63rd EAAP Annual Meeting 2012
August 27-31, Bratislava, Slovakia

Genetics of the mid-infrared predicted lactoferrin content in milk of dairy cows

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Bovine lactoferrin

- Lactoferrin = iron-binding glycoprotein present in milk
- Important host defence molecule:
  - antimicrobial/antiviral, antioxidant, immunomodulatory activities
    - ➔ role in the defence mechanisms in the mammary gland
- Used as a food additive:
  - 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: lactoferrin + penicillin ➔ ↗ 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.

Genetic selection for lactoferrin?

Measurable

Prediction by mid-infrared spectrometry

- R^2_{cv} =0.71 ; R^2_{v} = 0.60 ; RPD = 1.86

➔ **"indicator" of lactoferrin content in milk**

Soyeurt et al., 2012, Anim.

Economically interesting

- **Nutraceutical properties of milk**
- **Defence mechanisms in the mammary gland**

Variable and heritable

Objectives

Measurable

Economically interesting

Variable and heritable

Objectives:

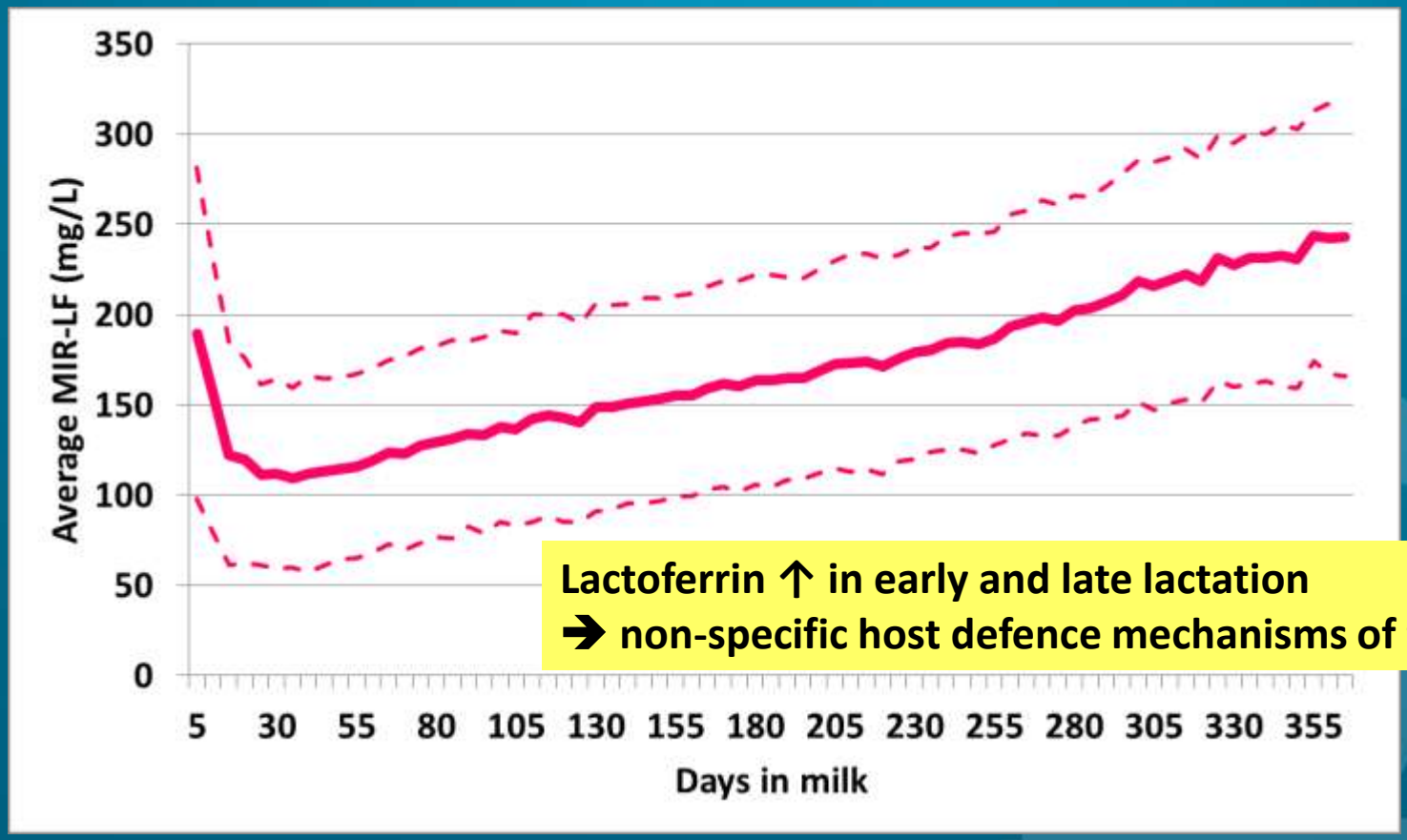
- genetic variability of the mid-infrared prediction of lactoferrin content in milk
- genetic correlations with
  - major production traits
  - udder health trait
  - fatty acid contents in milk

