Selection of milk fatty acid composition for improved dairy products from more fertile and healthier cows

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Why milk fatty acid profile?

- Growing consumers concern of the nutritional quality of dairy products
  - demand for low-fat, less saturated, healthy products
- Milk FA profile reflects the metabolism and the environment of the cow.
  - energy status
  - CH_4 emission

Why milk FA profile?

- How to alter milk FA composition?
  1. cow nutrition and management
  2. cow genetics
  3. dairy manufacturing technologies

How genetic selection for milk FA composition could improve the quality of dairy products and the robustness of dairy cows?

Genetic selection to alter milk FA?

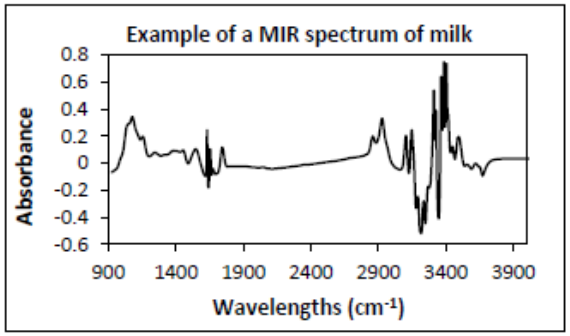
To be included in a breeding program, a trait should …

- ☐ be measurable, ideally at a low cost.
- ☐ exhibit heritable genetic variation.
- ☐ be of economic, social or environmental value.
- ☐ correlate with a trait of economic importance which is not easily or readily available.

Shook, 1989, J. Dairy Sci., 72:1349-1362

FA are measurable

- **Mid-infrared spectrometry**
  - **method of choice to quantify the major milk components (fat, protein, lactose)**
  - **used by milk recording and milk payment system**
  - **potential to predict accurately the content in milk of the major FA routinely at a low cost**



Soyeurt et al. 2006. J. Dairy Sci. 89:3690-3695.
Rutten et al. 2009. J. Dairy Sci. 92:6202-6209.

FA are measurable

FA (g/dl of milk)	RPD
C4:0	4.1
C6:0	5.7
C8:0	6.1
C10:0	5.1
C12:0	5.2
C14:0	5.4
C16:0	4.6
C17:0	3.1
C18:0	3.2
C18:1	7.7
C18:1 *cis*-9	5.9

Group of FA (g/dl of milk)	RPD
Saturated	15.7
Monunsaturated	8.9
Polyunsaturated	2.6
Unsaturated	9.6
Short chain	6.7
Medium chain	6.5
Long chain	6.5

RPD*	Class
≤ 2.3	Very poor
2.4 – 3	Poor
3.1 – 4.9	Fair
5.0 – 6.4	Good
6.5 – 8	Very good
≥ 8.1	Excellent

*RPD = Ratio of standard error of Prediction to standard Deviation

Soyeurt et al. 2011. J. Dairy Sci. 94:1657-1667.

