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Genetics of the mid-infrared prediction of lactoferrin content in milk for Holstein first-parity cows

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Bovine lactoferrin

- Lactoferrin = iron-binding glycoprotein present in milk
- It is considered as an important host defence molecule.
  - antimicrobial/antiviral activities, antioxidant activities, immunomodulatory activities
  - It seems to play a key role in the defence mechanisms in the mammary gland of dairy cows.
- Due to its properties, lactoferrin used as a food additive:
  - several beneficial effects of the oral administration of lactoferrin on the health of humans and animals
  - e.g. in humans: cancer protection
  - e.g. in animals: combination of lactoferrin with penicillin to increase the antibacterial activity against *S. aureus.*

Tsuda et al., 2000, Mutat. Res.; Diarra et al., 2002, J. Dairy Sci.; Wakabayashi et al., 2006, Int. Dairy J.

Bovine lactoferrin

Genetic selection for lactoferrin content in milk?

- **Trait economically interesting**
  - improvement of nutraceutical properties of milk
  - improvement of defence mechanisms in the mammary gland
- **Trait measurable**
  - Prediction by mid-infrared spectrometry
    - R^2_{cv} =0.71 ; R^2_{v} = 0.60 ; RPD = 1.86 *Soyeurt et al., 2012, Anim.*

    → "indicator" of lactoferrin content in milk = MIR-LF
- **Trait genetically variable and heritable:**
  - few studies suggested a moderate heritability

Gaunt et al., 1980, J. Dairy Sci.
Arnould et al., 2009, J. Dairy Sci.

Objectives

Study the genetic variability of the mid-infrared prediction of lactoferrin content in milk and its genetic correlations with:

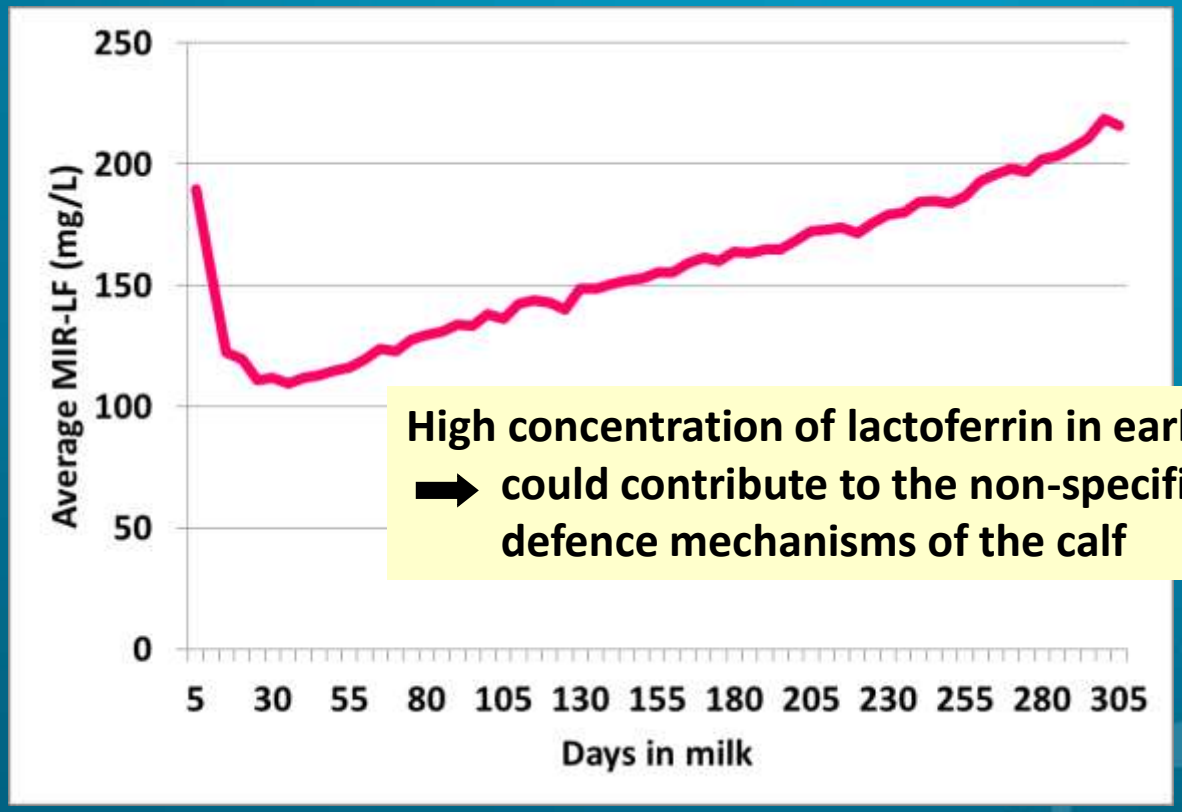
- **major production traits: milk, fat, and protein**
- **udder health trait: somatic cell score**
- **traits related to the nutraceutical properties of milk fat: major groups and individual fatty acid contents in milk**