Data and edits

- 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) :
  - 9,878 first-parity Holstein cows from 150 Walloon 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:



Correlations among observations

- Correlations among observations at the same day

Correlations between MIR-LF and:	
Milk (kg)	-0.42
Fat (kg)	-0.24
Protein (kg)	-0.22
Fat (%)	0.31
Protein (%)	0.59
Somatic cell score	0.30

Correlations between MIR-LF and the groups of FA (g/dL of milk):	
Saturated	0.30
Monounsaturated	0.17
Polyunsaturated	0.15
Short chain	0.23
Medium chain	0.36
Long chain	0.06

Model

- 23 two-trait random regression test-day models

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

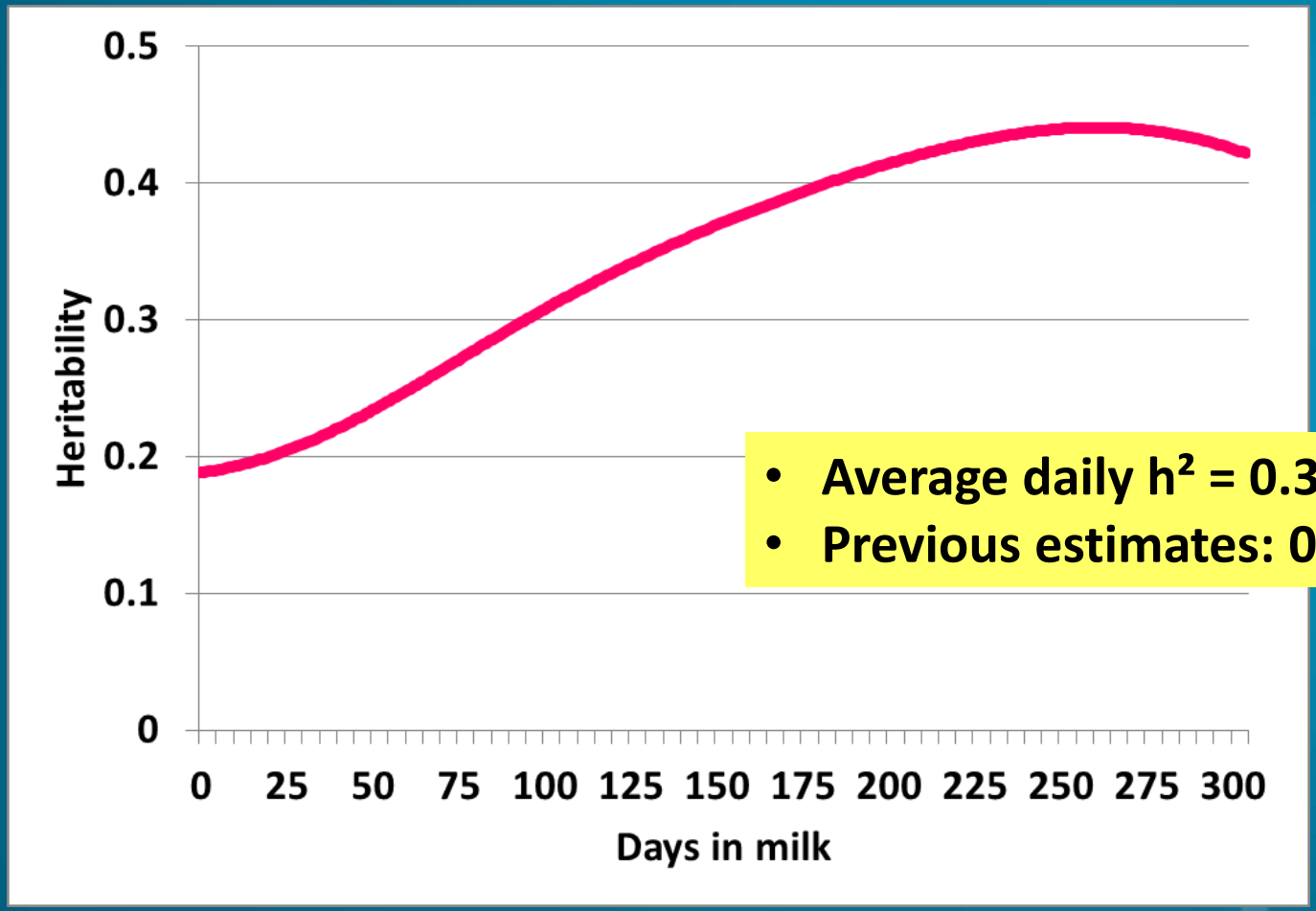
  - β = fixed effects
    - herd x test day
    - lactation stage (classes of 5 days)
    - gestation stage
    - age at calving x season of calving x lactation stage
  - p = permanent environmental random effect