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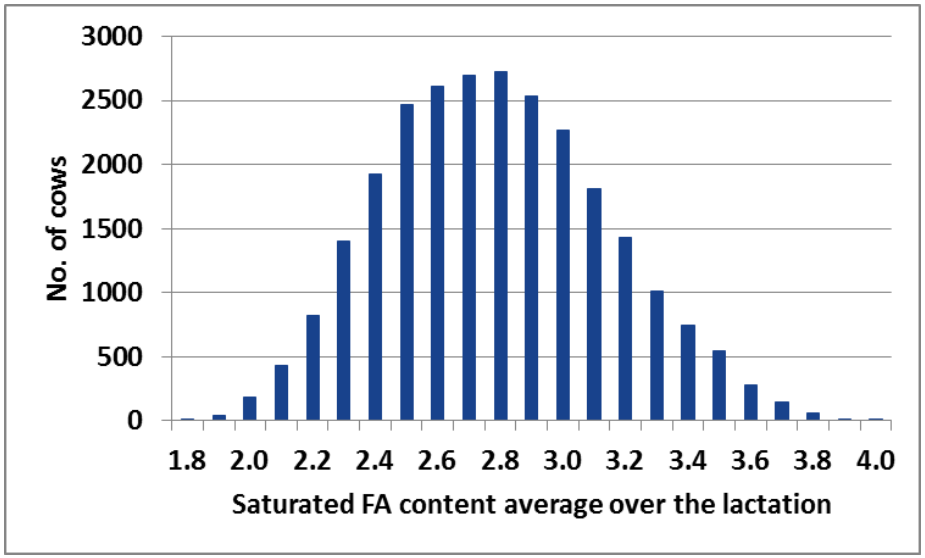
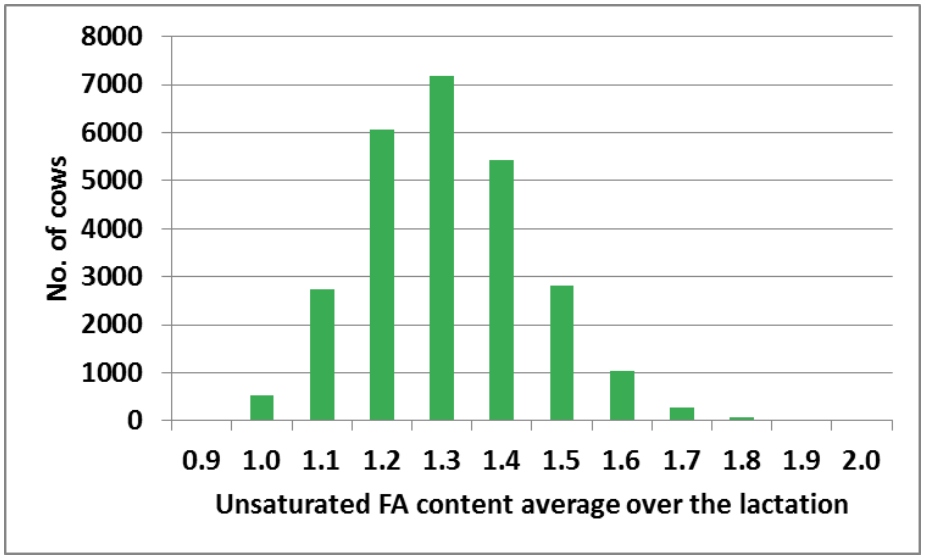
FA are variable and heritable

- Variability among cows





Derived from Bastin et al., 2011, J. Dairy Sci., 94:4152-4163

FA are variable and heritable

- Genetic differences in FA profile among breeds and cows exist.
- Genetic parameters for Walloon Holstein cows
  - according to the origin of FA
  - h^2 = 0.35-0.40 for FA synthesized de novo in the udder
    - C4:0 to C14:0 + half of C16:0
  - h^2 = 0.20-0.25 for FA from the diet and body fat mobilization
    - remaining C16:0 and long-chain

Bastin. 2012. J. Anim. Breed. Genet. 130:118–127.

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Economic value of milk FA?

⇨ Nutritional, technological, sensory quality of milk

- Nutritional quality → what about saturated FA?
  - typical milk fat: 70% of saturated FA
  - saturated fat → ↗ risk of cardiovascular diseases
  - dairy products are a major food sources of saturated fat → ~21% of total saturated fat intake in the U.S. diet

⇨ Demand for less saturated dairy products

⇨ Financial bonus to dairy farmers for less saturated milk

✓ "Good" saturated FA, e.g., C4:0 in cancer prevention

Haug et al. 2007. Lipids Health Dis, 6:25.
Huth and Parker. 2012, Adv. Nutr. 3: 266–285.

Economic value of milk FA?

⇨ Nutritional, technological, sensory quality of milk

- Nutritional quality → what about unsaturated FA?
  - typical milk fat: 25% of MUFA and 5% of PUFA
  - considered as "good fat", e.g., beneficial effects of CLA
  - C18:1 *cis*-9 favorable to human health

✓ More than the individual effect of milk components on human health, consumption of dairy products should be considered as a whole.

