Assessing fertility and welfare of dairy cows through novel mid-infrared milk-based biomarkers

H. Hammami, A. Lainé, F.G. Colinet, N. Gengler

ULg – Gembloux Agro Bio-Tech, 5030, Belgium

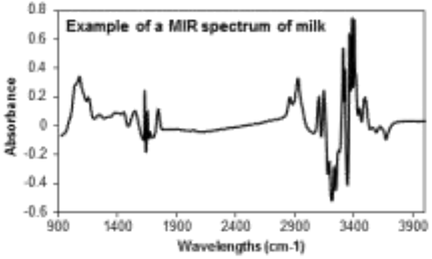
hedi.hammami@ulg.ac.be

Use of milk MIR spectra

❶

Most conventionnaly:

MIR spectra = predictor of trait of interest



+

Reference data

Calibration equations

Indicator traits

Breeding and herd management

What is next ? (1)

❷

MIR spectra (wavenumbers) = traits describing phenotypic and genetic variations

J. Dairy Sci. 93:1722–1728
doi:10.3168/jds.2009-2614
© American Dairy Science Association®, 2010.

Genetic variability of milk components based on mid-infrared spectral data

H. Soyeurt, I. Misztal, and N. Gengler

J. Dairy Sci. 96:5991–6006
http://dx.doi.org/10.3168/jds.2013-6583
© American Dairy Science Association®, 2013.

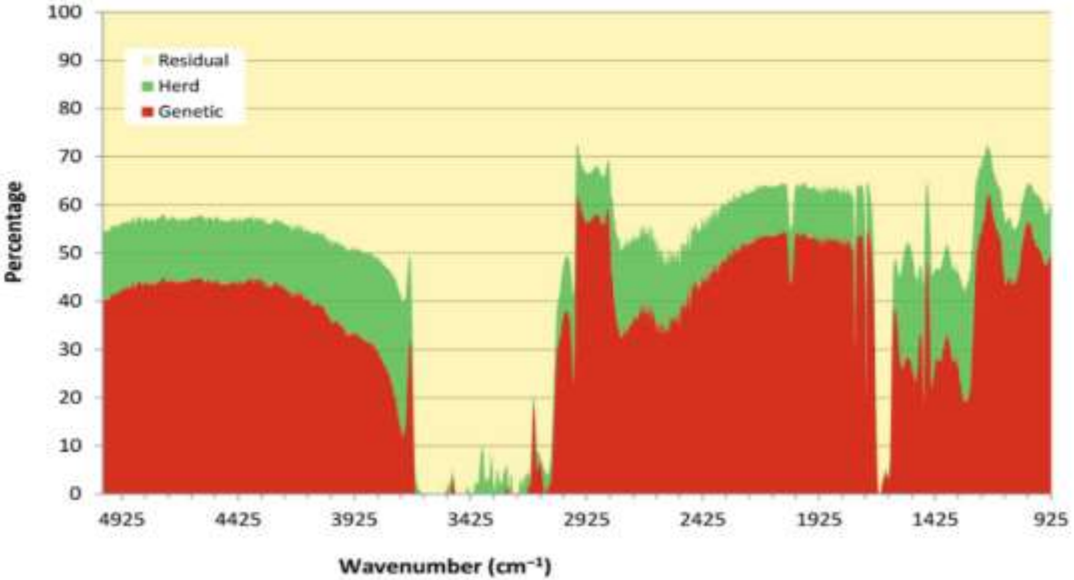
Genetic analysis of the Fourier-transform infrared spectra of bovine milk with emphasis on individual wavelengths related to specific chemical bonds

G. Bittante and A. Cecchinato

J. Dairy Sci. 99:6793–6803
http://dx.doi.org/10.3168/jds.2015-10488
© American Dairy Science Association®, 2016

Genetic and environmental variation in bovine milk infrared spectra

Qiuyu Wang, Alex Hulzebosch, and Henk Bovenhuis
Animal Breeding and Genomics Centre, Wageningen University, PO Box 338, 6700AH, Wageningen, the Netherlands



% of the total variation of MIR wavenumbers *Wang et al. 2016*

What is next (2) ?

❸

MIR spectra (wavenumbers) = response variables to known factors

- response → trait

Objectives of this talk:

- Compare the impact of known factors on wavenumbers with their impact on predicted components

- Ability of MIR spectra to identify cow sensitivity to known factors

Resilience to disturbances (example)

- Internal stress
  - Fertility: Gestation
    - Stress factor: length of gestation

- External stress
  - Welfare: Heat stress (HS)
    - Stress factor: trajectory of temperature-humidity (THI)

Phenotypic response to disturbances ?