    a = additive genetic random effect

    → regression curves modelled with 2nd order Legendre polynomials

- Variance components estimated using AIREMLF90 (Misztal, 2012)

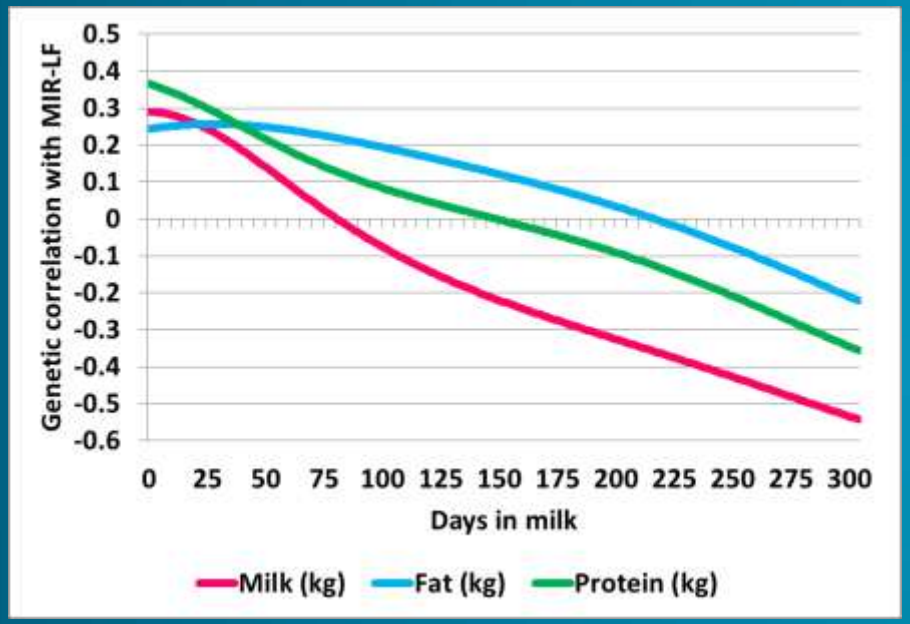
MIR-LF heritability

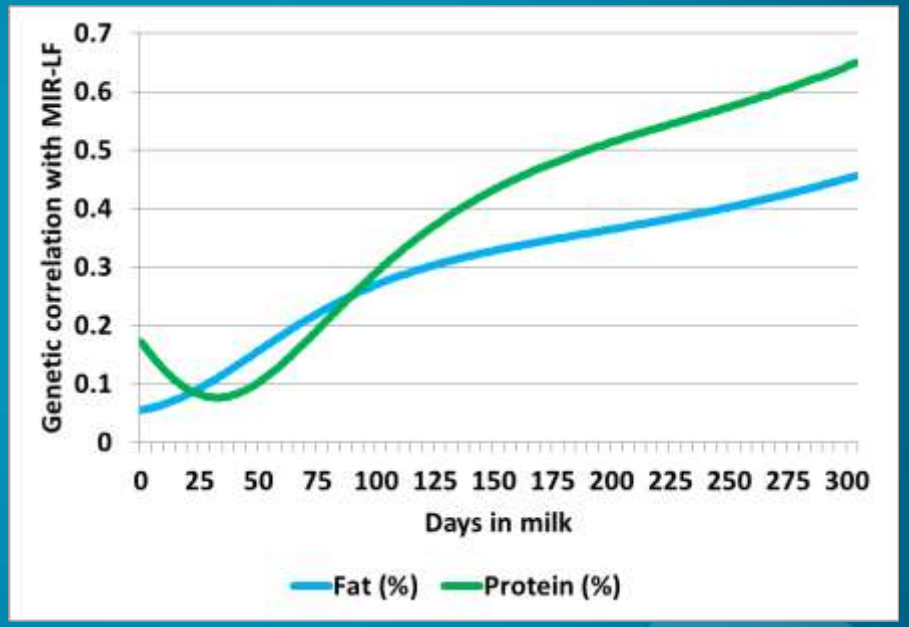