Haug et al. 2007. Lipids Health Dis, 6:25.
Huth and Parker. 2012, Adv. Nutr. 3: 266–285.

Economic value of milk FA?

⇨ Nutritional, technological, sensory quality of milk

- Technological and sensory quality of milk
  - e.g., melting point and hardness of butter
  - e.g., oxidative changes in FA

Palmquist et al. 1993. J. Dairy Sci. 76:1753-1771.

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FA as indicators of fertility?

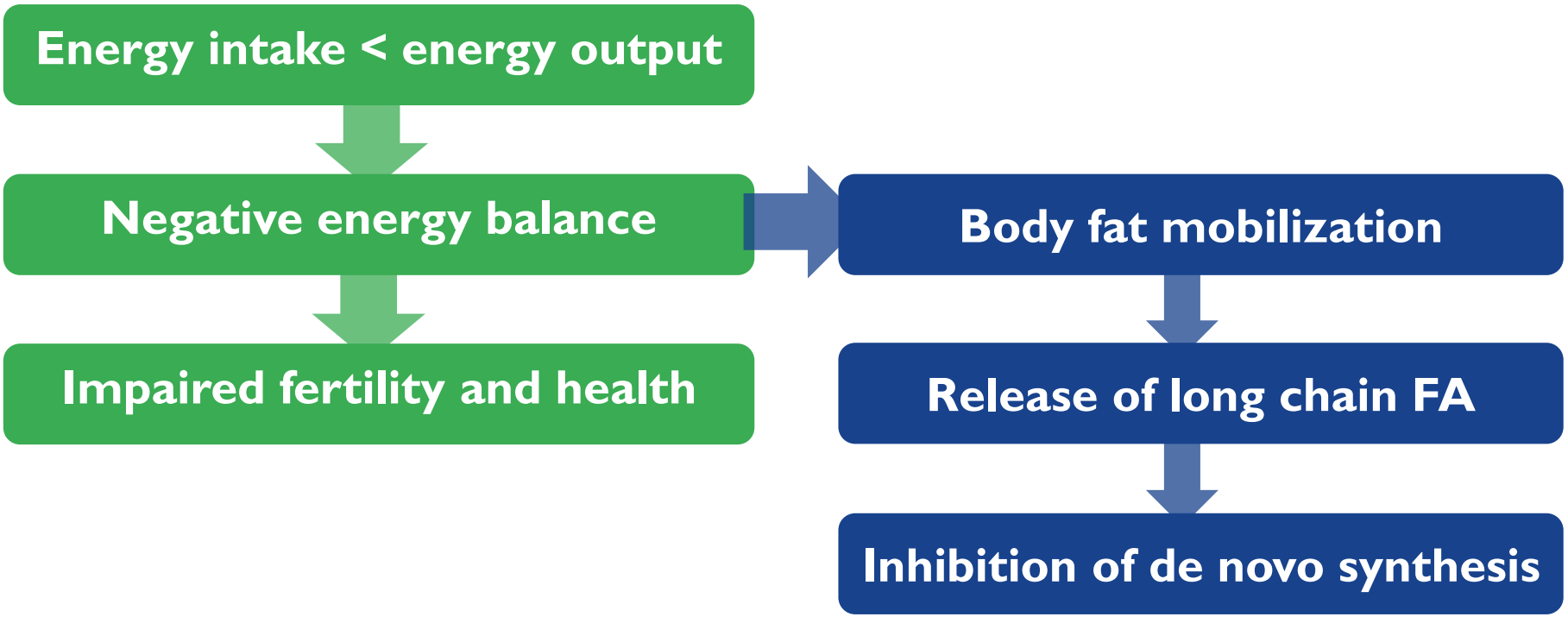
- Optimal fertility is vital for profitable dairy production systems but ... it has declined over the past decades.
- Achieve optimal fertility through direct genetic selection?
  - Genetic variation exists …
  - But:
    - difficulty in collecting direct relevant fertility records
    - long time required to validate data
    - low heritability (1-5%) Veerkamp and Beerda, 2007, Theriogenology
      - low accuracy of estimated breeding values
      - reduction of the overall response to selection

⇨ Indirect selection for fertility based on indicator traits

⇨ Milk FA as indicator traits for fertility?

