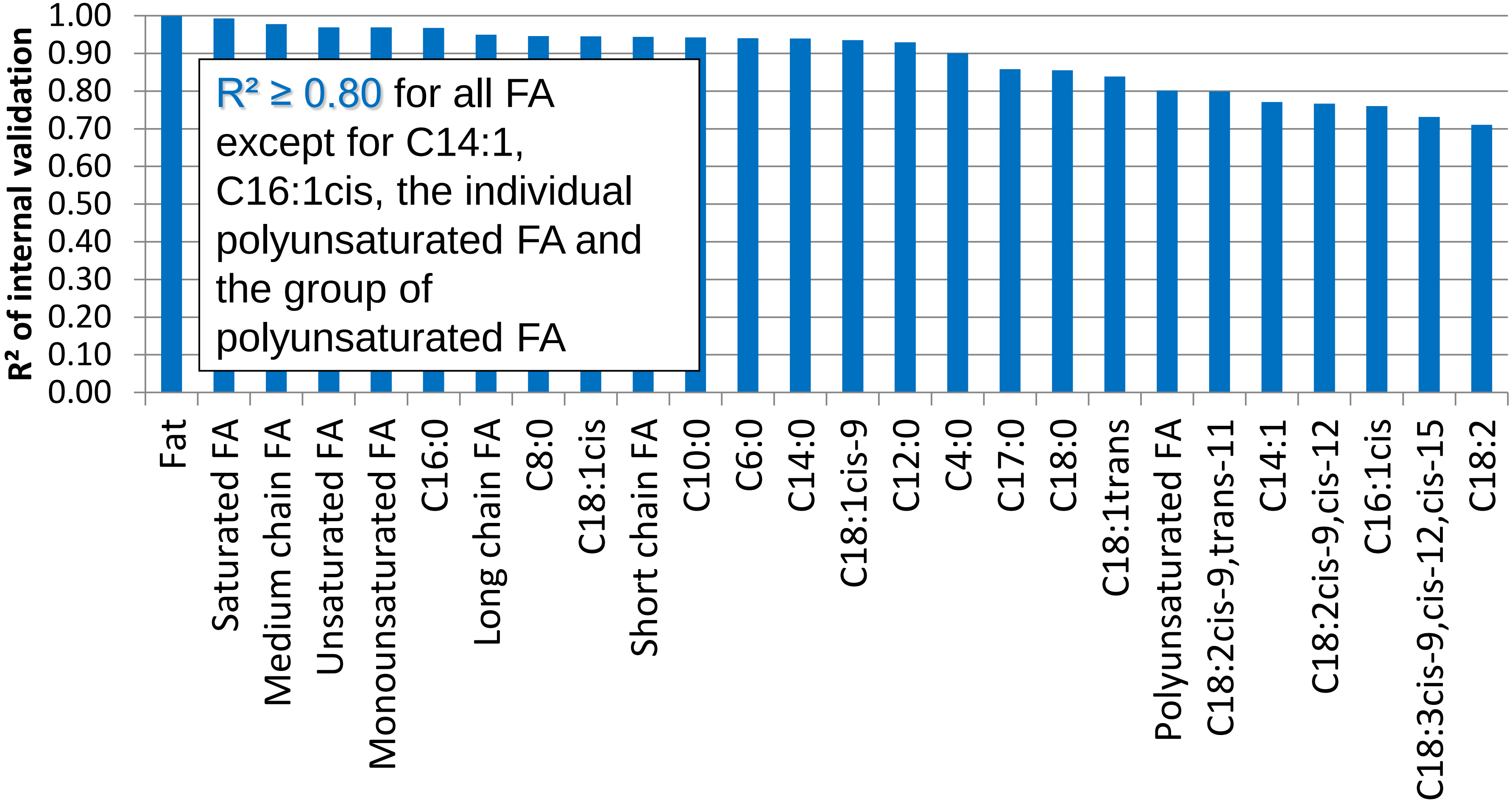
- Milk fatty acid (FA) equations:
  - First equations developed in 2005
  - Improved through international collaborations:
    - Belgium, France, Germany, Ireland, UK, Luxembourg
  - Multiple breeds, countries and production systems

