Feasibility of a Genetic Evaluation for Milk Fatty Acids in Dairy Cattle

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Introduction

- Why genetic evaluation for fatty acid (FA) contents in milk?
  - Human health:
    - The consumption of most of saturated FA seems to be related to cardiovascular diseases, cancers, and diabetes.
  - Economic interest:
    - Recently, one dairy company present in Belgium and in the Netherlands gives a subsidy to farmers who produce milk with higher unsaturated fatty acid contents in milk fat

Introduction

- Why not before?
  - Expensive chemical analysis
    - Gas chromatography analysis
  - Mid-infrared (MIR) spectrometry (Soyeurt et al., 2006 to 2010):
    - Fast analysis (up to 500 samples/hour)
    - Cheap analysis
    - Used in routine milk recording
    - Presentation on Wednesday at 11:00 am

Data

- Data collected during the routine milk recording of the Walloon part of Belgium
- MIR Prediction of FA:
  - All spectra generated by the routine infrared analysis are recorded in a database
  - Equations were those obtained through the European project RobustMilk (www.robustmilk.eu) and shown in the presentation shown on Wednesday at 11:00am

Data

- MIR predictions of FA in milk (Soyeurt et al., 2010):

g/dl of milk	R^2cv	SECV	RPD
Saturated FA	1.00	0.05	15.7
Monounsaturated FA	0.99	0.04	8.9

R^2cv = cross-validation coefficient of determination; SECV = standard error of cross-validation; RPD= the ratio of standard deviation of reference values to the standard error of cross-validation

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FAT CONTENT (100%):

- Saturated FA (+/- 65%)
- Unsaturated FA (+/- 35%)
  - Monounsaturated FA (+/- 30%)
  - Polyunsaturated FA (+/- 5%)

Methods

First dataset

Data

	Data from January 1974 to December 2009		
	N	Mean	SD
Milk yield (kg/day)	6730744	16.95	6.83
Fat yield (kg/day)	6728499	0.68	0.29
Protein yield (kg/day)	6709030	0.56	0.22
Saturated FA (g/dl of milk)	206990	2.79	0.50
Monounsaturated FA (g/dl of milk)	206997	1.15	0.24

Cows in first lactation

Data

- 4 separated files with similar number of:
  - Cows
  - Data
- Variance components were estimated by Gibbs sampling (gibbs1f90 program (Misztal,2010))
- Variance components used were the average of obtained estimates

Methods

First dataset

↓

Modified blupf90 program

Multiple trait random regression model

- milk yield
- fat yield
- protein yield
- saturated FA in milk
- Monounsaturated FA in milk

Model used in the routine Walloon genetic evaluation for production traits (www.elinfo.be)

See the following presentation of Arnould et al. about the robustness of this model to study FA traits

Methods

First dataset

Modified blupf90 program

Estimated breeding values (EBV)
+ reliabilities (REL)

Methods

First dataset

Modified blupf90 program

Estimated breeding values (EBV)
+ reliabilities (REL)

Second dataset

Data

	Data from Januray 1974 to February 2010		
	N	Moyenne	Ecart-type
Milk yield (kg/day)	6749239	16.96	6.83
Fat yield (kg/day)	6746993	0.68	0.29
Protein yield (kg/day)	6727524	0.56	0.22
Saturated FA (g/dl of milk)	220397	2.79	0.49
Monounsaturated FA (g/dl of milk)	220396	1.15	0.24