FA as indicators of fertility?

In early lactation …



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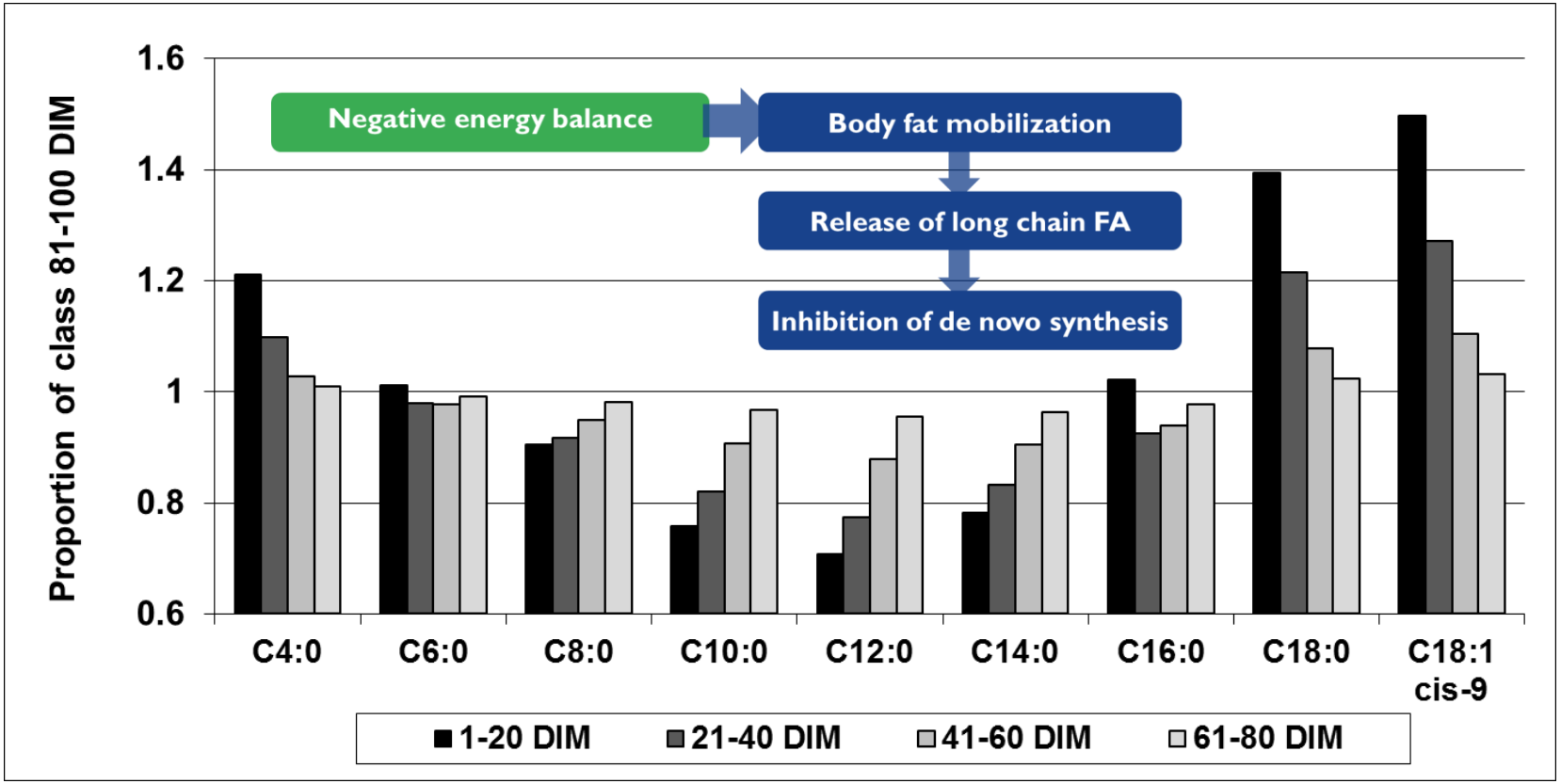
Gross et al. 2011. J. Dairy Res. 78:479.
Van Haelst et al. 2008. J. Dairy Sci. 91:4683-4686.