- Average daily h^2 = 0.35 (± 0.02)
- Previous estimates: 0.20 – 0.44

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

Correlations with production

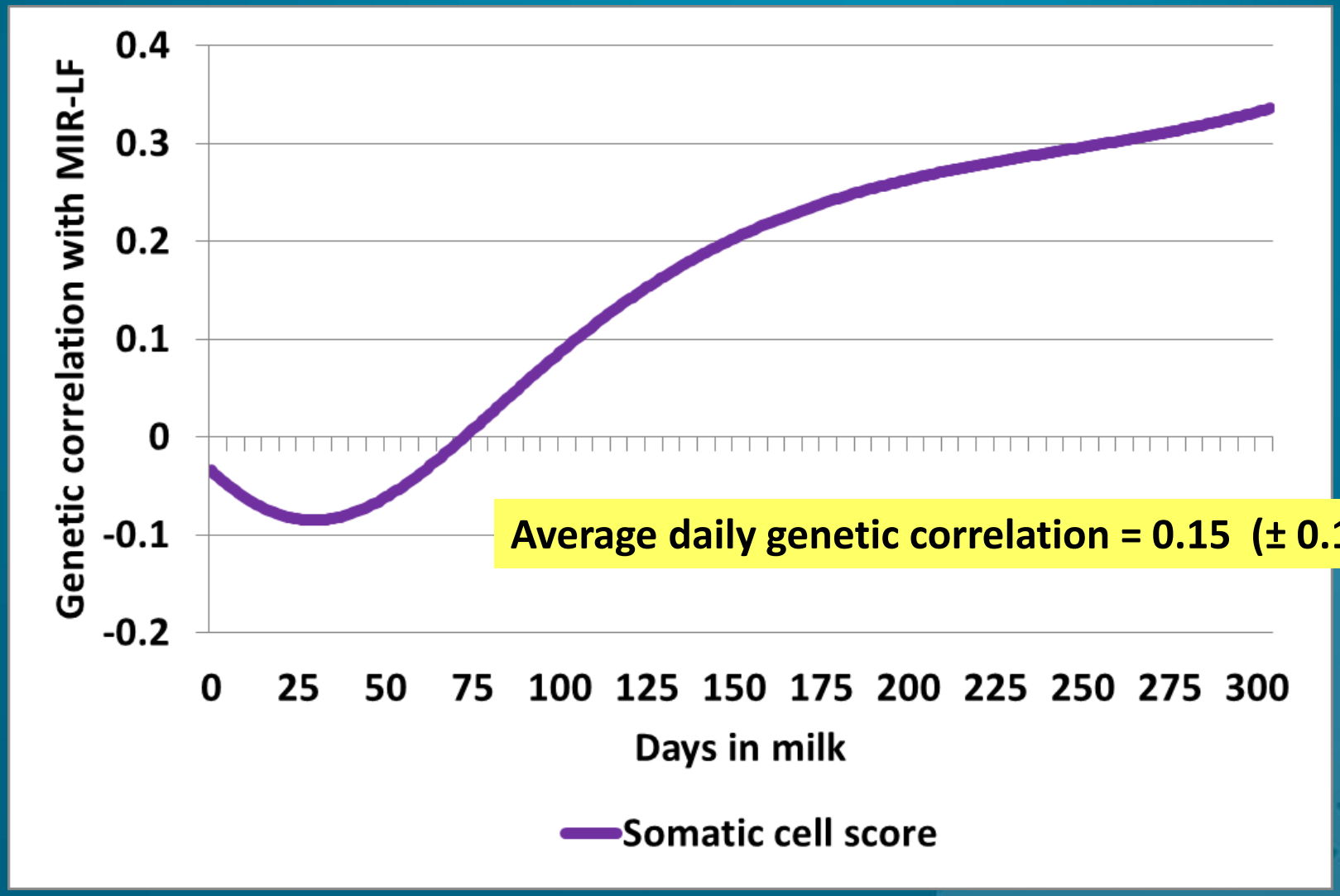




Average daily genetic correlation with MIR-LF (SE = 0.06 - 0.08)