Accuracy of fatty acids calibration equations



Calibration equations were developed from at least 1,600 milk samples

Accuracy of fatty acids calibration equations



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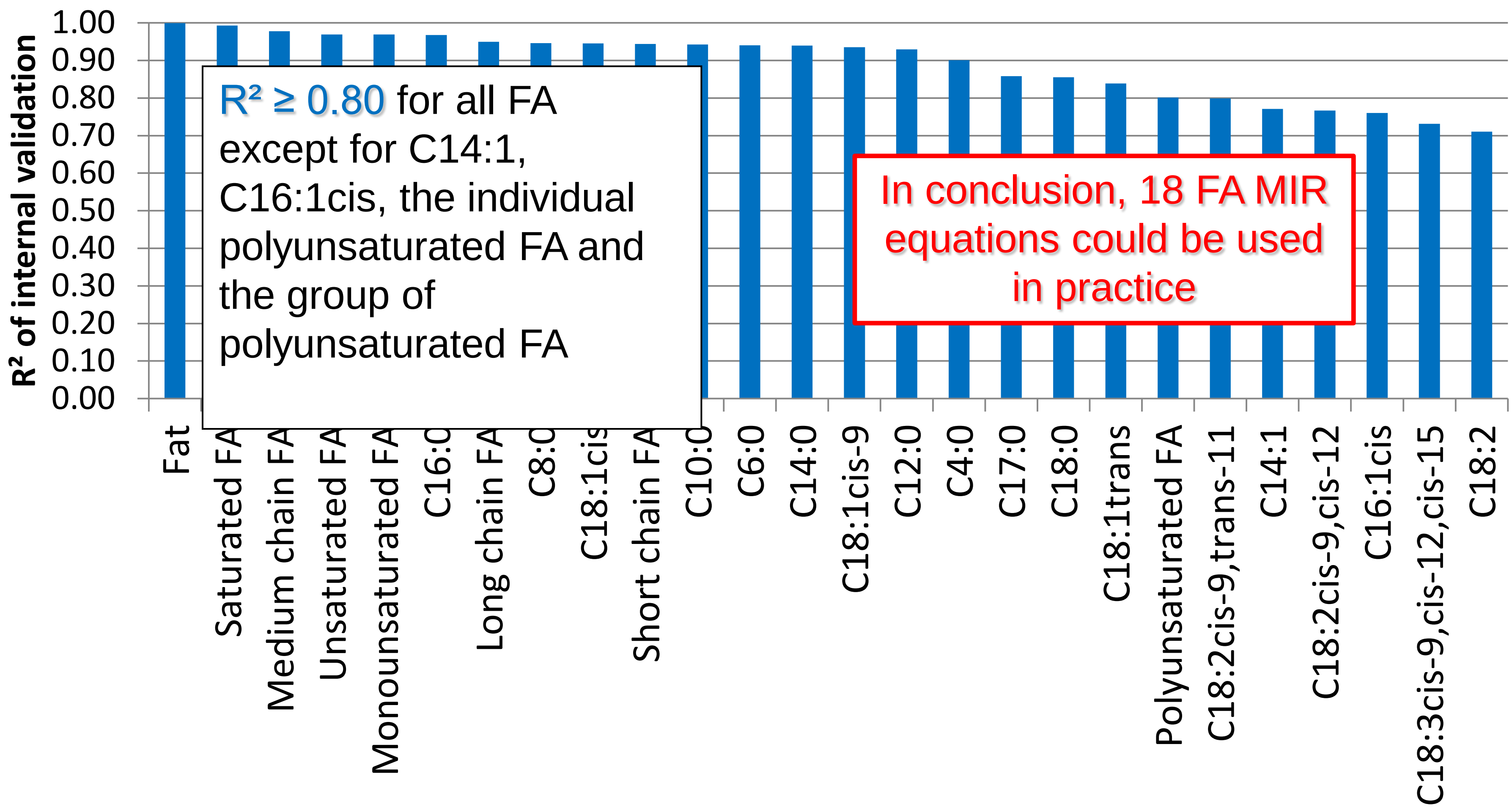

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MIR calibration equations: Nutritional quality

