Mid-infrared prediction of cheese yield from milk and its genetic variability in first-parity cows

F.G. Colinet1, T. Troch1, S. Vanden Bossche1, H. Soyeurt1, O. Abbas2, V. Baeten2, F. Dehareng2, E. Froidmont2, G. Sinnaeve2, P. Dardenne2, M. Sindic1, and N. Gengler1

1 University of Liège, Gembloux Agro-Bio Tech, Belgium
2 Walloon Agricultural Research Center, Belgium

Introduction

- Cheese manufacture and yield
  - Economical importance
  - Empirical and theoretical formula for cheese yield (CY)
  - Generally based on some factors:
    - Milk fat content
    - Milk protein content
    - Milk casein content
    - Moisture
    - Salt
    - ...

Objectives

- To determine CY of fresh milk at large scale
  - Expressed as fresh Individual Laboratory Cheese Yield (ILCYf)
  - Fast method using small quantity of milk
  - Adapted to Walloon dairy cattle (multi-breed)
  - MIR spectrometry already implemented in milk labs
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⇒ MIR chemometric method for ILCY prediction

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⇒ MIR chemometric method for ILCY prediction

- To study the genetic variability of predicted ILCY
  - First-parity Holstein cows in Wallonia (Belgium)

MIR chemometric method

- Sampling
  - Wallonia
  - Spectra and reference data variability: several criteria
    - Milk sampling: individual or bulk milk
    - Breed: Dual Purpose Belgian Blue, Holstein, Red-Holstein, Montbeliarde and Jersey
    - Time of sampling: morning milking, evening milking
      mix of 50% morning & 50% evening milk samples

⇒ 258 fresh samples collected

MIR chemometric method

- Analysis
  - Milk lab (Comité du Lait, Battice, Belgium)
    - FT-MIR
  - Fresh Individual Laboratory Cheese Yield (ILCY)
    - g coagulum / 100 g milk
    - Determined according to Hurtaud et al. 1995
      (Ann. Zootech. 44, 385-398)
    - Intra-assay variation coefficient = 3.2%
    - Sample analyzed in duplicate
MIR chemometric method

Methods
- Modified Partial Least Square regressions
  - [Shenk & Westerhaus, 1991]
- Use of a first derivative pretreatment
  - To correct the baseline drift
- Detection of spectral outliers
  - Based on Mahalanobis distance
- Use of a repeatability file
  - Spectra from the same samples analyzed on different spectrometers

Calibration equation
- Statistical parameters of final dataset

<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>26.8 g/100g</td>
</tr>
<tr>
<td>Standard deviation (SD)</td>
<td>6.5 g/100g</td>
</tr>
<tr>
<td>Range (from 13.8 to 47.9)</td>
<td>34.1 g/100g</td>
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</table>

- Calibration

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<tr>
<td>Standard error of calibration (SE_c)</td>
<td>2.6 g/100g</td>
</tr>
<tr>
<td>Calibration coefficient of determination (R²_c)</td>
<td>0.83</td>
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MIR chemometric method

Methods
- Internal cross-validation (50 groups)
  - To determine the number of factors
  - To assess the robustness of equation
- T-outlier test
  - Compared observed and predicted values
  - Samples with T-outlier value > 2.5 were discarded
  - Maximum 5 tests performed
  - 22 additional samples discarded

Calibration equation
- Statistical parameters to assess the accuracy

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<td>Cross-validation coefficient of determination (R²_cv)</td>
<td>0.81</td>
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<td>RPD = SD / SE_cv</td>
<td>2.27</td>
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<td>RER = Range / SE_cv</td>
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MIR chemometric method

- Calibration equation
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<td>2.27 &gt; 2</td>
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<tr>
<td>RER = Range / SEcv</td>
<td>12.0 &gt; 10</td>
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Calibration equation: good practical utility

Result: Prediction

- Data editing
  - Walloon MIR spectral database
    - > 2,500,000 spectra
    - Routinely collected since 2007 by milk recording
  - Outliers discarding
    - Based on Mahalanobis distance computing using 234 MIR spectra of the final calibration dataset as reference
    - Upper standardized Mahalanobis distance cut off: 3
    - Below 0.5 percentile and above 99.5 percentile

Result: Prediction

- Averaged MIR predicted ILCYf throughout first three lactations

Genetic variability

- Data editing
  - After edits:
    - 7,870 first-parity Holstein cows from 101 herds
    - Cows with ≥ 4 predicted ILCYf and known parents
    - > 58,000 animals in extracted pedigree file
    - > 51,000 records for MIR predicted ILCYf
### Genetic variability

**Data**
- Average MIR predicted ILCYf = 24.2 g/100g (± 4.5 g/100g)
- MIR predicted ILCYf throughout first lactation

### Genetic variability

**Single-trait random regression animal test-day model**

\[
y = X\beta + Q(Z_p + Z_a) + e
\]

- **\(\beta\)** = fixed effects
  - Herd x test day
  - Lactation stage (classes of 5 days)
  - Gestation stage
  - Age at calving x season of calving x lactation stage

- **\(p\)** = permanent environment random effect
- **\(a\)** = additive genetic random effect
- Regression curves modelled with 2nd order Legendre polynomial

**Variances components estimated by AIREMLF90**

(Misztal, 2012)
ILCYf heritability

- Daily heritability throughout first lactation
  
  Average daily $h^2 = 0.52$
  Average daily SE of $h^2 = 0.03$
  Min = 0.31 at 5th DIM
  Max = 0.59 at 279th DIM

**Conclusions**

- MIR chemometric methods
  - Developed equation
  - $R^2_{cv} = 0.81$
  - $RPD > 2$ and $RER > 10$
  - Good practical utility
  - Results are promising for the prediction of fresh Individual Laboratory Cheese Yield from MIR spectrum

- Genetic variability study
  - Moderate daily heritability
  - Potential of selection for ILCYf

**Next steps**

- Improvement with new samples
- Study of phenotypic and genetic correlations of ILCYf with
  - milk production traits
  - other milk components
  - milk technological properties
- Feasibility/opportunity to develop a genetic evaluation?

**Thank you for your attention**

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  - Service Public de Wallonie SPW – DG03 and European Commission (ERDF) through projects D31-1255/S1 ProfFARMilk and INTERREG IVA BlueSel

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  - Walloon Breeding Association (AWE asbl)
  - Walloon dairy breeders

Corresponding author’s e-mail: Frederic.Colinet@ulg.ac.be