Cows in first lactation

Methods

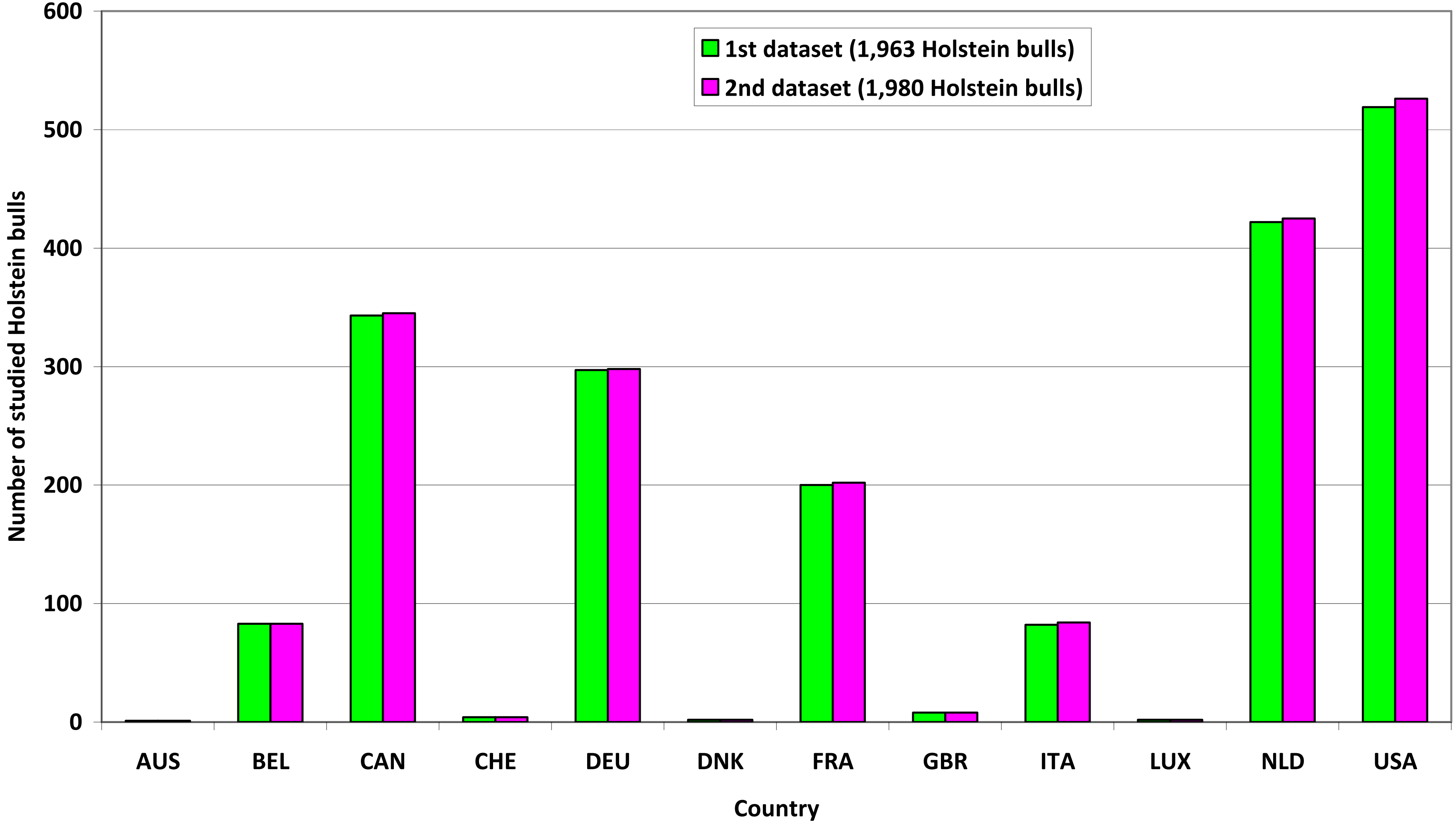
First dataset → Modified blupf90 program → Estimated breeding values (EBV) + reliabilities (REL)

Second dataset → Modified blupf90 program → Estimated breeding values (EBV) + reliabilities (REL)

