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Genetic variability of stearoyl coenzyme-A desaturase activity

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Context

- Interest for human health
- Many factors affecting milk fat composition have been reviewed (e.g., Palmquist *et al.*, 1993; Soyeurt *et al.* 2006):
    - Feeding, season
    - Breed
    - Lactation stage
    - Number of lactation, age
    - ...

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Δ^9 desaturase

- Also named stearoyl Coenzyme-A desaturase or SCD

- Able to introduce a cis-bond between carbons 9 and 10 of SFA

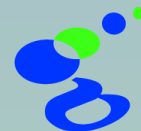- Involved in the production of the majority of MONO and CLA in milk

General objective

- Study the genetic variation of Δ^9-desaturase activity in bovine milk within and between lactations using multitrait random regression test-day models

Lactation stage effect

- Milk fat composition significantly change with lactation stage (Stoop *et al.*, 2008)

- Principally due to changes in energy status
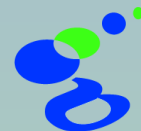
Lactation number effect

- Few information are available on lactation number effect on $\Delta 9$ activity
- Lactation number effect = age effect ?
- Contradictions / fat content:
  - Milk fat not affected by lactation number
  - Fat content decreases with increasing number of lactation (or age of cow)

Lactation number effects

- Contradictions / fat composition
  - No difference
  - The amount of UNSAT increases with increasing age
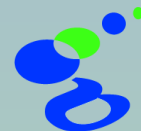 - While palmitic acid decreases

Materials & Methods

- Data set
  - spectra collected between January 2007 and October 2008
  - Holstein cows (> 84%)
  - Milk history
    - Milk yield, %Fat, %Protein
    - 4 < DIM < 365
  - Multi-trait random regression test-day models
- Studied traits
  - Milk yield
  - Fat content
  - Protein content
  - 2 Δ^9 indices (product / substrate):
    - C14:1 cis-9/C14:0
    - C16:1 cis-9/C16:0

Materials & Methods

- Lactations were grouped in 3 groups as following:
  - First lactation 39%
  - Second lactation 29%
  - Third and fourth lactations 32%

- Random herd-based data sub set

Materials & Methods

- Models:
  - Fixed effects:
    - Herd x date of test
    - Class of 15 days in milk (20)
    - Class of age (16)
  - Random effects:
    - Herd x year of calving
    - Permanent environment
    - Additive genetic effect
    - Residuals

Second order Legendre Polynomials

Studied traits

		N		Mean		SD	
		Total population	Sample data set	Total population	Sample data set	Total population	Sample data set
Milk (kg/day)	Lact 1	81,576	30,137	22.63	22.64	6.17	6.13
	Lact2	46,984	23,643	25.45	25.58	8.17	8.20
	Lact 3 and 4	70,655	24,579	27.00	26.93	8.92	8.97
Fat (g/100 g of milk)	Lact 1	81,576	30,137	3.98	3.98	0.67	0.67
	Lact2	46,984	23,643	4.07	4.06	0.71	0.71
	Lact 3 and 4	70,655	24,579	4.06	4.06	0.71	0.73
Protein (g/100g of milk)	Lact 1	81,576	30,137	3.35	3.36	0.34	0.36
	Lact2	46,984	23,643	3.43	3.44	0.38	0.38
	Lact 3 and 4	70,655	24,579	3.39	3.40	0.38	0.39

Studied traits

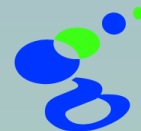|		N		Mean		SD	
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				4.07	4.06	0.71	0.71
				4.06	4.06	0.71	0.73
				3.35	3.36	0.34	0.36
				3.43	3.44	0.38	0.38
of milk)	Lact 3 and 4	70,655	24,579	3.39	3.40	0.38	0.39

Similar statistical characteristics between population and sample data set

Studied traits

		N		Mean		SD	
		Total population	Sample data set	Total population	Sample data set	Total population	Sample data set
Milk (kg/day)	Lact 1	81,576	30,137	22.63	22.64	6.17	6.13
	Lact2	46,984	23,643	25.45	25.58	8.17	8.20
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	Lact2	46,984	23,643	4.07	4.06	0.71	0.71
	Lact 3 and 4	70,655	24,579	4.06	4.06	0.71	0.73
Protein (g/100g of milk)	Lact						0.36
	Lact						0.38
	Lact and						0.39