FA as indicators of fertility?

Variation of milk FA contents in early lactation

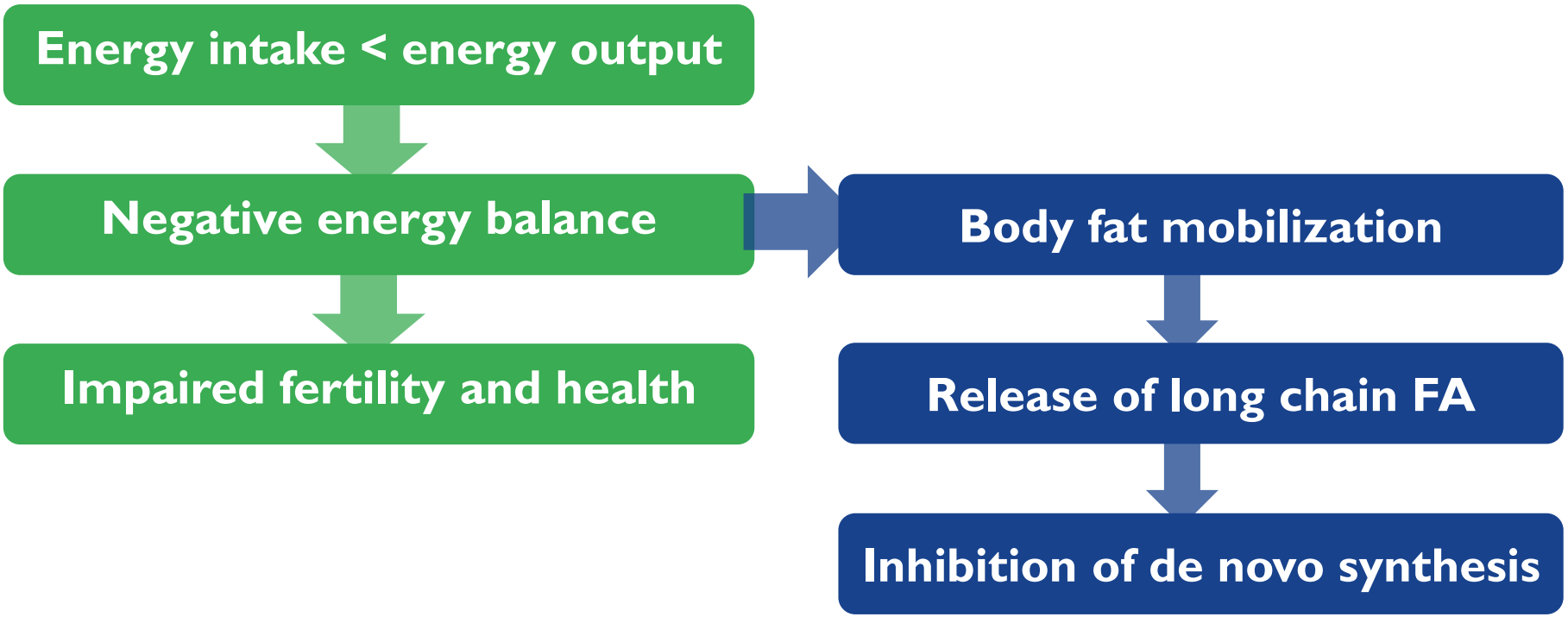


DIM = days in milk

Bastin et al., 2011, J. Dairy Sci., 94:4152-4163

FA as indicators of fertility?