Methods

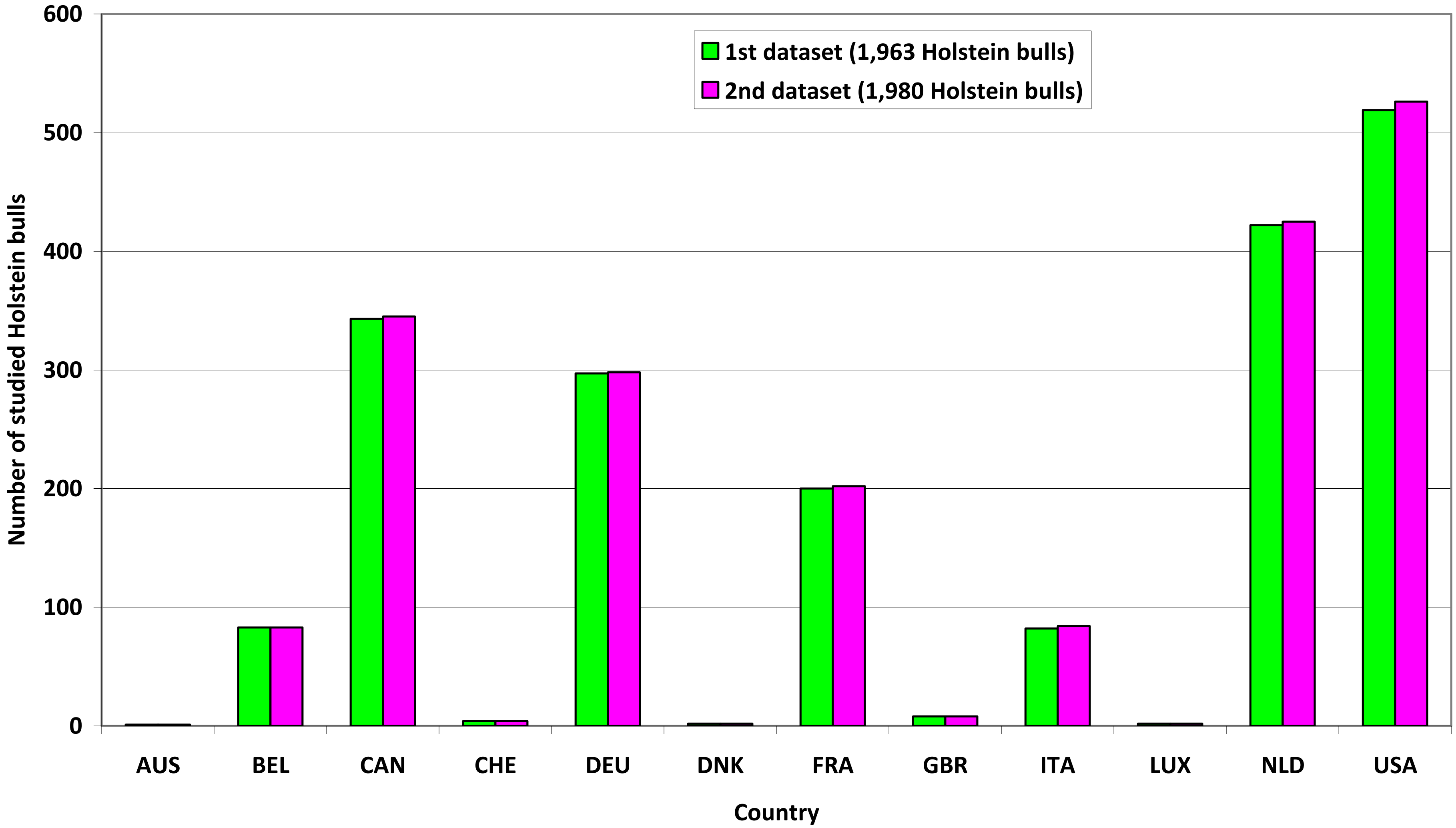
1,963 Holstein bulls with REL ≥ 0.40	1,980 Holstein bulls with REL ≥ 0.40
First dataset	Second dataset
↓	↓
Modified blupf90 program	Modified blupf90 program
↓	↓
Estimated breeding values (EBV) + reliabilities (REL)	Estimated breeding values (EBV) + reliabilities (REL)