Data and model

- Mid-infrared prediction of
  - lactoferrin content in milk (MIR-LF; mg/L)
  - content in milk of 10 individual and 7 groups of fatty acids (FA; g/dL)
- After edits (and random selection of herds) :
  - 9878 first-parity Holstein cows from 150 herds
  - > 88,000 records for milk, fat, and protein traits
  - > 85,000 records for somatic cell score (SCS)
  - > 61,000 records for FA and MIR-LF traits

Data: MIR-LF

- Average MIR-LF = 162.81 ± 68.76 mg/L CV=42%
- Average MIR-LF across days in milk



High concentration of lactoferrin in early lactation ➡ could contribute to the non-specific host defence mechanisms of the calf

Model

23 two-trait random regression test-day models

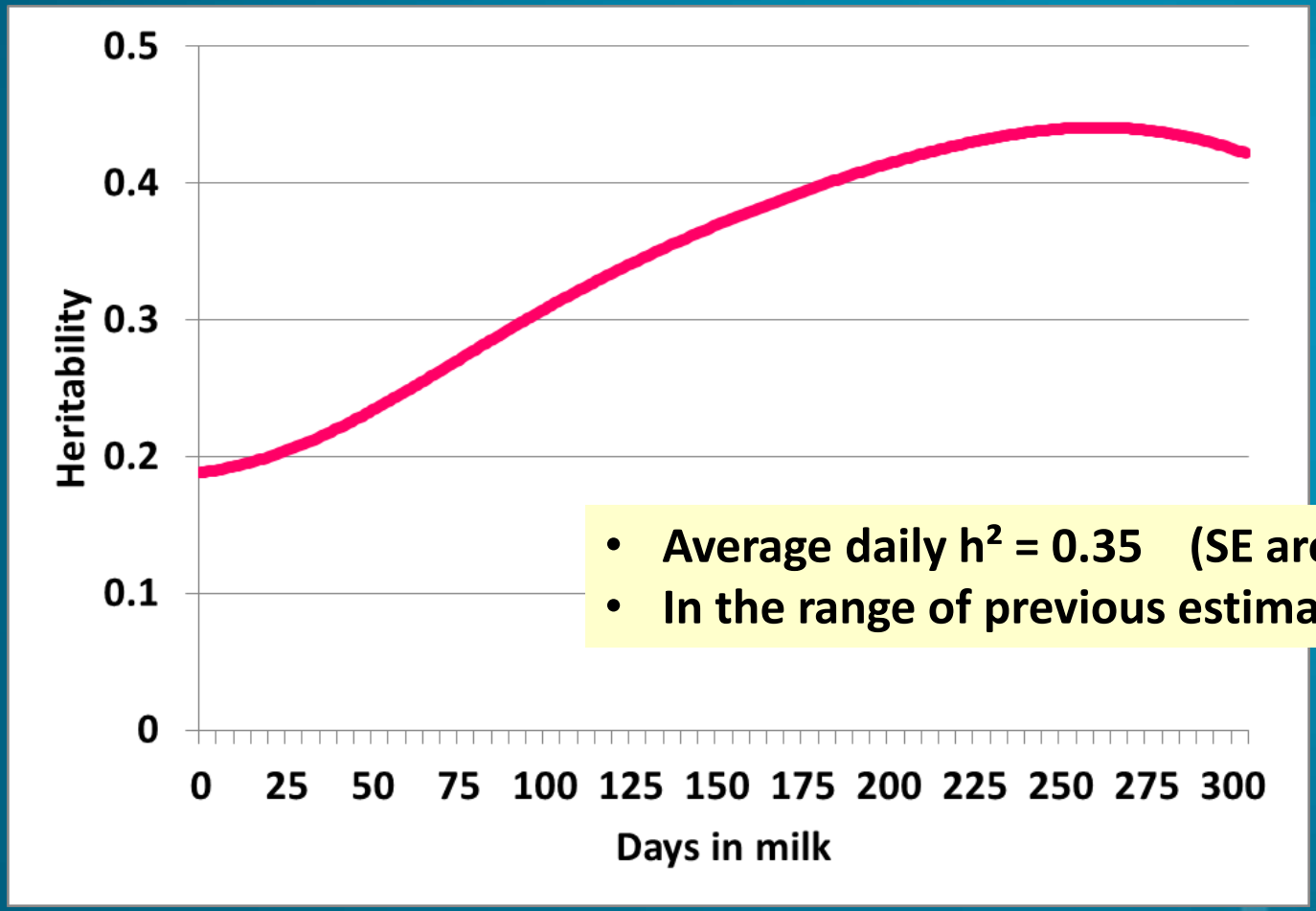
$$y = X\beta + Q\,(Zp + Za) + e$$

- β = 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 environmental random effect

  a = additive genetic random effect

  → regression curves modelled with 2nd order Legendre polynomials

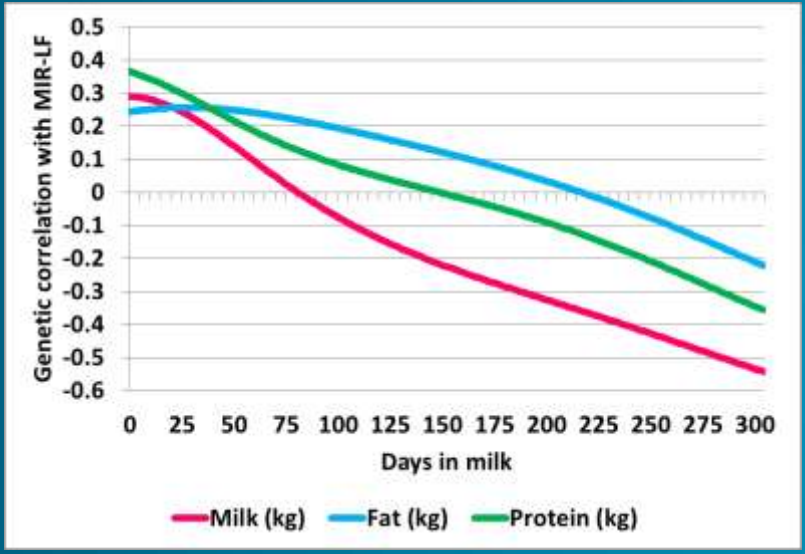
MIR-LF heritability

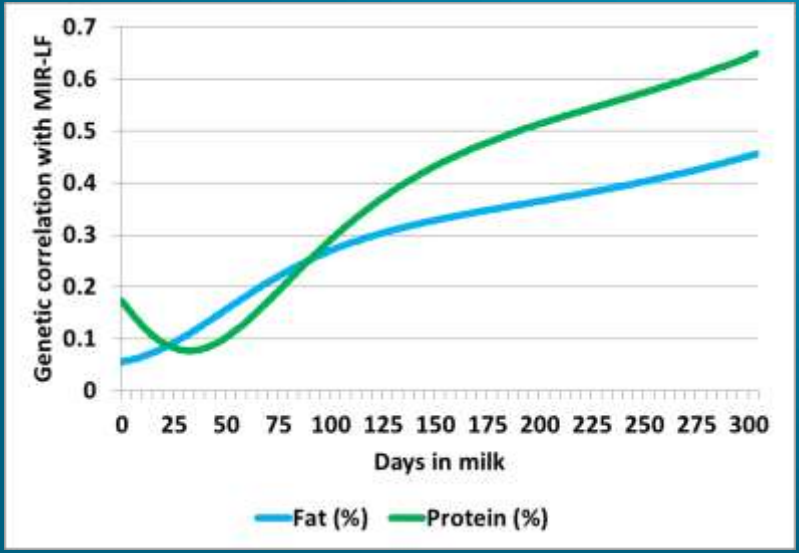


- Average daily h^2 = 0.35 (SE around 0.02)
- In the range of previous estimates: 0.20 – 0.44

Gaunt et al., 1980, J. Dairy Sci.
Soyeurt et al., 2007, J. Dairy Sci.
Arnould et al., 2009, J. Dairy Sci.