Slightly increasing of milk yield with increasing number of lactation

Studied traits

		N		Mean		SD	
		Total population	Sample data set	Total population	Sample data set	Total population	Sample data set
Milk (kg/day)	Lact 1	81,576	30,137	22.63	22.64	6.17	6.13
	Lact2	46,984	23,643	25.45	25.58	8.17	8.20
	Lact 3 and 4	70,655	24,579	27.00	26.93	8.92	8.97
Fat (g/100 g of milk)	Lact 1	81,576	30,137	3.98	3.98	0.67	0.67
	Lact2	46,984	23,643	4.07	4.06	0.71	0.71
	Lact 3 and 4	70,655	24,579	4.06	4.06	0.71	0.73
Protein (g/100g of milk)	Lact						0.36
	Lact						0.38
	Lact and						0.39

Any modification of fat content with increasing number of lactation

Studied traits

		N		Mean		SD	
		Total population	**Sample data set**	**Total population**	**Sample data set**	**Total population**	**Sample data set**
C14:1 cis-9 / C14:0	Lact 1	81,576	30,137	0.097	0.098	0.014	0.014
	Lact2	46,984	23,643	0.095	0.096	0.014	0.014
	Lact 3 and 4	70,655	24,579	0.094	0.094	0.014	0.014
C16:1 cis-9 / C16:0	Lact 1	81,576	30,137	0.064	0.064	0.012	0.012
	Lact2	46,984	23,643	0.065	0.064	0.012	0.012
	Lact 3 and 4	70,655	24,579	0.066	0.066	0.012	0.012

Results

Lactation stage effect

Heritability
Lactation 1

C14:1 cis-9/C14:0   **C16:1 cis-9/C16:0**

Chart: Heritability (y-axis, values 0,05 to 0,35) vs Days in Milk (x-axis, 5 to 365)

Heritability
Lactation 1

Legend: C14:1 cis-9/C14:0 — C16:1 cis-9/C16:0

Variability of heritability
C14:1 cis-9/C14:0
0.22 - 0.28
C16:1 cis-9/C16:0
0.10 - 0.12