Country origin of studied Holstein bulls with REL ≥ 0.40

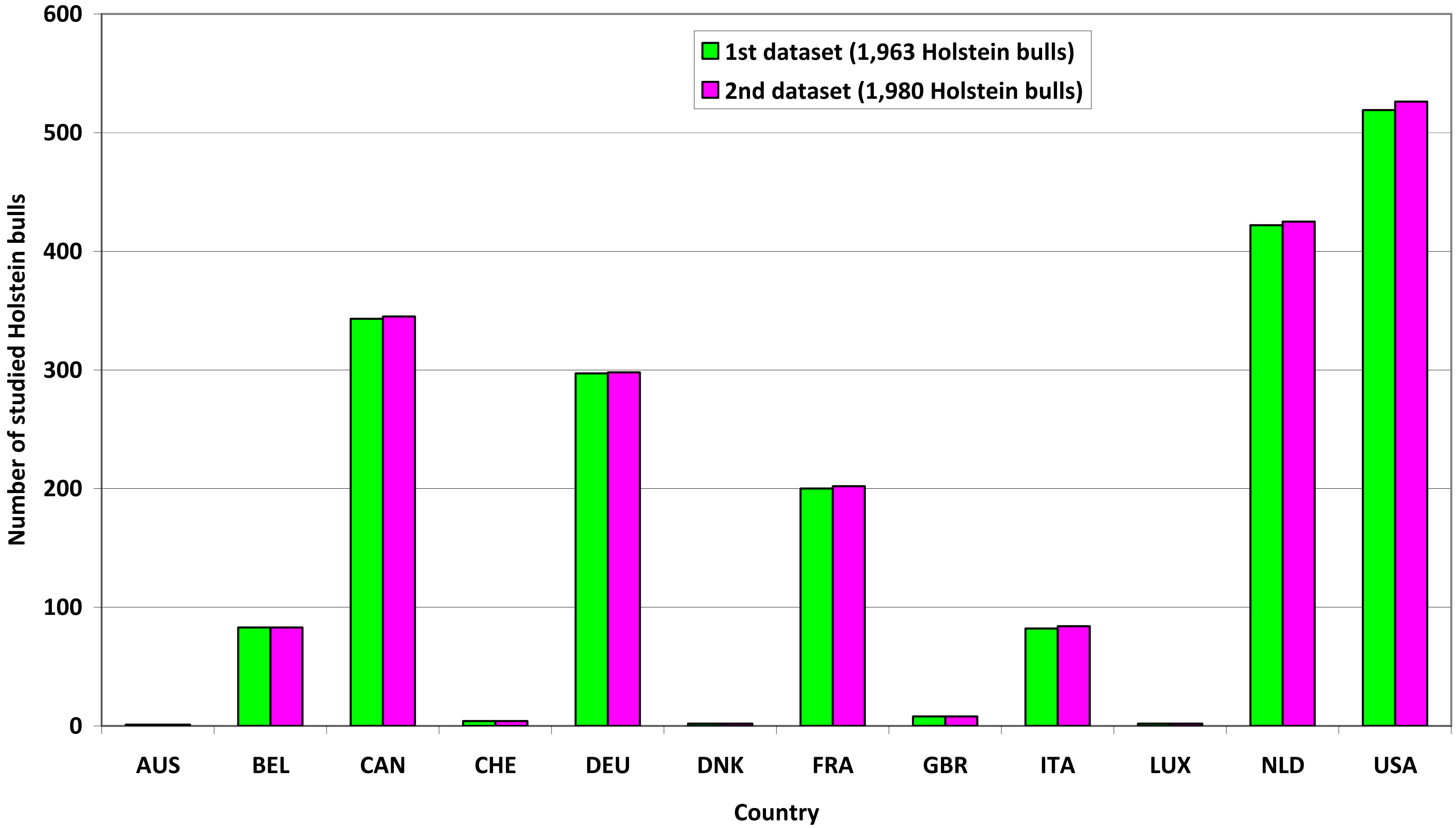


Thanks to the addition of new FA data, the number of bulls with REL ≥ 0.40 increased

Country origin of studied Holstein bulls with REL ≥ 0.40



Thanks to the addition of new FA data, REL increased. More than 100 bulls had an increased REL (≥0.01). Maximum increases were 0.09 for SAT and 0.13 for MONO.