Genetic correlations with production





Average daily genetic correlation with MIR-LF (average SE from 0.06 to 0.08)

Milk (kg)	Fat (kg)	Protein (kg)	Fat (%)	Protein (%)
-0.17	0.09	-0.01	0.30	0.39

Genetic correlations of MIR-LF:

- **with yields: positive in early lactation then negative in mid to late lactation**
- **with contents: positive**
- **greater at the end of the lactation**
- **in the range of previous estimates**

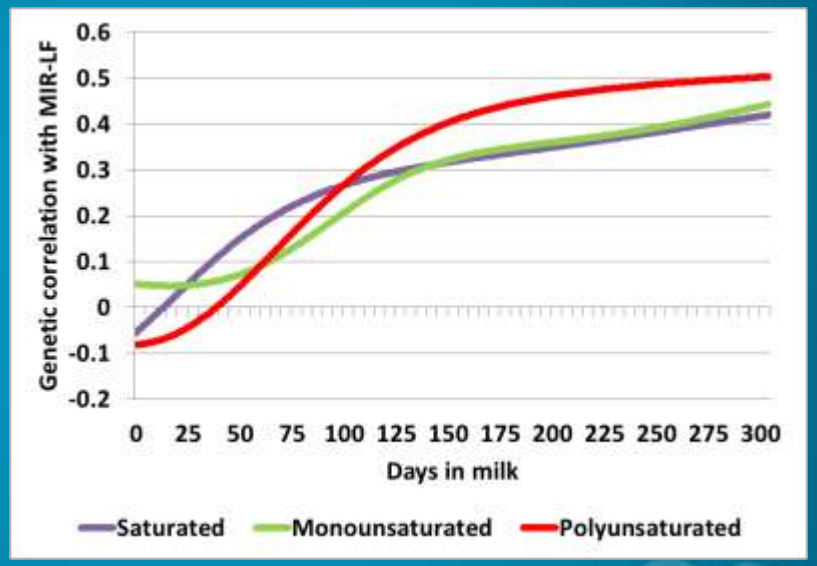
Soyeurt et al., 2007, J. Dairy Sci.
Arnould et al., 2009, J. Dairy Sci.

Genetic correlations with fatty acids

Average daily genetic correlation with MIR-LF (average SE from 0.06 to 0.08)

Individual FA (g/dL of milk)	
C4:0	0.14
C6:0	0.21
C8:0	0.25
C10:0	0.27
C12:0	0.31
C14:0	0.31
C16:0	0.33
C17:0	0.32
C18:0	0.04
C18:1 *cis-9*	0.20