Heritability
Lactation 1

Legend: C14:1 cis-9/C14:0 — C16:1 cis-9/C16:0

Variation of heritability values throughout the lactation
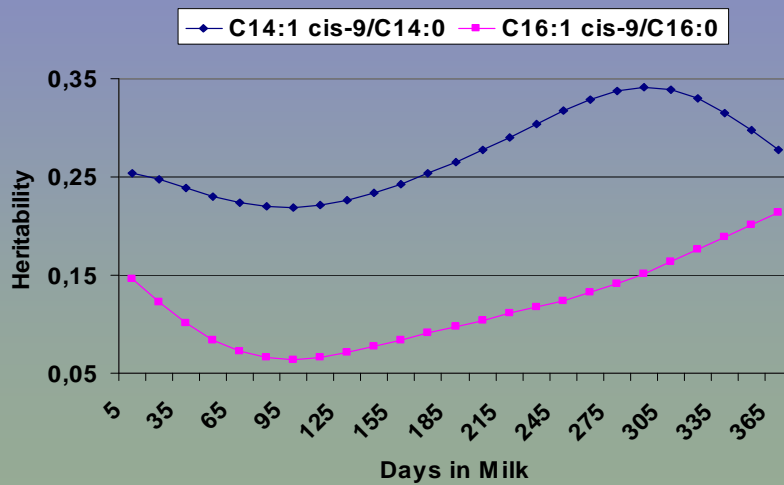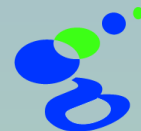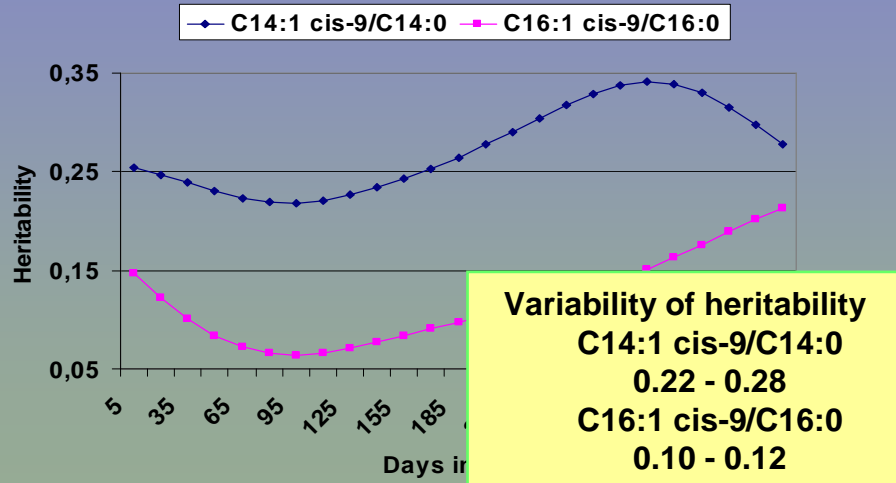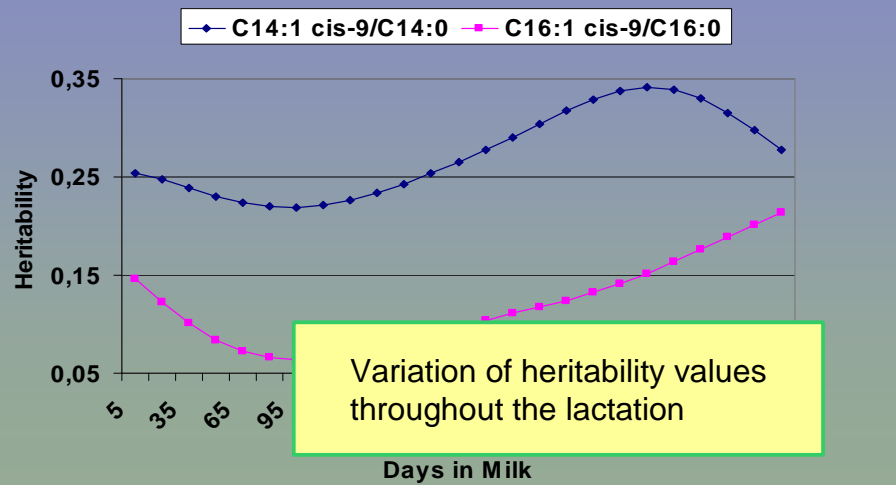
Variance component Lactation 1

Herd x year test **Permanent environment** **Genetic**
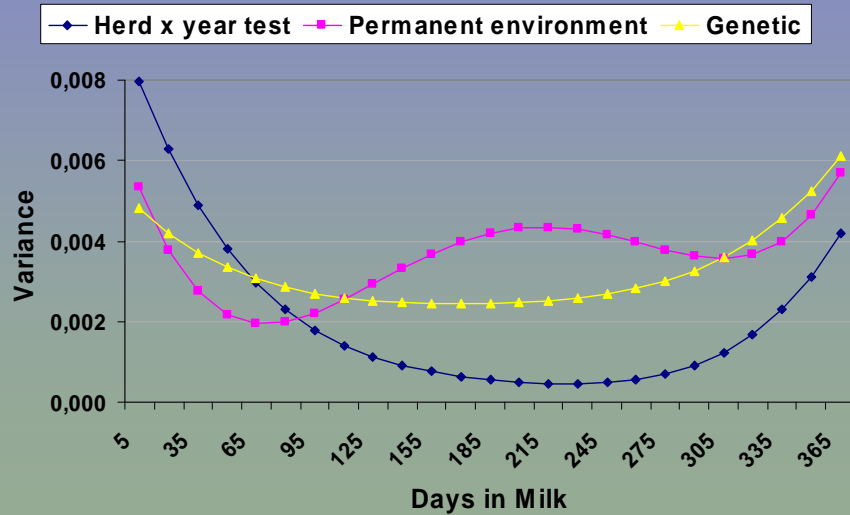
Results