MIR FA Predictions

- MIR predictions of FA in milk (Soyeurt et al., 2010):

g/dl of milk	R^2cv	SECV	RPD
Saturated FA	1.00	0.05	15.7
Monounsaturated FA	0.99	0.04	8.9

R^2cv = cross-validation coefficient of determination; SECV = standard error of cross-validation; RPD= the ratio of standard deviation of reference values to the standard error of cross-validation

- Lower ability to predict FA in fat by MIR
- High error to use directly the MIR fat and FA prediction in milk to express the FA content in fat

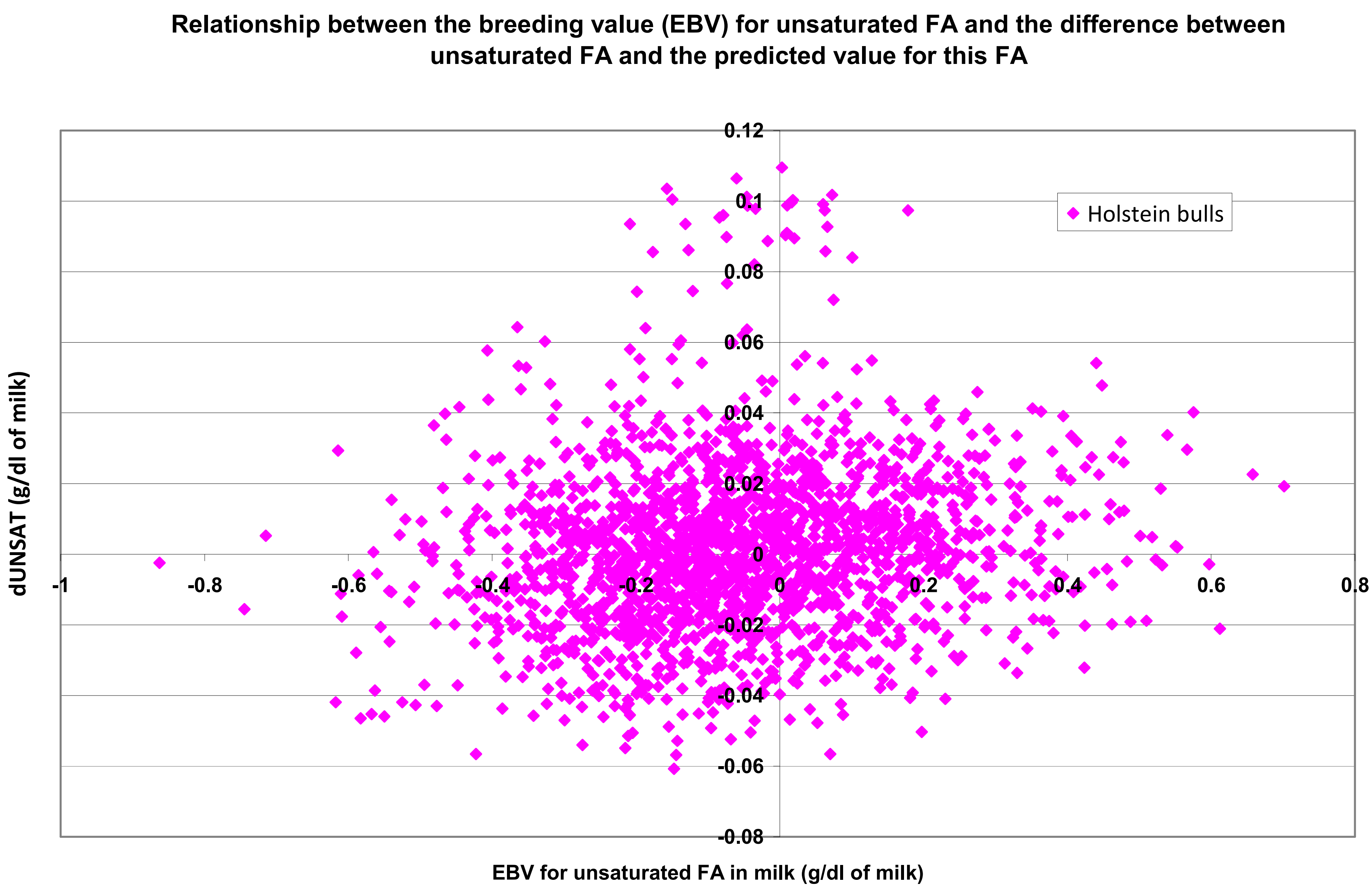
→ Post-treatment of results

Desaturation

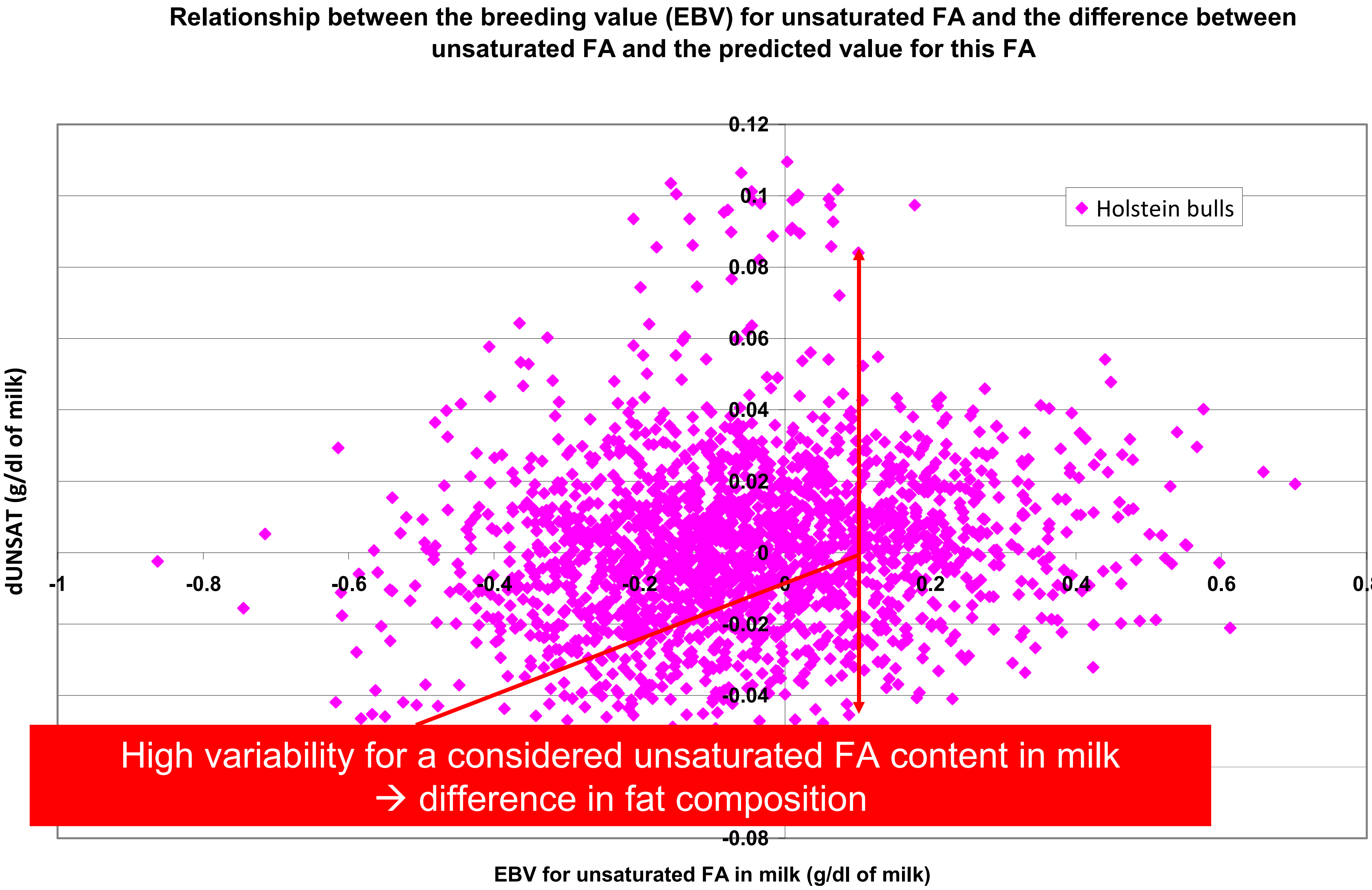
- Create indicators independent of %fat to represent the desaturation of fat
  - higher content of unsaturated FA in milk fat

➔ $dUNSAT = -(EBV_{SAT} - EBV_{SAT,expected})$

- $EBV_{SAT,expected}$ was estimated using coefficients calculated from the genetic variance components estimated for milk and fat yields
  - The similar coefficients were obtained by using EBV for milk and fat yields