In early lactation …



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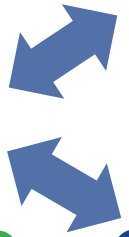


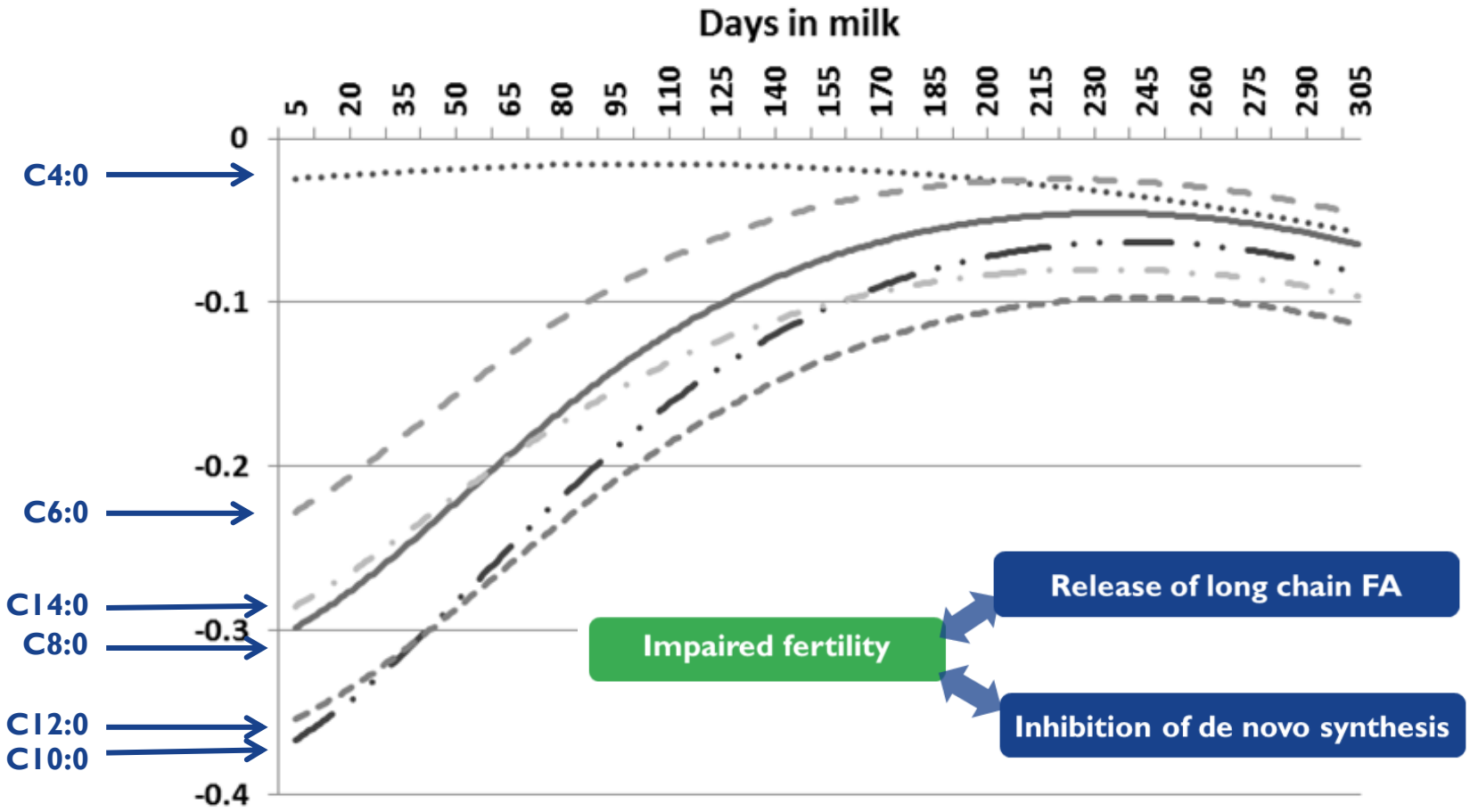
Impaired fertility and health

Release of long chain FA

Inhibition of de novo synthesis

FA as indicators of fertility?