Lactation number effect

Heritability
C14:1 cis-9/C14:0
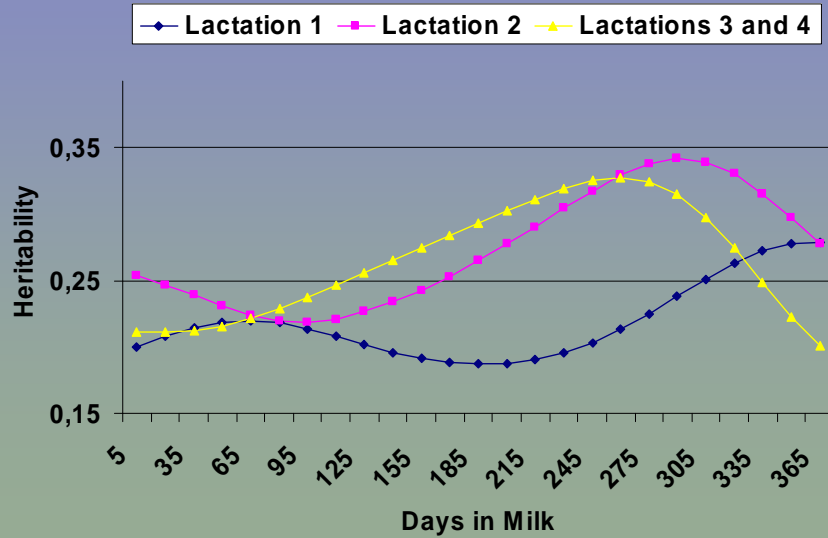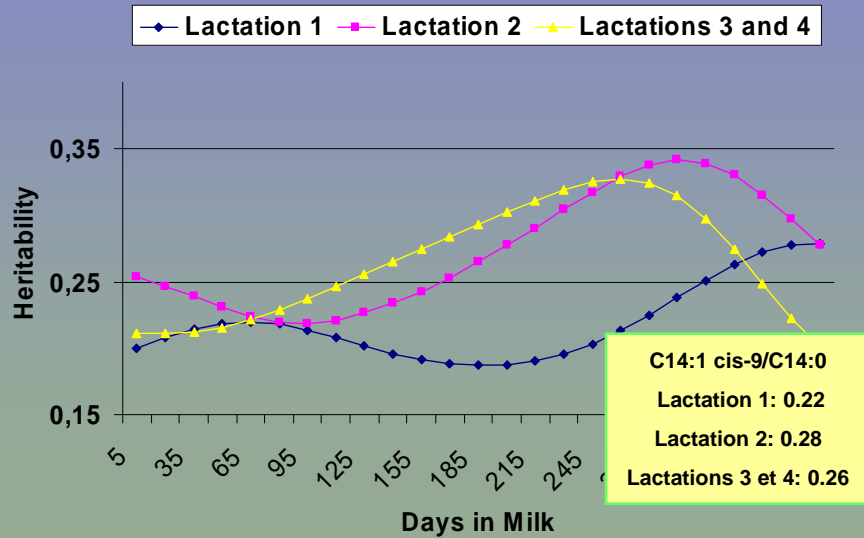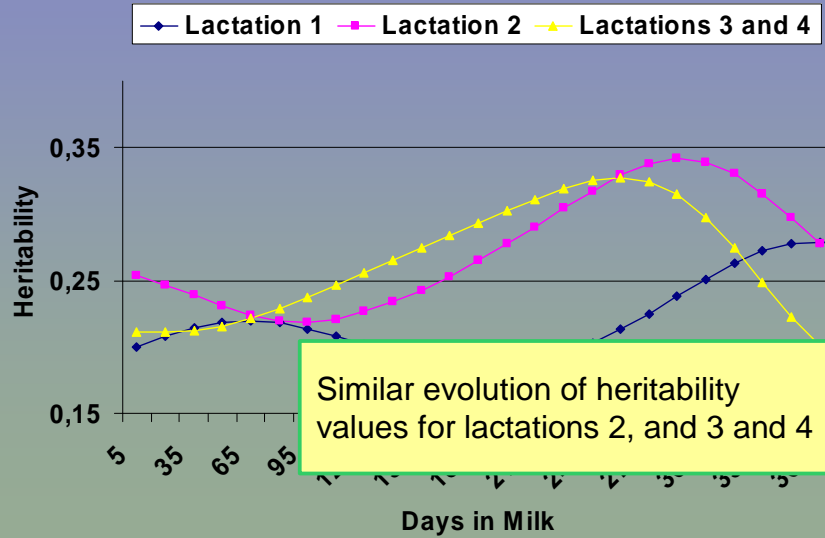
Lactation 1 ■ **Lactation 2** ▲ **Lactations 3 and 4**