- Impact of gestation and HS on :
  - milk, fat, and protein (well reported): decrease in yields and depression of quality
  - novel milk-biomarkers (recently for some fatty acids)
  - wavenumbers (still unknown)
- First question
  - Is there any phenotypic variation of those novel milk-based biomarkers as linked to those stress factors ?

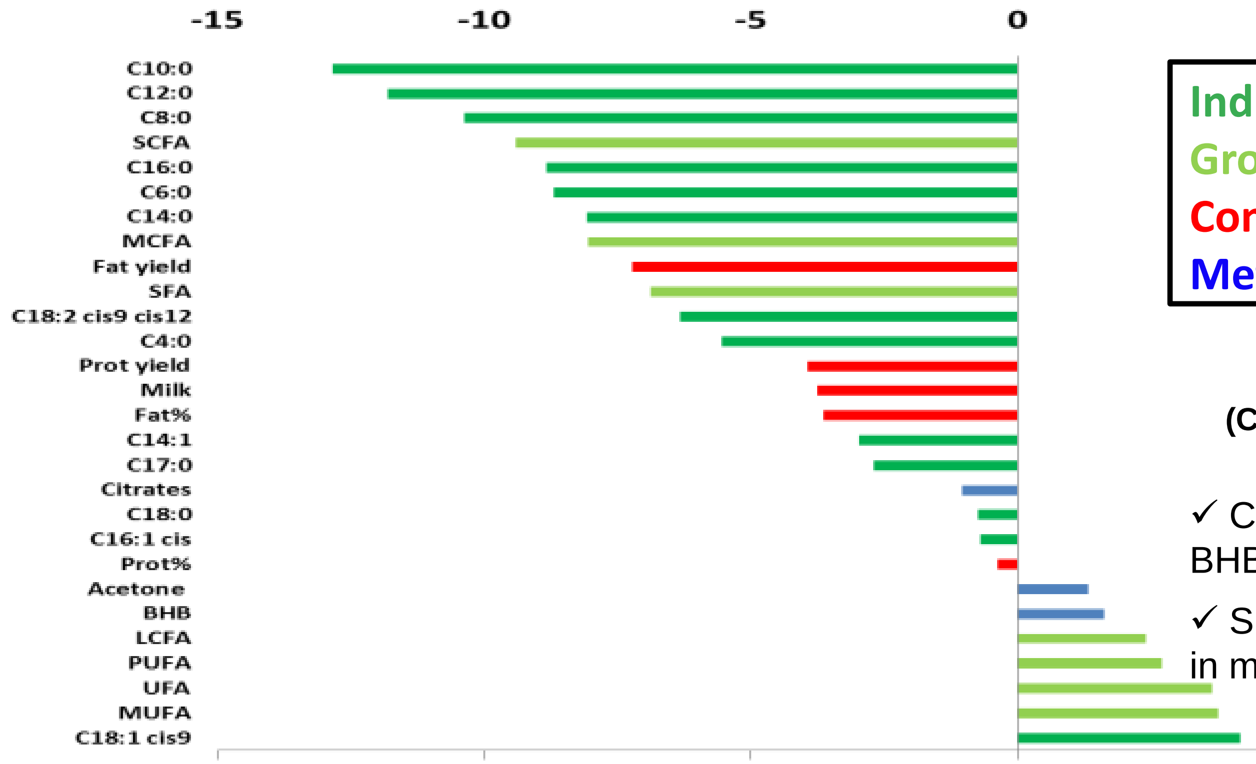
External stress: Heat stress

- Data
  - 205,987 TD records (from 29,467 primiparous Holsteins)
    - Milk, fat%, protein%, fat and protein yields (5)
    - Fatty acid profile (20) and metabolites (3)
    - 289 informative « wavenumbers » after 1st derivative
  - TN (THI <=62): Thermo-neutral zone
  - HS (THI > 62): Heat stress zone
- Proc Mixed (SAS, 9.4)
  - Lsmeans

317 traits !