EBV for unsaturated FA = - EBV for saturated FA



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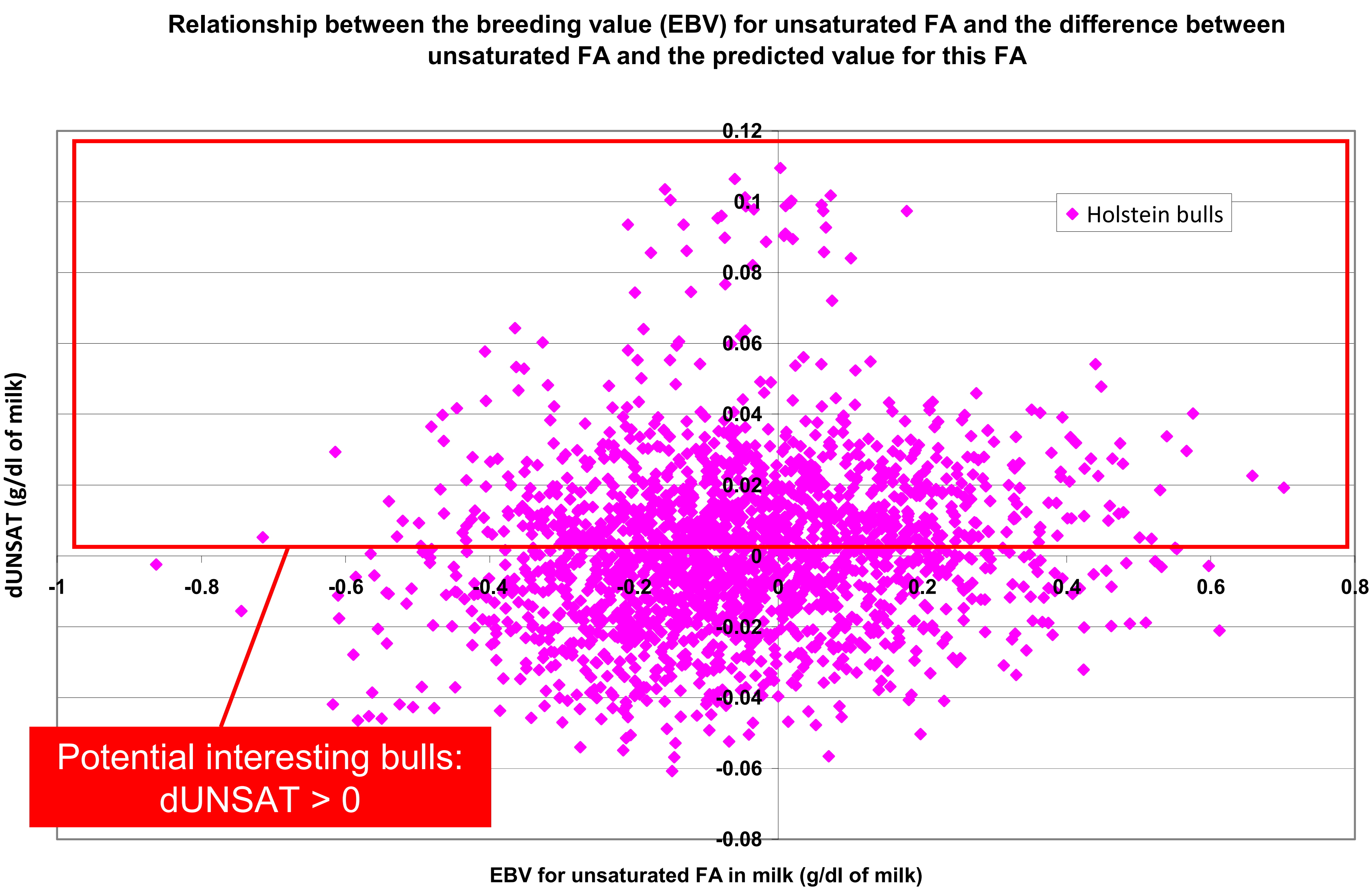