Similar evolution of heritability values for lactations 2, and 3 and 4

Heritability (y-axis): 0,15 — 0,25 — 0,35

Days in Milk (x-axis): 5 — 35 — 65 — 95 ...

Heritability
C16:1 cis-9/C16:0

Lactation 1 ■ **Lactation 2** ▲ **Lactations 3 and 4**

Heritability (y-axis): 0,00 — 0,05 — 0,10 — 0,15 — 0,20 — 0,25

Days in Milk (x-axis): 5 — 35 — 65 — 95 — 125 — 155 — 185 — 215 — 245 — 275 — 305 — 335 — 365

Heritability
C16:1 cis-9/C16:0

Lactation 1 — Lactation 2 — Lactations 3 and 4

C16:1 cis-9/C16:0
Lactation 1: 0.10
Lactation 2: 0.12
Lactations 3 and 4: 0.10

Heritability
C16:1 cis-9/C16:0

Lactation 1 — Lactation 2 — Lactations 3 and 4

Similar evolution of heritability values for studied lactations
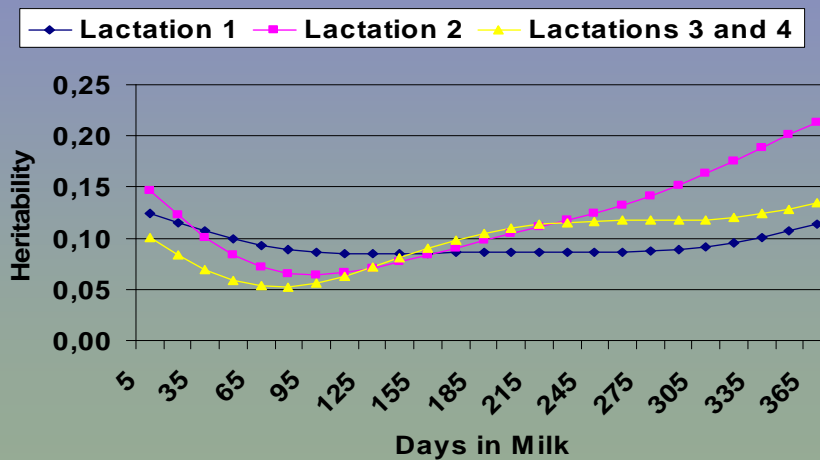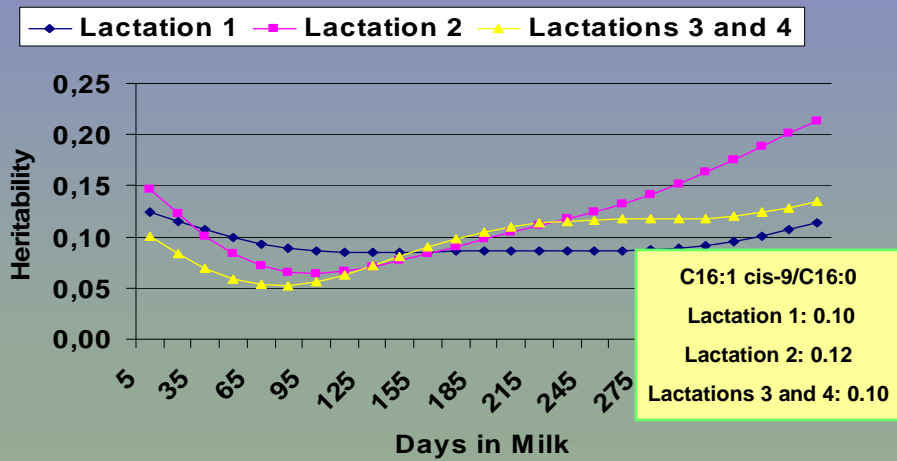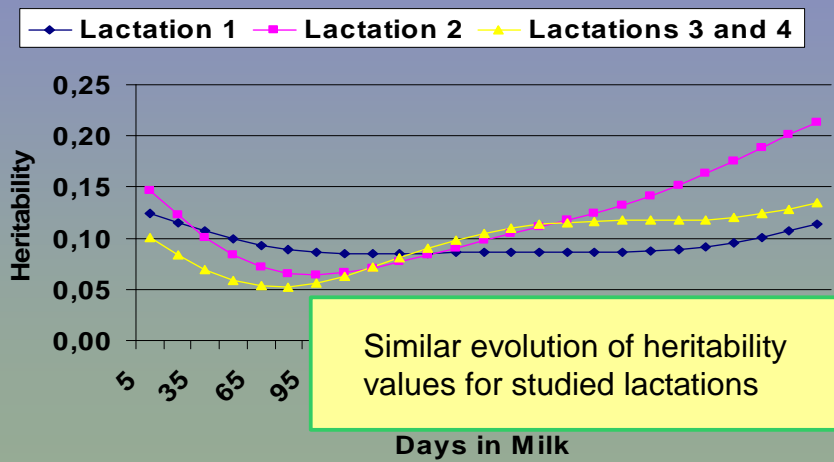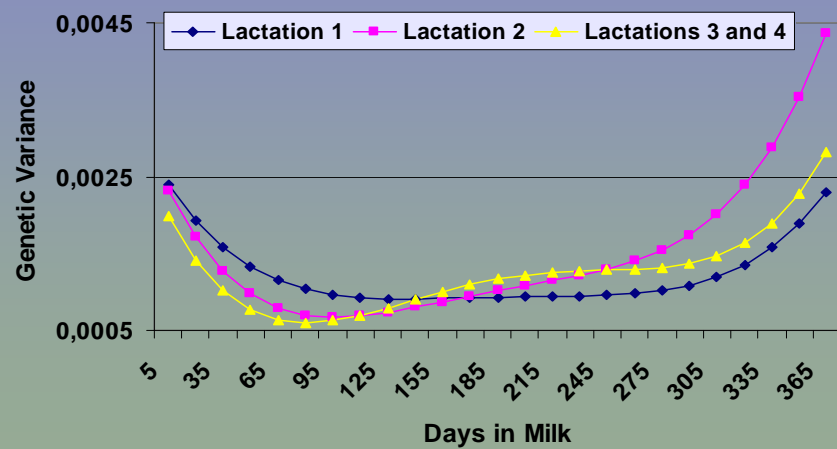
Genetic variance component C14:1 cis-9/C14:0
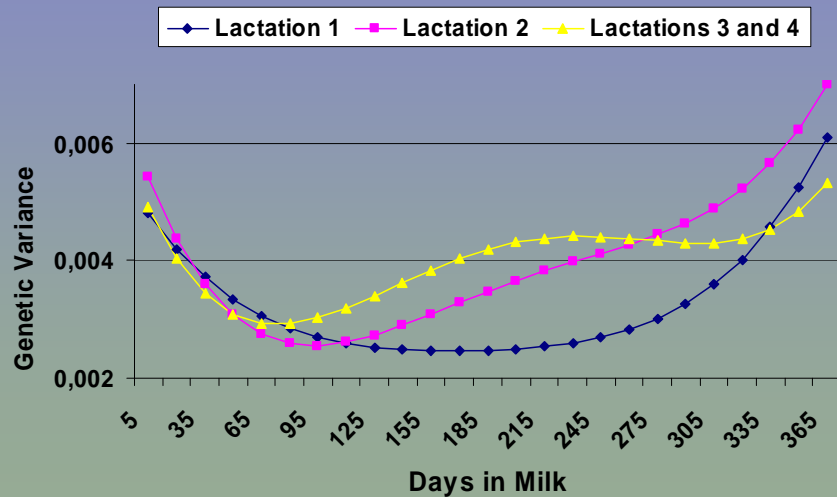
Genetic variance component C16:1 cis-9/C16:0