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

Correlations with SCS

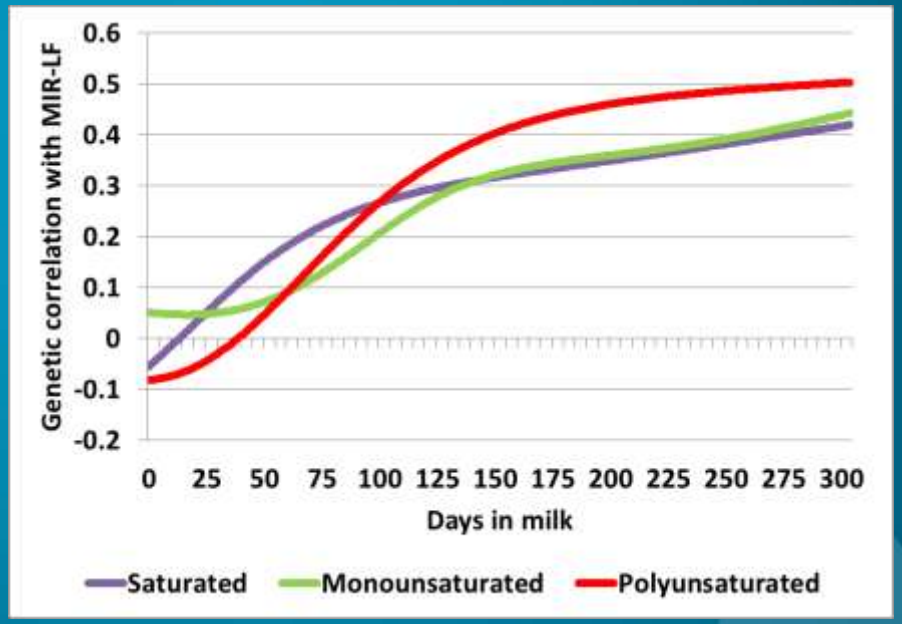


Correlations with fatty acids

Average daily genetic correlation with MIR-LF (SE = 0.06 - 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 selection for lactoferrin?