- Milk fatty acid (FA) equations:
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- Milk mineral equations:
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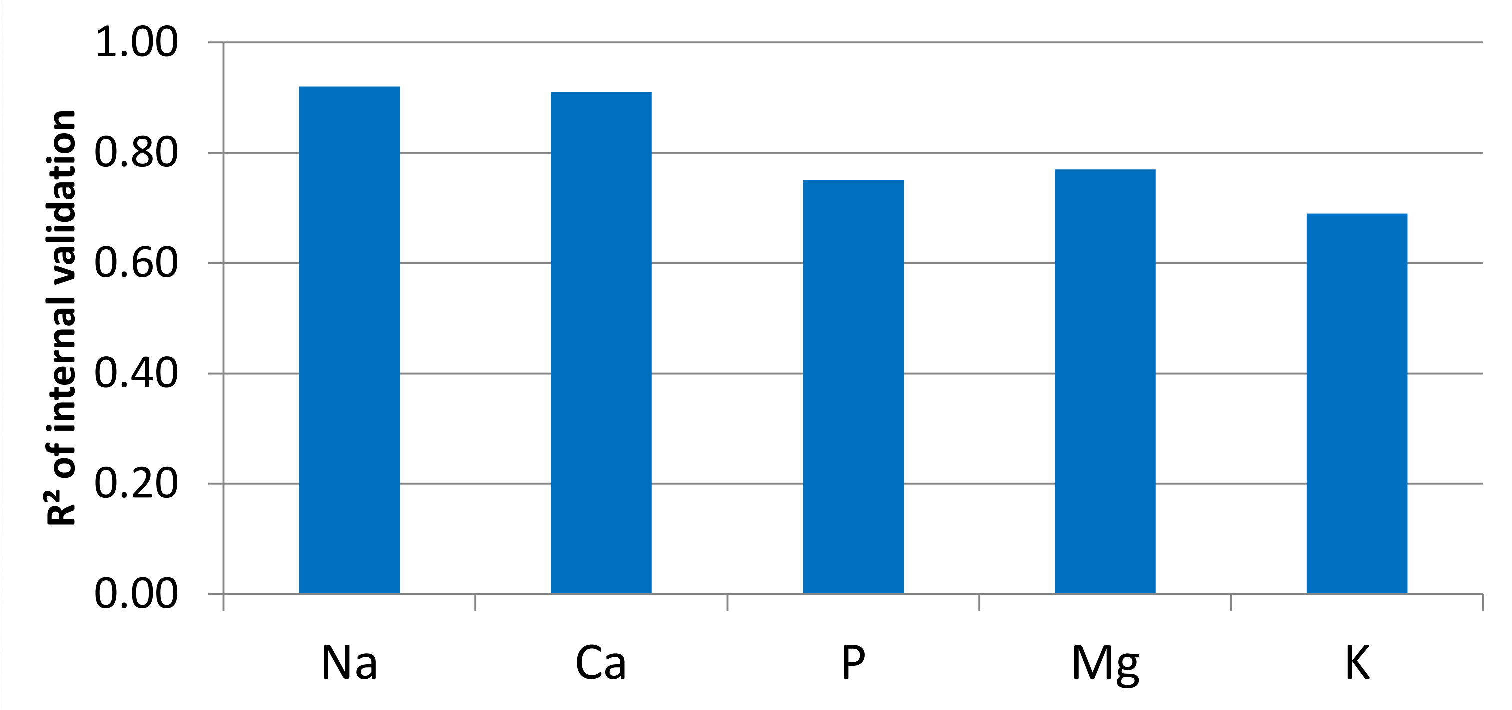
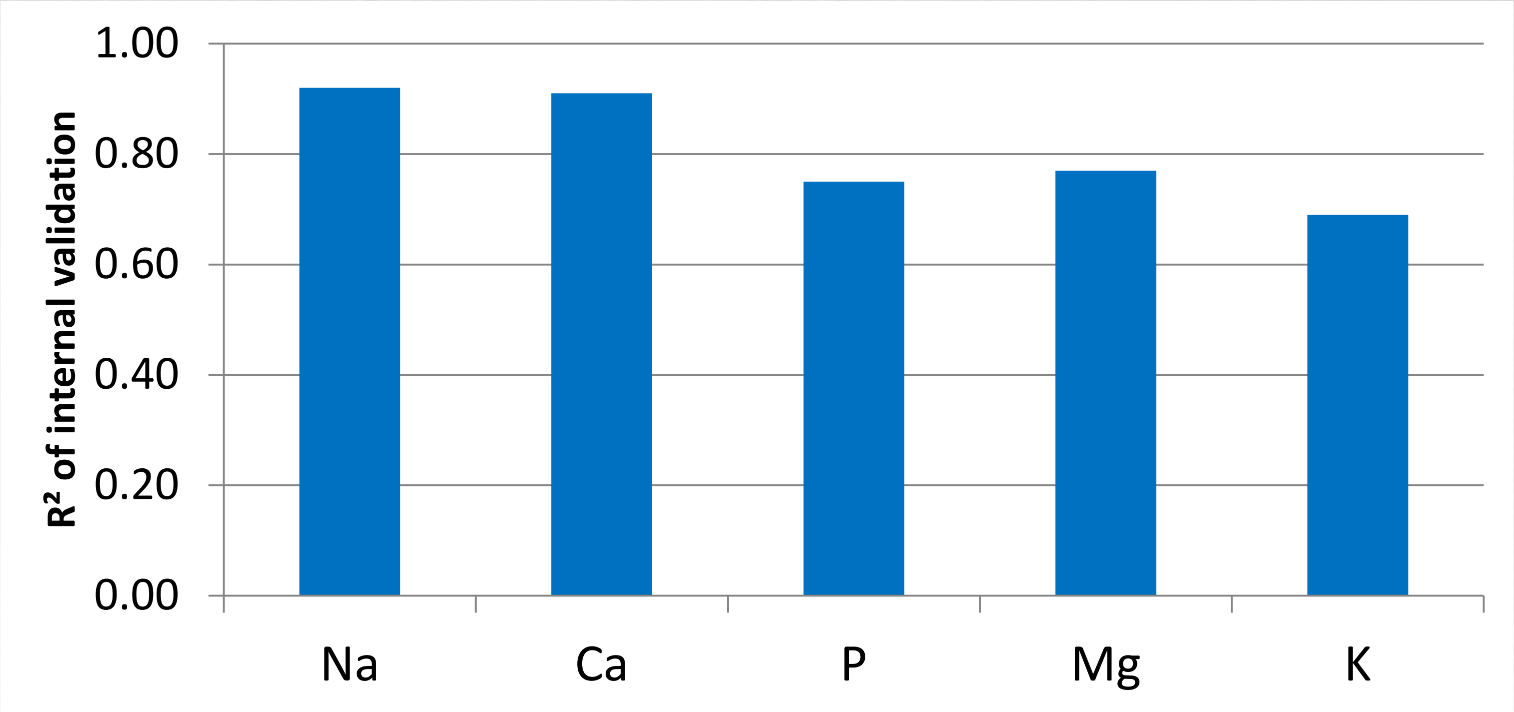
Accuracy of milk minerals calibration equations