Results

Correlations

Relationships
C14:1 cis-9/C14:0

Genetic correlation

Phenotypic correlation

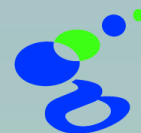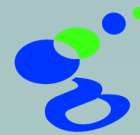|	Milk (kg/day)	Fat content (g/100 g of milk)	Protein content (g/100 g of milk)
Lactation 1	0.43	-0.54	-0.20
	-0.03	-0.31	-0.09
Lactation 2	0.13	-0.45	-0.15
	-0.10	-0.29	0.04
Lactation 3	0.046	-0.37	-0.17
	-0.11	-0.27	0.07

Relationships C14:1 cis-9/C14:0

Genetic correlation

Phenotypic correlation

	Milk (kg/day)	Fat content (g/100 g of milk)	Protein content (g/100 g of milk)
Lactation 1	0.43	-0.54	-0.20
	-0.03	-0.31	-0.09
Lactation 2	0.13	-0.45	-0.15
	-0.10	-0.29	0.04
Lactation 3	0.046	-0.37	-0.17
	-0.11	-0.27	0.07

Relationships C14:1 cis-9/C14:0

Legend:
- Genetic --- Lactation 1
- Genetic --- Lactation 2
- Genetic --- Lactations 3 and 4

Y-axis: Genetic Correlation (0,4 to -0,8)
X-axis: Days in Milk (5 to 365)

Relationships
C16:1 cis-9/C16:0

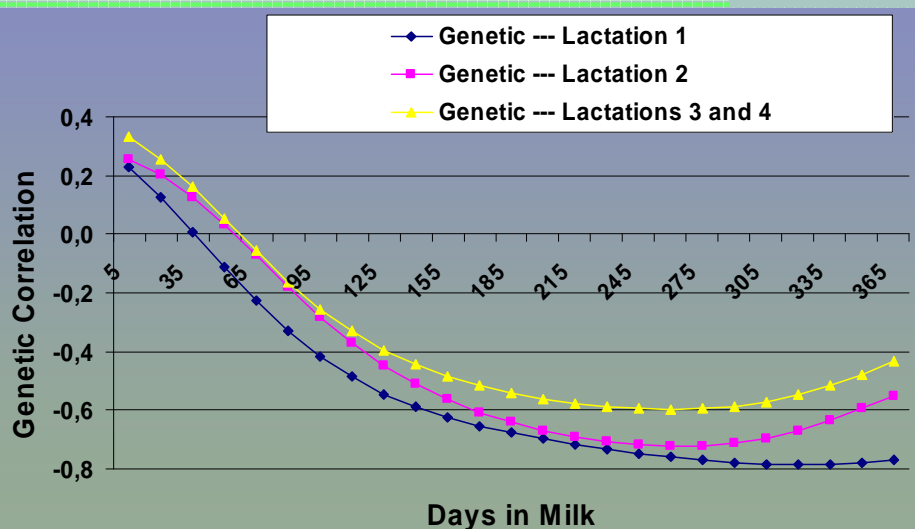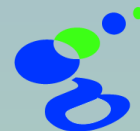**Genetic correlation**

Phenotypic correlation

	Milk (kg/day)	Fat content (g/100 g of milk)	Protein content (g/100 g of milk)
Lactation 1	0.32	-0.34	-0.16
	-0.06	-0.10	-0.01
Lactation 2	0.10	-0.43	-0.08
	-0.07	-0.12	0.12
Lactation 3	0.046	-0.37	-0.17
	-0.08	-0.11	0.00