MIR predicted phenotypic variation

% of variation between lsmeans (TN) and lsmeans (HS)



Individual fatty acids
Group of fatty acids
Conventional milk components
Metabolites

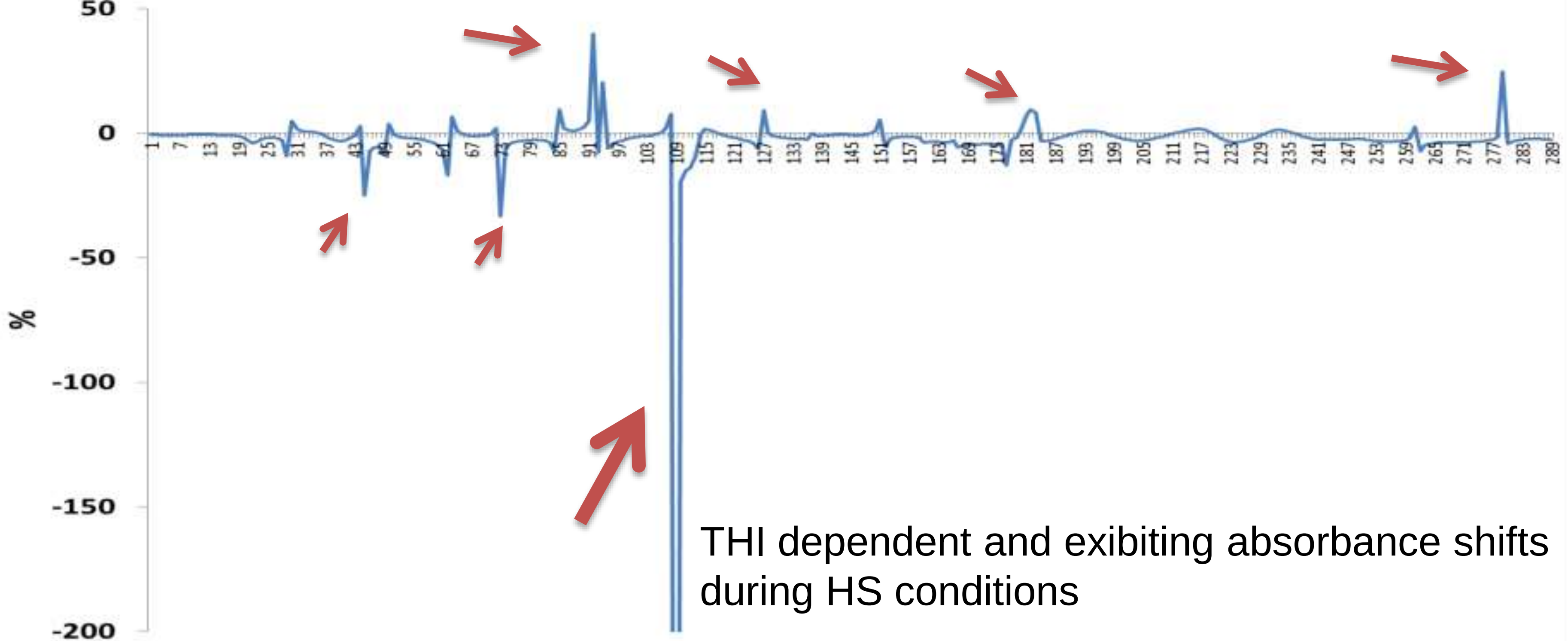
Metabolomics study (China)
(Chromatography mass & proton nuclear magnetic resonance spectrometry)

- ✓ C18:1cis9, PUFA, LCFA, Acetone and BHB (main sensitive biomarkers to HS)
- ✓ Siginificant correlations between levels in milk and blood plasma

Thin et al. (2016)

MIR absorbance variation

% of variation between lsmeans estimates in (TN) conditions and (HS)