Calibration equations were developed from at least 465 milk samples

Accuracy of milk minerals calibration equations



$R^2 \geq 0.80$ for Na and Ca ⇨ potential practical uses

- Ca: milk fever, osteoporosis
- Na: indicator of mastitis

Calibration equations were developed from at least 465 milk samples

MIR calibration equations: Nutritional quality

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  - Multiple breeds, countries and production systems
- Milk mineral equations:
  - First equations developed in 2006
  - Improved through international collaborations:
    - Belgium, France, Germany, and Luxembourg
- Lactoferrin equations:
  - Cooperative effort of Belgium, Ireland and UK

Lactoferrin

- Glycoprotein present naturally in milk
- Involved in the immune system
- Interests:
  - Potential indicator of mastitis
  - Help to maintain a good immune system in Humans
- R^2 of internal validation = 0.71

⇨ MIR indicator of lactoferrin

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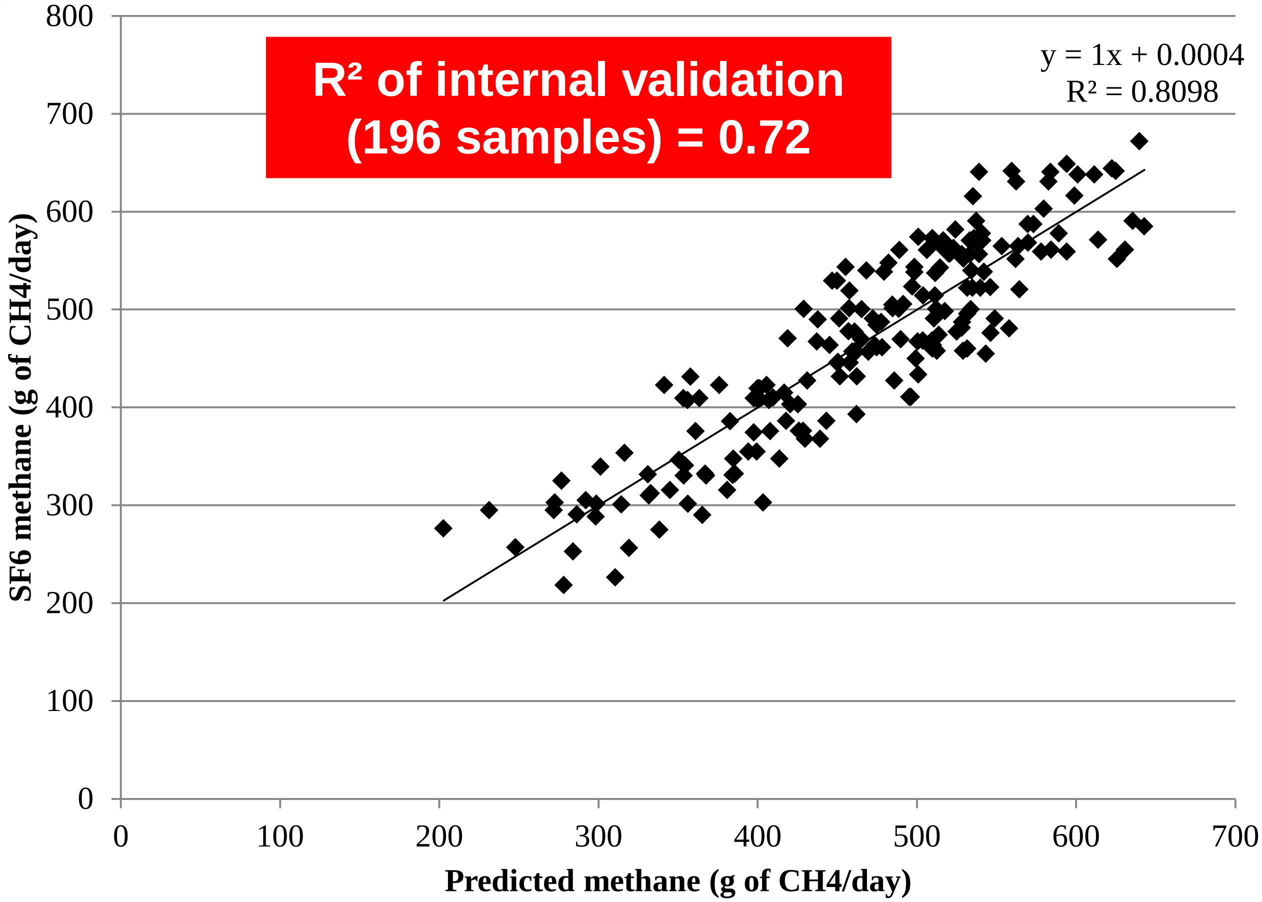
$R^2 < 0.80$ ⇨ MIR indicator of lactoferrin
Improves slightly detection of mastitis
compared to just using somatic cell score