Relationships
C16:1 cis-9/C16:0

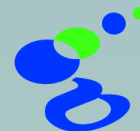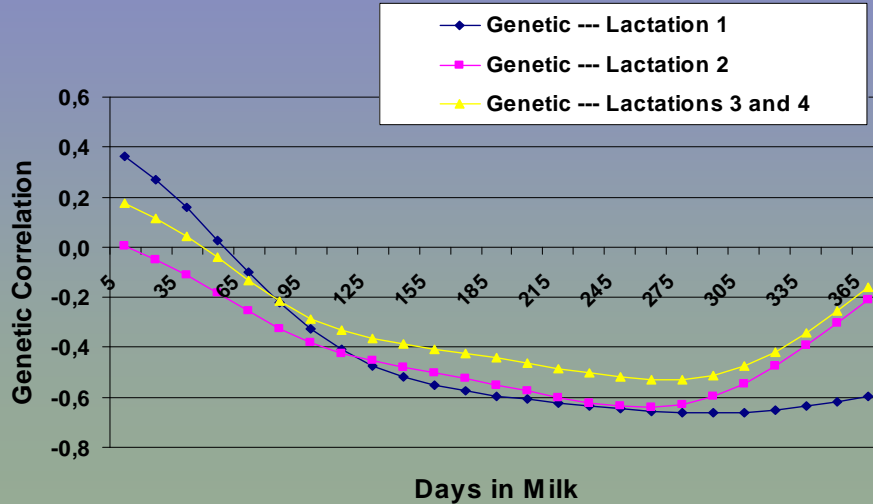**Genetic correlation**

Phenotypic correlation

	Milk (kg/day)	Fat content (g/100 g of milk)	Protein content (g/100 g of milk)
Lactation 1	0.32	-0.34	-0.16
	-0.06	-0.10	-0.01
Lactation 2	0.10	-0.43	-0.08
	-0.07	-0.12	0.12
Lactation 3	0.046	-0.37	-0.17
	-0.08	-0.11	0.00

Relationships C16:1 cis-9/C16:0

Genetic --- Lactation 1
Genetic --- Lactation 2
Genetic --- Lactations 3 and 4

Genetic Correlation (y-axis: -0,8 to 0,6)

Days in Milk (x-axis: 5 to 365)
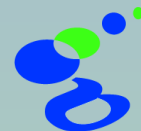
Spearman correlation

- Application:
  - Short sire according to their breeding values
    for C14:1 cis-9/C14:0

- Comparison among the lists of sire obtained for the 3 lactations

Spearman correlat

	Lactation 1	Lactation 2	Lactation 3 and 4
Lactation 1	**1**	**0.71**	**0.58**
Lactation 2		**1**	**0.68**
Lactation 3			**1**

Spearman correlat

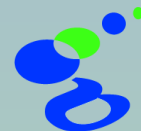| Lactation 1	Lactation 2	Lactation 3 and 4
	Sire 1	Sire 8
Sire 1	Sire 4	Sire 3
	Sire 10	Sire 10
Sire 2		Sire 12
Sire 3		
Sire 4	Sire 8	Sire 9
Sire 5	Sire 5	
Sire 6		Sire 1
	Sire 11	Sire 13
Sire 7	Sire 6	Sire 11
	Sire 12	
	Sire 9	
	Sire 13	
Sire 8	Sire 2	
		Sire 4
Sire 9	Sire 7	
Sire 10		

Conclusions:

- The top 20 is similar for the 3 lactation groups
- So, dairy cow in first lactation is as good in second or third lactation.

Conclusions

- Lactation stage effects
  - Genetic variability of Δ9 activity throughout lactation

- Lactation number effects
  - None or few useful effects of lactation number on Δ9 activity

Conclusions

- The desaturation of milk fatty acids present a substantial genetic component
→ possibility to modulate milk fat profile by selective breeding

- Negative correlations between Δ9 activity (ratios) and fat and protein content: increasing activity of Δ9 → could inhibit the synthesis of fat and protein in bovine milk

In the future

- Study the difference between Δ9 activity estimator

- Enlarge the studied number of lactation: per example: 1-3 vs 4-6

Thank you for your attention

Acknowledgments

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AWE

Milk committee (Battice)

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