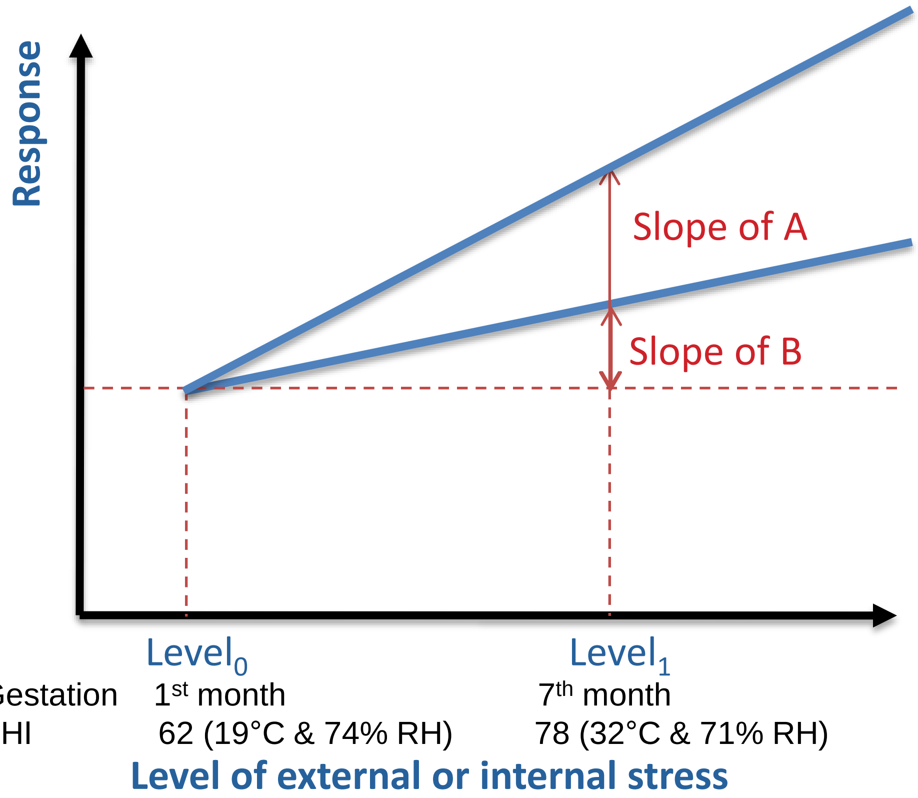


THI dependent and exibiting absorbance shifts during HS conditions

Genetic variation ?

- Genetic variability in individual responses to HS
  - Productive traits (tropical and even temperate)
  - Recently reported for fatty acids
- Second question
  - Is there a genetic variation of resilience to those internal and external stress factors ?
- Concept of "Reaction Norm" defined as:
  - Phenotypic expression of a "genotype" across a range of "environments"

Reaction norm



- **Hypothesis:**
  - **Animals that react less are more resilient**
- **Therefore:**
  - Larger slope indicating stronger reactions
- **In this figure:**