MIR calibration equations: Environmental quality

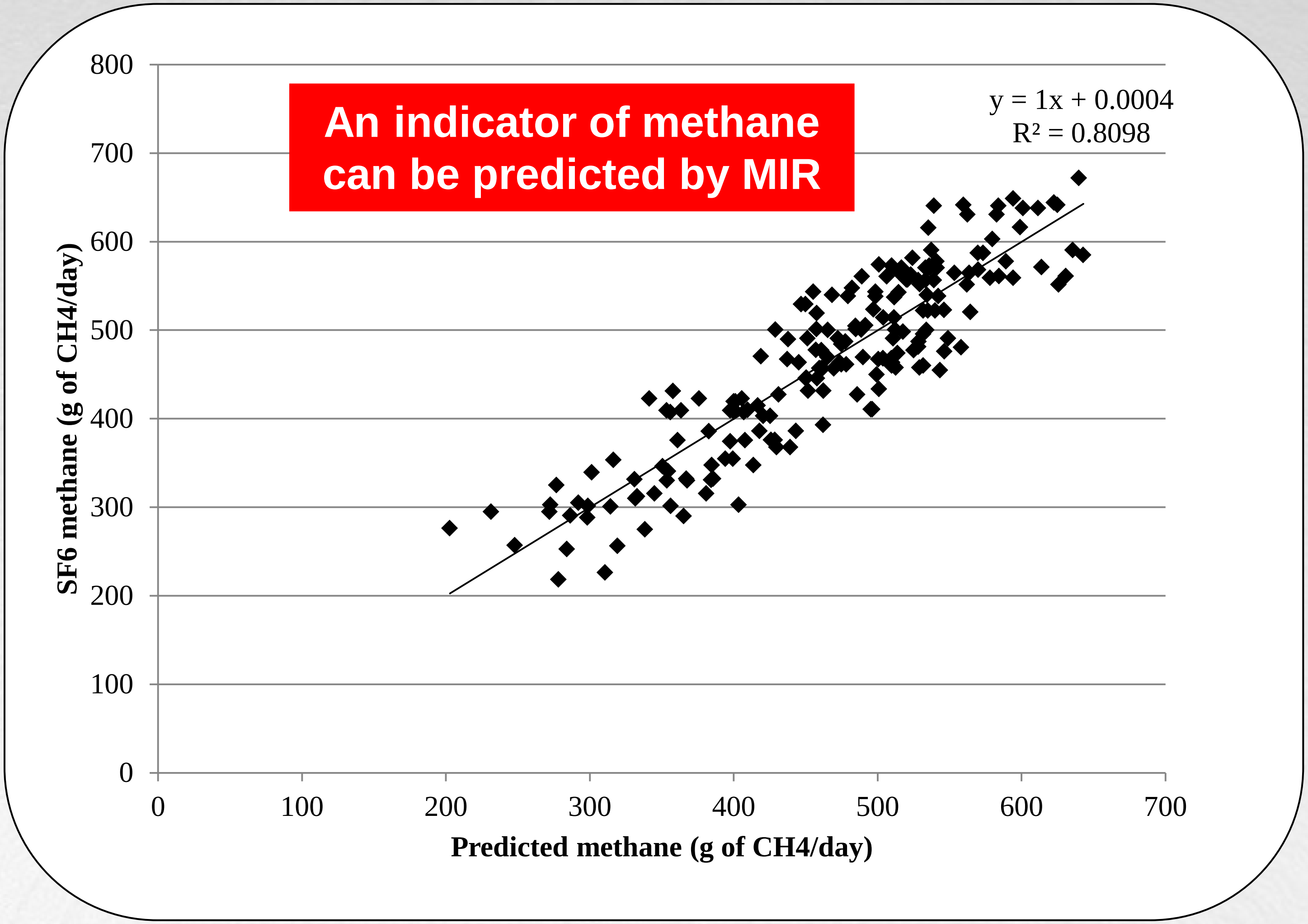
- Methane reference trait
  - Measured by the SF6 method
- Indirect link with milk FA (predicted by MIR)
  ⇨ Direct prediction of methane by MIR ?
- If possible can be used for:
  - Inventory of methane emissions
  - Environmental labeling of food
  - Reducing methane produced by individual cows

Methane



R² of internal validation
(196 samples) = 0.72
y = 1x + 0.0004
R² = 0.8098
SF6 methane (g of CH4/day)
Predicted methane (g of CH4/day)
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700

Methane


An indicator of methane can be predicted by MIR
y = 1x + 0.0004
R² = 0.8098
SF6 methane (g of CH4/day)
Predicted methane (g of CH4/day)
0
100
200
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Conclusions

- MIR spectrometry under-utilized in practice
- Potential to predict new traits with real economic and societal interests
- However, this is not always easy …

Not so easy…

- Developed MIR equations
  - Must be validated on used dairy population (even if the equation was built internationally)
  - Because of differences in breeds and production systems affecting prediction
- Adding specific samples needed!
  - Variability of calibration set ↗
  - Adaptation of equations to new population ↗
  - Therefore: general robustness of equations ↗

Not so easy…

- If spectral data was recorded, should be easy to implement new equations in milk laboratories?
- However
  - Specific spectrometers were used to develop given calibrations
  - To avoid any additional bias all the spectral data need to be standardized with those used in calibration

Not so easy…

- Accuracy of the MIR prediction must be tested regularly based on reference samples
- Creation of reference samples needs
  - Reliable reference values (traits to predict from MIR), potential difficult to obtain (e.g., methane)
  - Conservation and distribution of fresh milk samples (needed to be analyzed by MIR)
- Many logistical challenges

Part II:
Capitalizing on MIR traits for dairy cattle breeding and management

MIR spectral databases

- Creation of spectral databases related to milk recording needed
  - Already in Walloon Region of Belgium and in Luxembourg
- In August 2012, available spectral records:
  - 2,305,838 test-day records from Walloon Region of Belgium
  - 1,262,190 test-day records from Luxembourg
- This allows
  - Large scale studies of genetic and phenotypic variability

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⇨ Development of selection and management tools