Genetic correlations between days open and FA contents in milk



Bastin et al., 2012, J. Dairy Sci., 95:6113-61211

FA as indicators of fertility?

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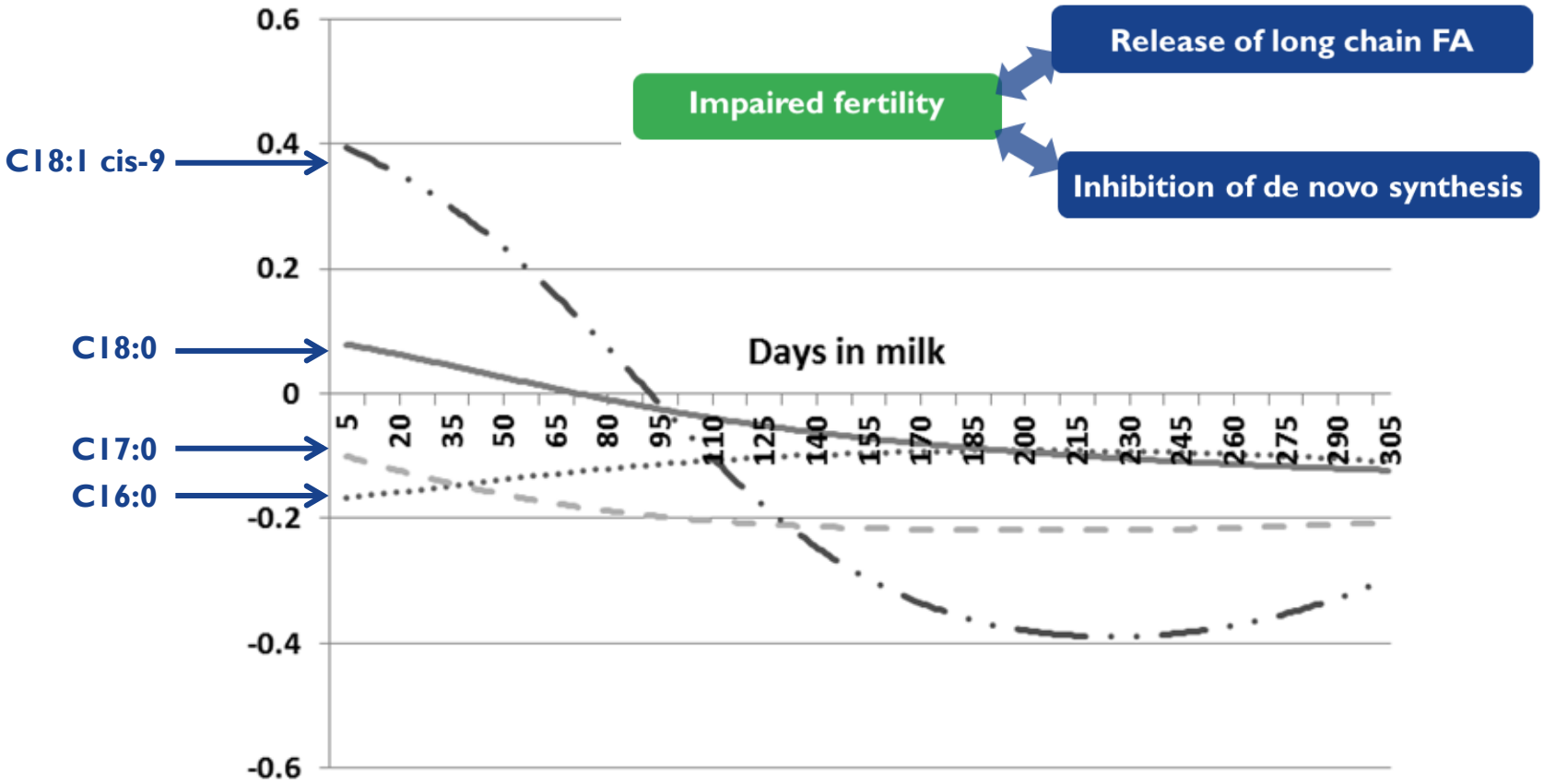

Bastin et al., 2012, J. Dairy Sci., 95:6113-61211

FA as indicators of fertility?