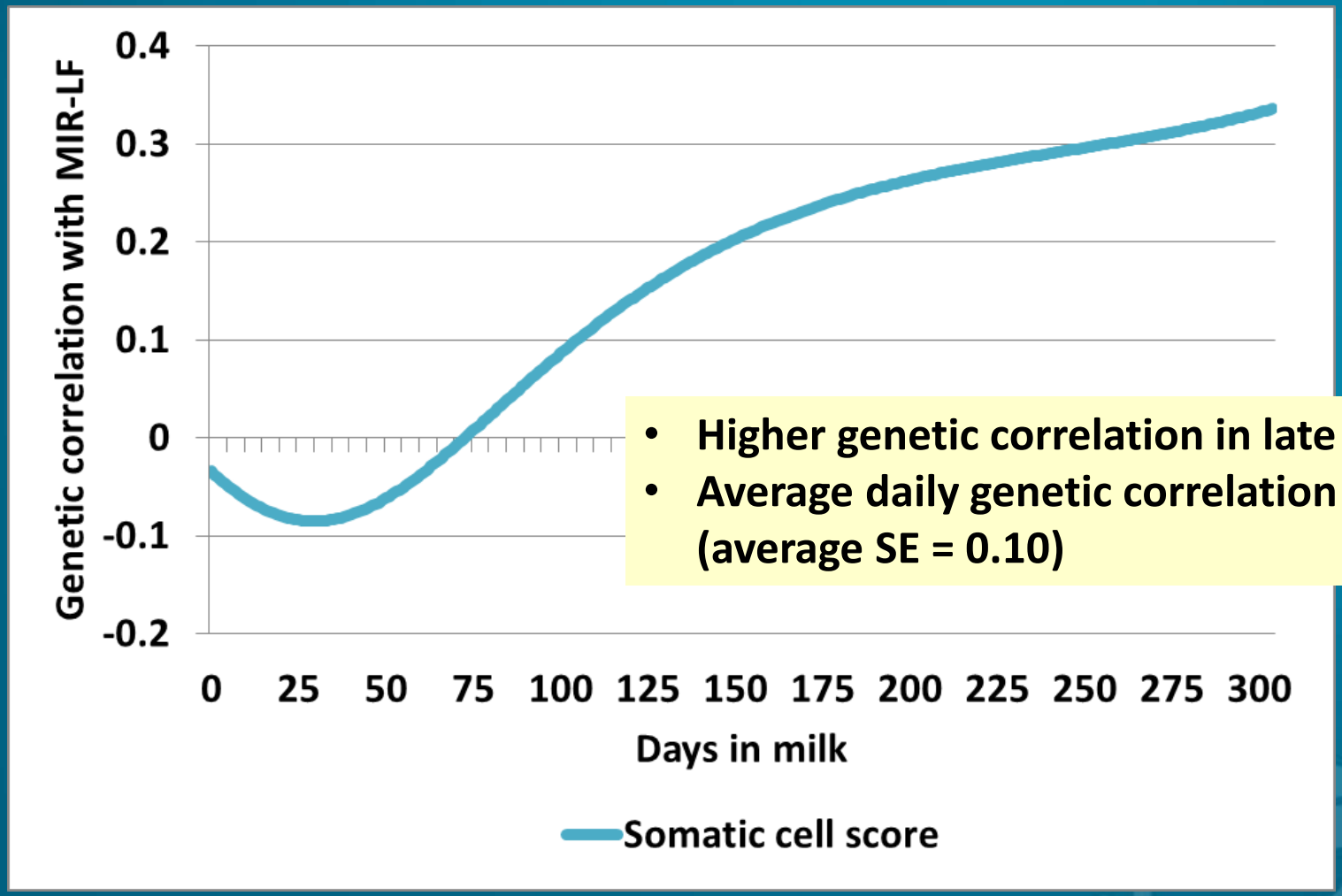
Groups of FA (g/dL of milk)	
Saturated	0.28
Monunsaturated	0.27
Polyunsaturated	0.31
Unsaturated	0.27
Short chain	0.24
Medium chain	0.34
Long chain	0.17



Genetic correlations of MIR-LF with content of FA in milk:

- **Positive and higher in late lactation**
- **On average, low to moderate**

Genetic correlations with SCS



- Higher genetic correlation in late lactation
- Average daily genetic correlation = 0.15 (average SE = 0.10)

Selection for MIR-LF?

Selection for higher MIR-LF to improve udder health ?

- **A sufficient level of lactoferrin is necessary to prevent certain infections.**
  - **Cows with lactoferrin < 200 μg/ml may have not sufficient ability to inhibit the growth of *E. coli.***

- **High levels of lactoferrin at some day of the lactation could reflect udder infection.**
  - **generally: lactoferrin level in mastitic milk >>> normal milk**
  - **But level of lactoferrin in mastitic milk vary according to the pathogen and the pathogenicity of the bacteria.**

    e.g. acute >< peracute mastitis caused by *E. coli*

Kawai et al., 1999, Vet. Res. Commun.
Hagiwara et al., 2003, J. Vet. Med. Sci.
Lee et al., 2004, J. Vet. Med. Sci.

Selection for MIR-LF?

- **Selection for higher MIR-LF to improve udder health ?**
  - **MIR-LF could be included in an "udder health index"**
  - **higher levels desirable to select for improved ability of the cow to fight infections**
  - **but concomitant selection for improved SCS and mastitis resistance is required**
- **Selection for higher MIR-LF to improve nutraceutical properties of milk?**
  - **great interest for lactoferrin as a biologically active food component**
  - **could be included in a "nutraceutical properties of milk index" with milk fatty acids (monounsaturated and polyunsaturated)**

Conclusions

- The mid-infrared prediction of lactoferrin
  - = indicator of lactoferrin content in milk
  - variable and heritable especially in mid to late lactation
  - low and negative genetic correlation with milk yield
  - positive genetic correlations with fat, protein and fatty acid contents
- Selection for improved MIR-LF is feasible
  - MIR-LF could be included in both “udder health index” and “nutraceutical properties of milk index”

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