Capitalizing for breeding

Daily h^2 for saturated FA = 0.59
Daily h^2 for monounsaturated FA = 0.26

Soyeurt et al. (2012), EAAP

Daily h^2 for lactoferrin = 0.35
Previous estimates: 0.20 – 0.44

Bastin et al. (2012), EAAP

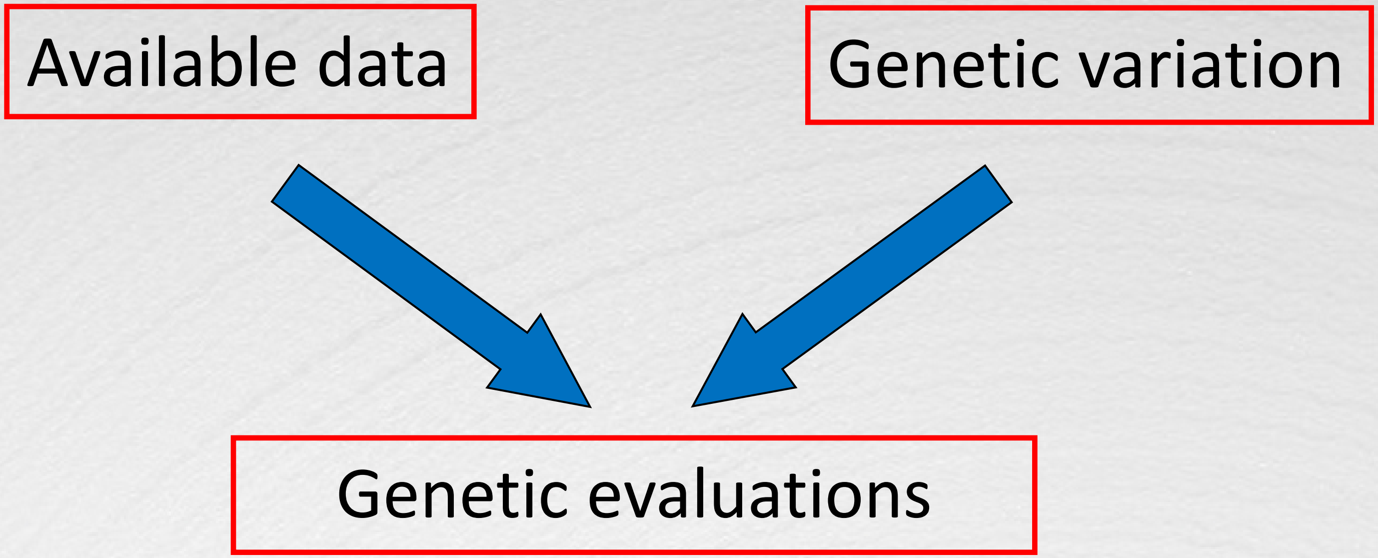
Daily h^2 for calcium = 0.50
Daily h^2 for sodium = 0.34
Daily h^2 for magnesium = 0.52
Daily h^2 for potassium = 0.48
Daily h^2 for phosphorus = 0.55