⇨ C18:1*cis*-9 in early lactation → good indicator of fertility

↳ What would be the benefit?

Parameter	Days open	C18:1 *cis*-9 at 5 DIM (g/dl)
Genetic standard deviation	18.432	0.07667
Heritability	0.05	0.13
Repeatability	-	0.63
Genetic correlation with days open	-	0.39
Phenotypic correlation with days open	-	0.04

Parameters obtained from 1st parity Walloon Holstein cows
DIM = days in milk

Accuracy of an index for fertility including various traits estimated for a bull having a varying number of daughters with records

Trait(s) in the index	Accuracy of the index		
	p=20	p=100	p=200
Days open	0.46	0.76	0.86
C18:1 *cis*-9 at 5 DIM	0.28	0.36	0.38
Days open + C18:1 *cis*-9 at 5 DIM	0.51	0.78	0.86

Bastin et al., 2013, PhD thesis

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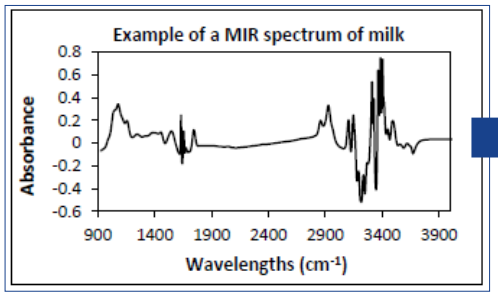
Genetic selection to alter milk FA?

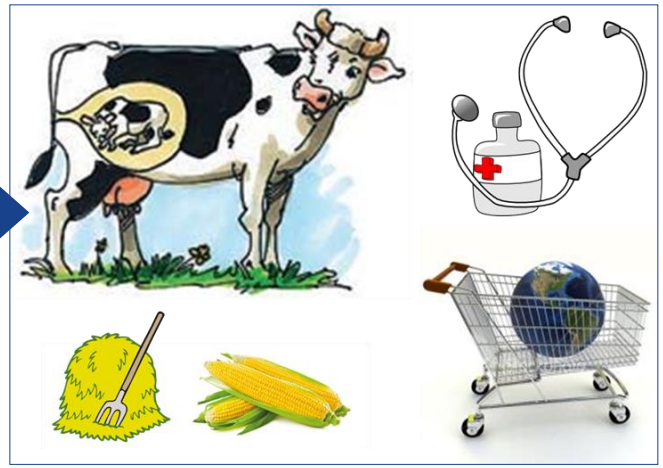
- Milk FA fulfill the conditions but …
- Desirable direction and importance of change should be defined.
  - ⇨ Example of C18:1 *cis*-9
    - High C18:1 *cis*-9 → desirable for human health
    - High C18:1 *cis*-9 in early lactation → poor fertility
    - But there is an opportunity to select for low content in milk of C18:1 *cis*-9 in early lactation with limited impact on average MUFA
- Relationships with other traits should be verified.
- Overall breeding goal should be defined.

Getting more out of milk?

- Variety of interesting milk components
  - e.g., lactoferrin
- Using directly the mid-infrared spectrum?
  - spectrum = fingerprint of the whole milk composition

↳ The spectrum may provide information on fertility, health, feeding, and environmental impact of dairy cows.





Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
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INTERREG IVB

Summary

- Why looking into milk FA?
  - Nutritional, sensory and technological quality of milk
  - Related to cow robustness
- Conditions are fulfilled:
  - Measurable → mid-infrared spectrometry
  - Variable and heritable
  - Economic interest
  - Indicator traits for energy balance and fertility
  - But overall breeding goal should be defined.
- Wide range of investigations for milk-based traits to improve the quality of dairy products and the robustness and productivity of cows producing them

Thank you for your attention!

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