Slope A > Slope B

↓

Resilience A < Resilience B

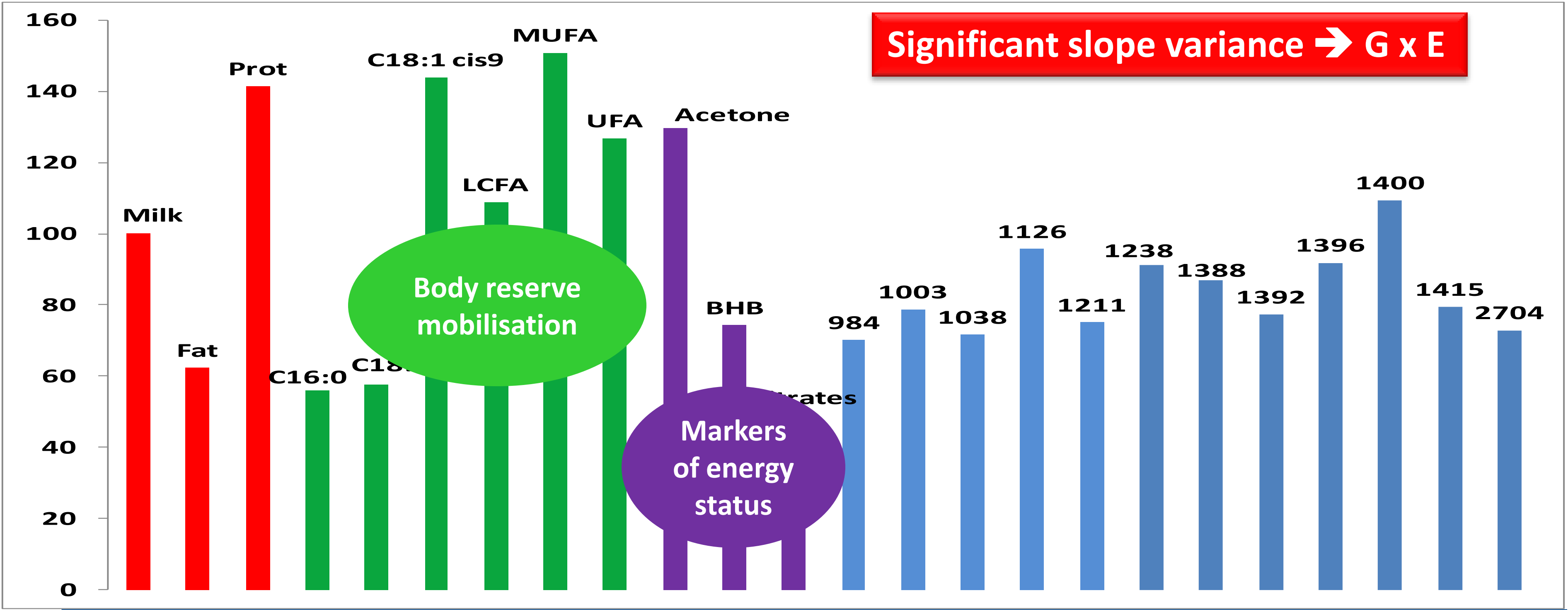
Reaction norm models

- y_{ij} = common factors …+ a_{0_i} + f(j) x a_{1_i} +….   where
  - Common factors = other needed fixed and random effects
  - y_{ij} = response j of animal i
  - a_{0_i} and a_{1_i} = random genetic effects of animal i
  - f(j) in our 2 examples:
    - f(j) = THI (TD_j) – 62   if THI(TD_j) > 62
      = 0   if THI(TD_j) ≤ 62
    - f(j) = days carried calf at TD_j if pregnant
      = 0   if not-pregnant

Data

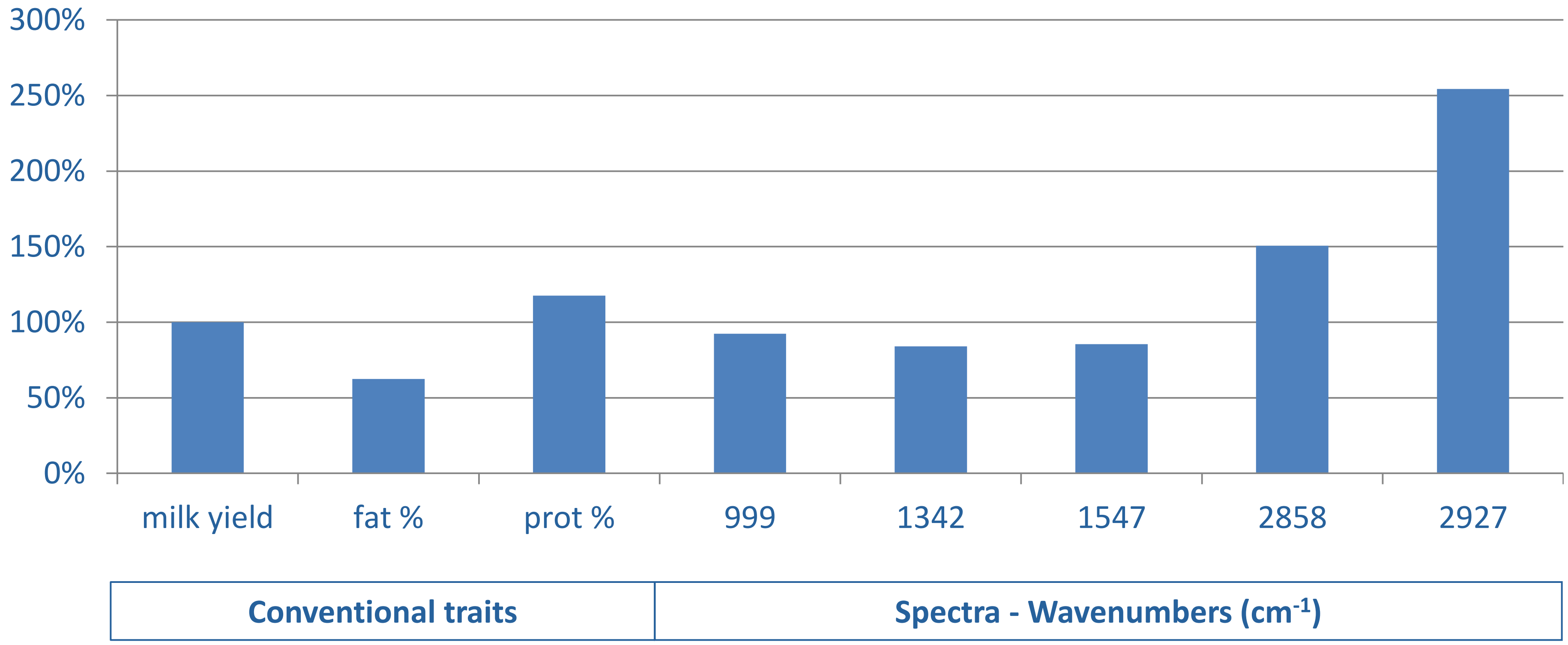
- Heat stress
  - Same dataset
  - THI values of 3-d lag correspondant to each TD
- Gestation
  - 56,902 TD records
    - Milk yield, fat%, protein% and 5 wavenumbers, identified for showing highest phenotypic response
  - Confirmed gestations → confirmed days carried calf
  - 9,757 primiparous Walloon Holstein cows