Soyeurt et al. (2012), EAAP

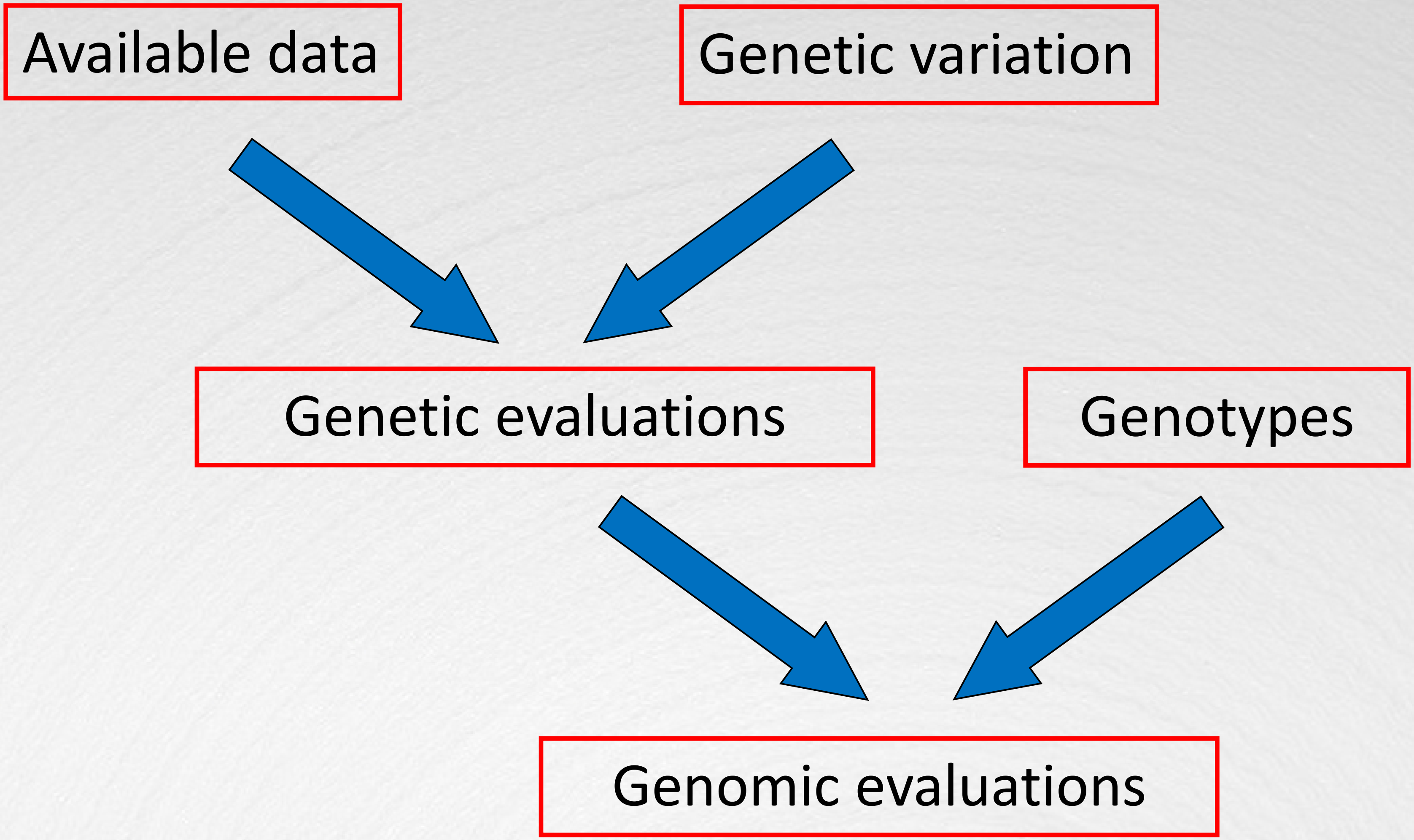
Lactation	Records	Holstein cows	Daily h^2 CH_4 (g/day)	Daily h^2 CH_4 (g/L milk)
1	270,902	54,355	0.37	0.45
2	209,663	42,306	0.36	0.42
3	145,540	29,749	0.36	0.39

First results obtained by Purna Badhra Kandel (ITN Marie Curie, GreenHouseMilk project)

Capitalizing for breeding



Capitalizing for breeding



Capitalizing for breeding

- Potentially useful also for other countries which have not access to these phenotypes…
- Different opportunities:
  - Collaboration in genomic prediction
    - Sharing of phenotypes and genotypes ⇨ up to joint evaluations
    - Creating and capitalizing on local prediction equations
  - Collaboration in genome wide association studies
    - Combining station and MIR predicted field data (e.g., bull EBVs)
    - Example for fatty acids done in RobustMilk project, more details given by Catherine Bastin (EAAP, 2012)

Capitalizing for management

- Novel MIR traits not only interesting for breeding
- Thanks to available large milk recording databases:
  - Study the phenotypic variability of MIR new traits
- Define best practices, potentially useful:
  - To mitigate the CH_4 emissions
  - To decrease the release of urea in milk
  - To improve the FA content of milk
- New step: direct use of MIR variability
  - OptiMIR project (www.optimir.eu)

Conclusion

- MIR interesting for breeding purposes

However ….

However …

- Position of novel MIR traits in future breeding (and production) goals still uncertain
  - Need to discuss with all stakeholders to know what will be the future of dairy products and production
  - Better knowledge of relationships of these traits with other traits having economical and societal interests (e.g., production, health and fertility, longevity) needed
- Therefore:
  - Definition of new breeding programs and management objectives taking into account all these aspects needed

Collaborations

- If you are interested in joining the consortium to improve the MIR equations:

hsoyeurt@ulg.ac.be

- If you are interested in sharing phenotypes and genotypes:

nicolas.gengler@ulg.ac.be

Thank you for your attention