Measurable

Economically interesting

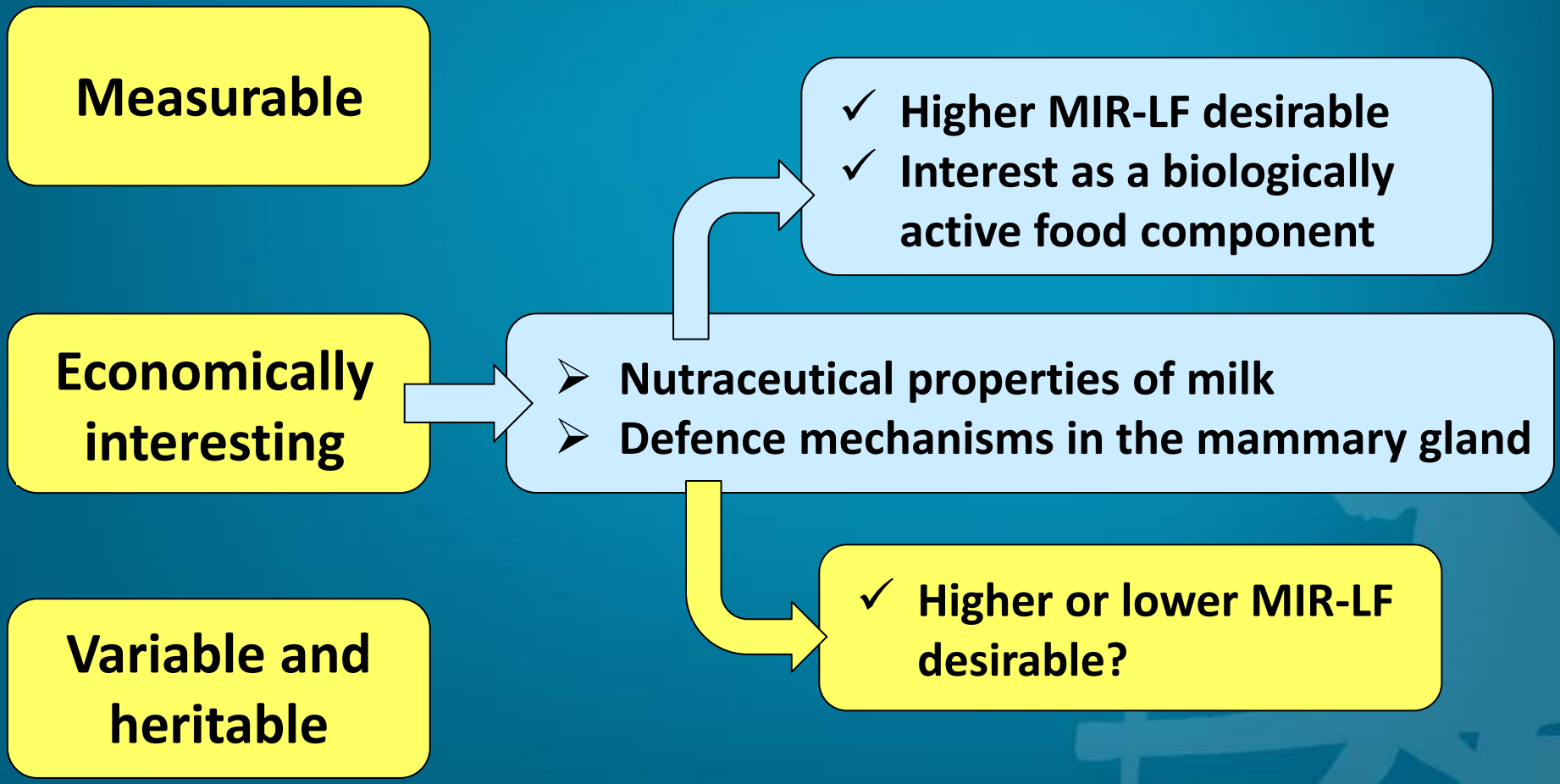
Variable and heritable

- ✓ Higher MIR-LF desirable
- ✓ Interest as a biologically active food component

- ➢ Nutraceutical properties of milk
- ➢ Defence mechanisms in the mammary gland

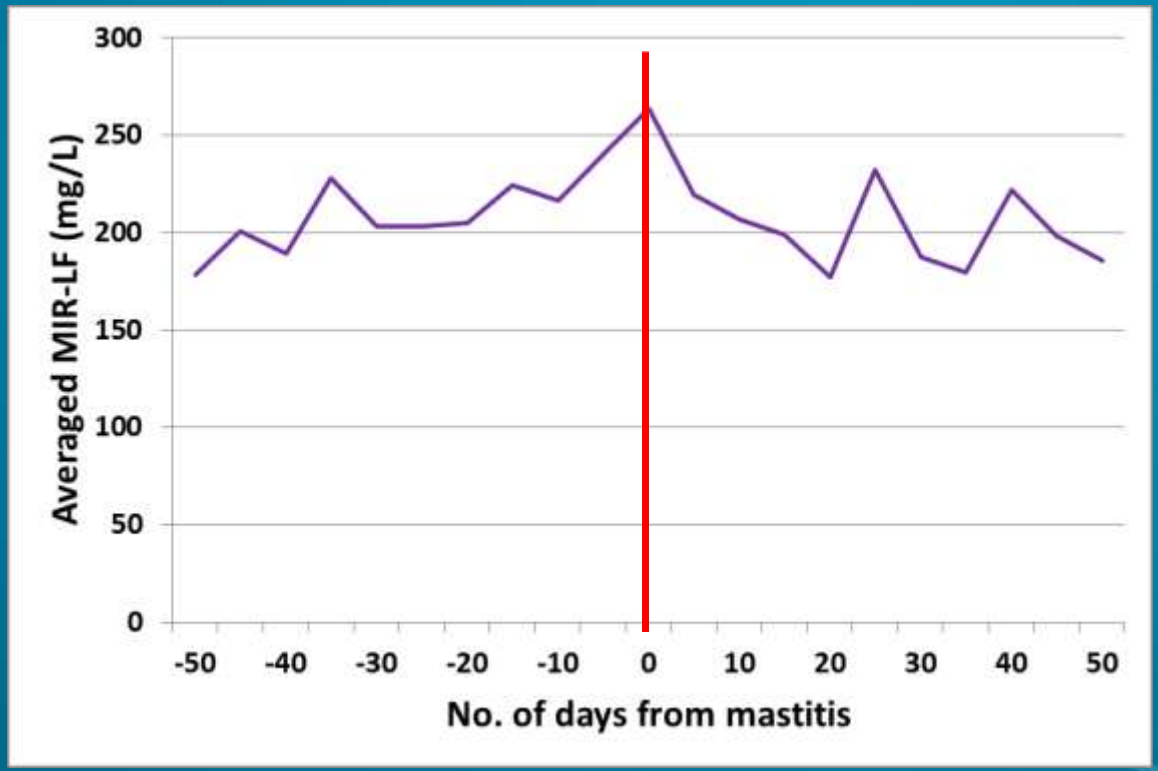
- ✓ Higher or lower MIR-LF desirable?

Genetic selection for lactoferrin?



MIR-LF and udder health

- Generally: lactoferrin level in mastitic milk >>> normal milk



- Mastitis and MIR-LF data from 26 Walloon herds since 2010
- 1497 lactations (of which 446 with mastitis) with at least 3 MIR-LF records

MIR-LF and udder health

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	N	Average MIR-LF over the lactation	
		Mean	SD
Non mastitic cows	1051	197.2	63.9
Mastitic cows	446	208.3	60.9

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Significantly higher for mastitic cow

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MIR-LF and udder health

- Generally: lactoferrin level in mastitic milk >>> normal milk
- But lactoferrin in mastitic milk varies according to the pathogen and the pathogenicity of the bacteria.

  e.g. acute >< peracute mastitis caused by *E. coli*
- Sufficient level of lactoferrin necessary to prevent certain infections
  - Threshold of 200 mg/l to inhibit the growth of *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.

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- Sufficient level of lactoferrin necessary to prevent certain infections
  - Threshold of 200 mg/l to inhibit the growth of *E. coli.*

- ✓ lactoferrin = optimum trait
- ✓ higher level: ability of the cow to fight infections *vs.* occurrence of mastitis
- ✓ joint selection for improved SCS and mastitis resistance required

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 feasible
  - “nutraceutical properties of milk index”
  - “udder health index”

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Study supported by:

- Public Service of Wallonia (SPW-DGO 3; project D31-1273)
- LAECEA project for providing mastitis data
- European Commission, Directorate-General for Agriculture and Rural Development, under Grant Agreement 211708 (project Robustmilk)

This study has been carried out with financial support from the Commission of the European Communities, FP7, KBBE-2007-1. It does not necessarily reflect its view and in no way anticipates the Commission's future policy in this area.

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