Heat stress: Ratio of Slope / Intercept Variances



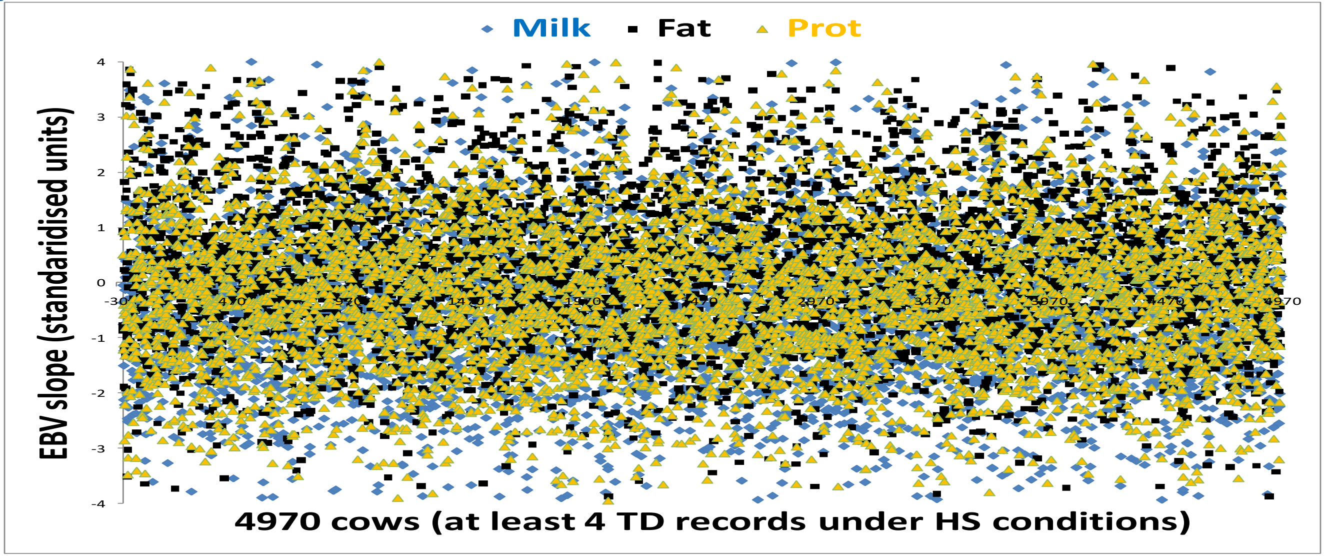
Conventional traits	Individual and groups of fatty acids	Milk metabolites	Spectra - Wavenumbers (cm^{-1})

Gestation: Ratio of Slope / Intercept Variances

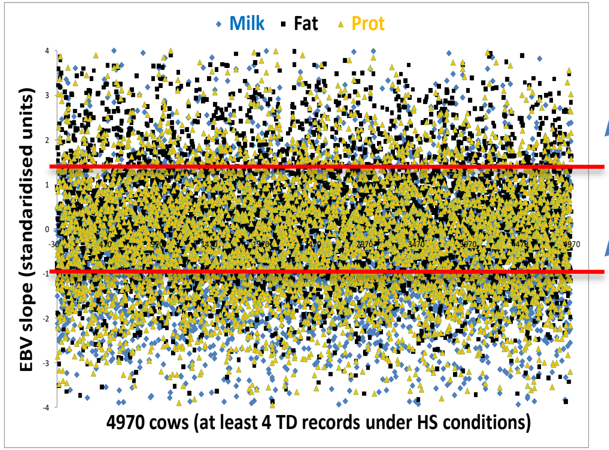


Slope: phenotype for heat tolerance

- Third question
  - How to identify individuals sharing similar reaction to THI?
- EBV slope: estimated for each cow and for the 317 traits

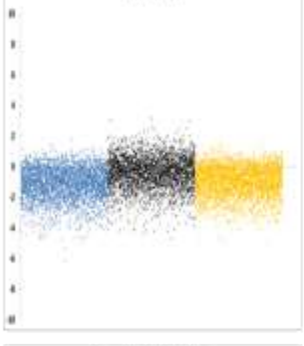


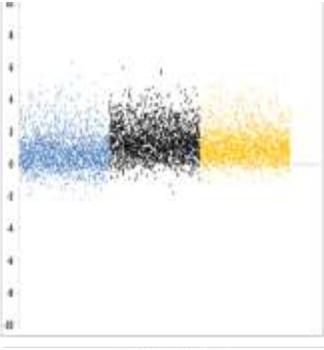
Unsupersived clustering: K-Mean



Seed 1

Seed 2



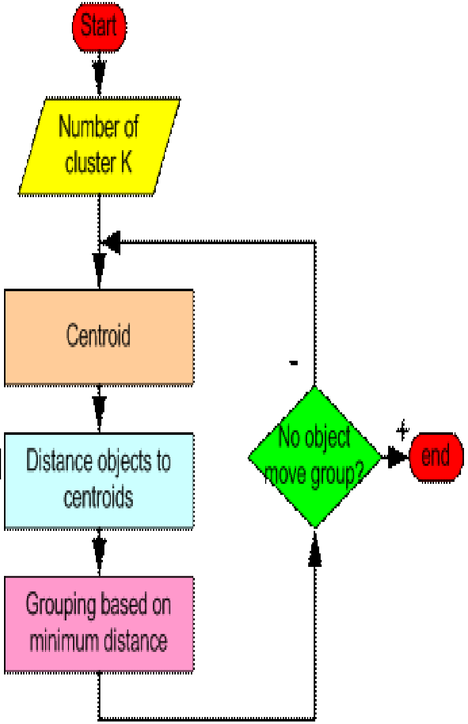


Step 0: 2

Step 1: random selection of seed clusters

Step 2: calculate the squared euclidien distance from each cow slope to each cluster seed

Step 3: Assign each cow to the closest cluster



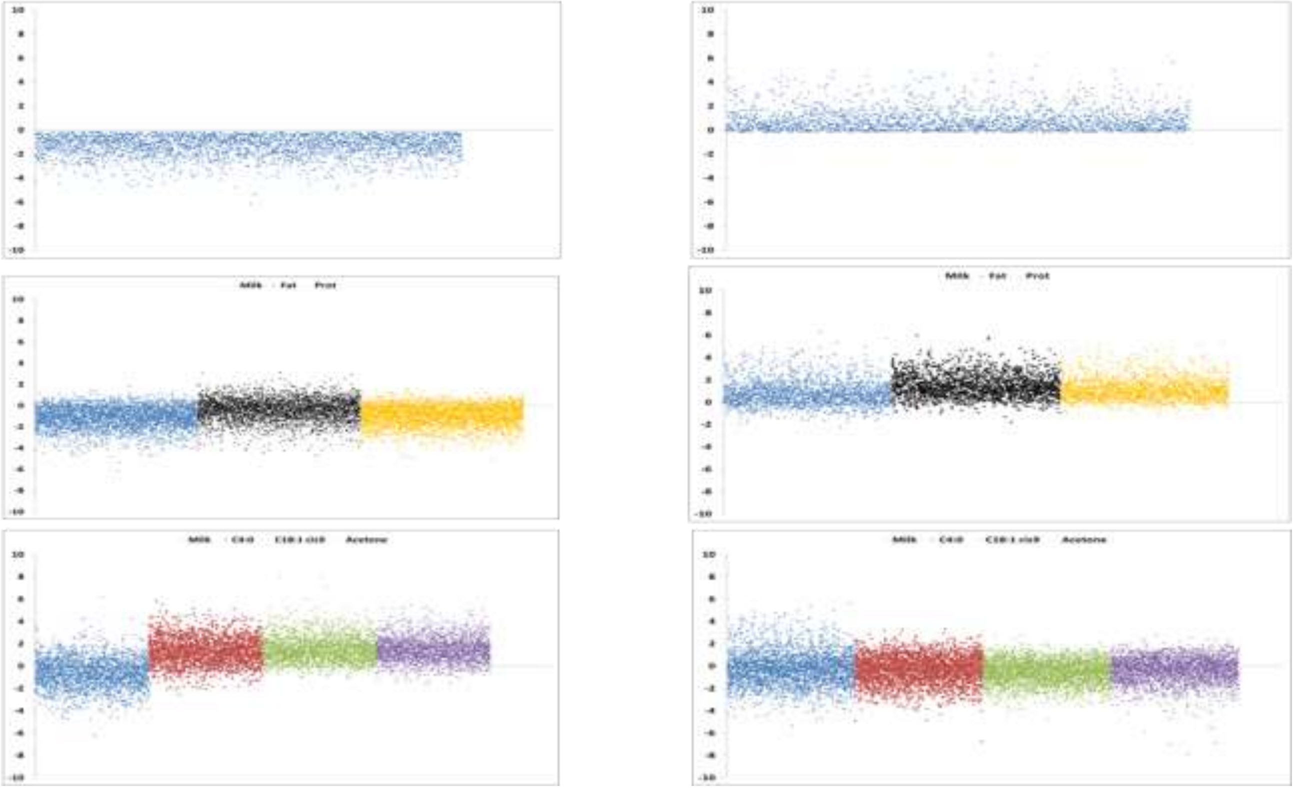
Clustering sensitive vs robust

Cluster 1: ***Sensitive*** | Cluster 2: ***Robust***

Milk

Milk-Fat-Protein

Milk
+
C4:0-C18:1 cis9-Acetone

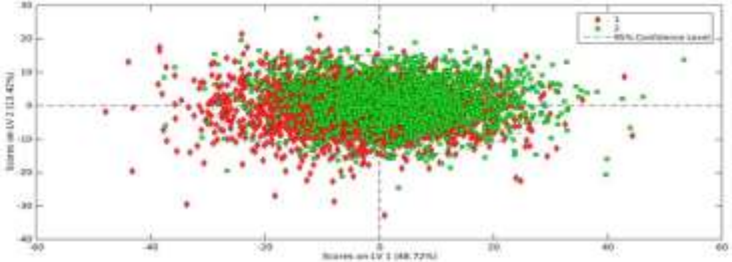


MIR spectra response to THI: slope

- **Fourth question**
  - **Can we identify sensitive and robust cows based on the response of MIR spectra to HS?**
- **Discriminant analysis: PLS-DA**
  - **Sensitivity to heat stress based on K-mean clustering:**
    - **Only slope of milk yield**
    - **Slope of milk, fat, and protein yields**
    - **Slope of milk, C4:0, C18:1cis9, and Acetone**

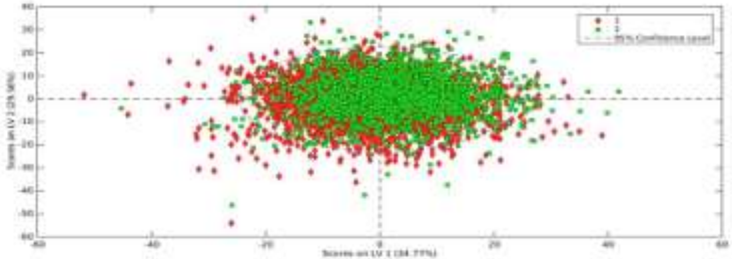
Characteristics of the discrimant models

Milk



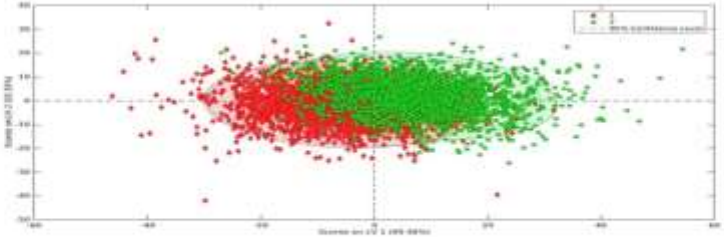
Rate of correct classification
72%

Milk-Fat-Protein



Rate of correct classification
71%

Milk
+
C4:0-C18:1 cis9-Acetone



Rate of correct classification
92%

Conclusion

- First promising results from on-going studies
- Comparison of MIR wavenumbers with yield and MIR-predicted components showed potential
- Heat-stress:
  - Use of MIR signal to identify sensitive and robust cows with good accuracy
- Gestation:
  - Some wavenumbers showed stronger signals than conventional traits

Acknowledgements

- Support of the Futurospectre partnership
  - AWE – Comité du Lait – CRA-W – ULg-GxABT
- CECI Consortium for computational resources
- Service Public de Wallonie (SPW – DGO3, Belgium)
- National Fund for Scientific Research
- Support by different European Projects:

The content of the presentation reflects only the view of the authors; the Community is not liable for any use that may be made of the information contained in this presentation.