EBV for unsaturated FA = - EBV for saturated FA

Desaturation

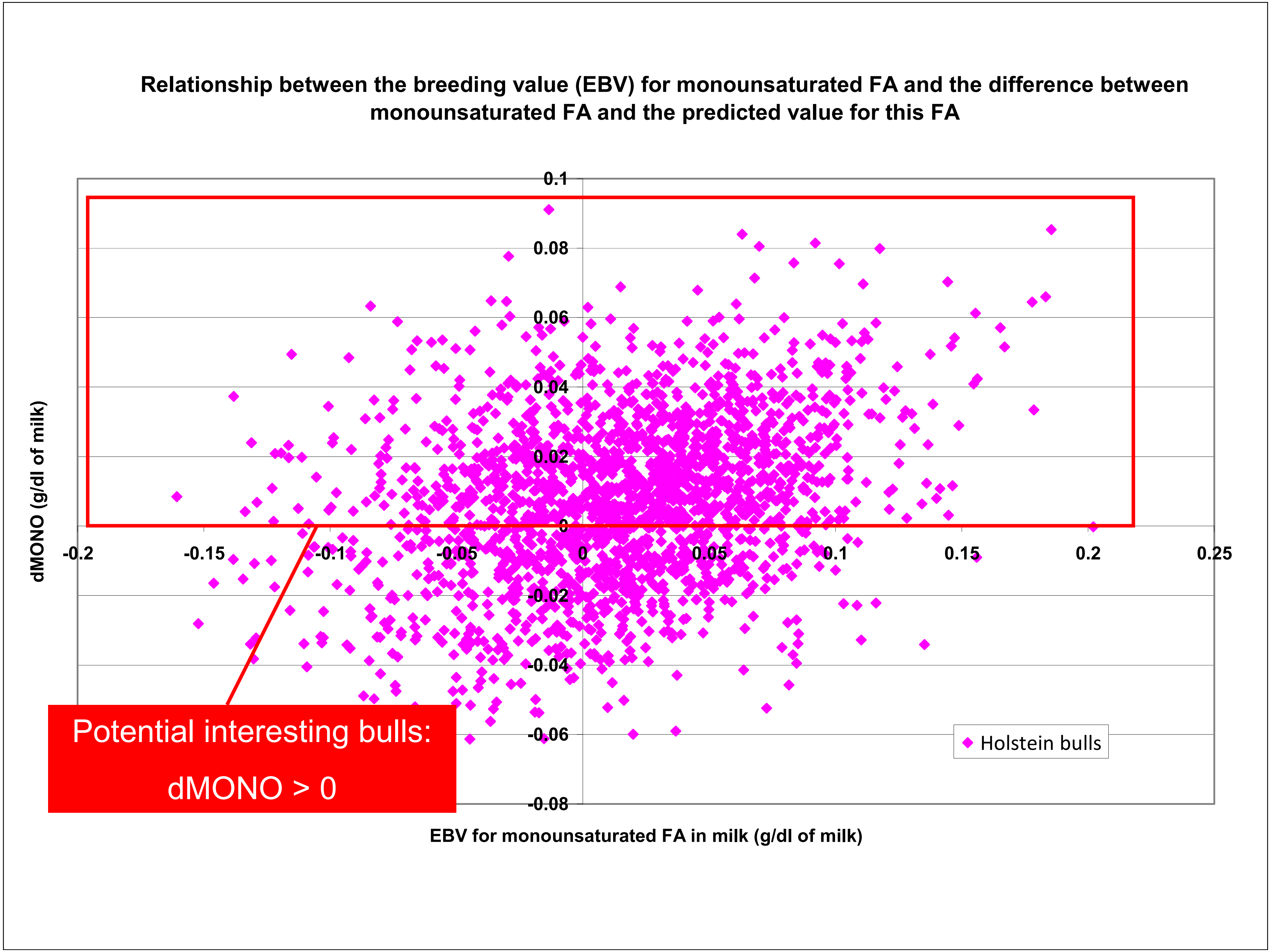
- Create indicators independent of %fat to illustrate the desaturation of fat
  - – higher content of unsaturated FA in milk fat

→ $dUNSAT = -(EBV_{SAT} - EBV_{SAT,expected})$

- $EBV_{SAT,expected}$ was estimated from the genetic variance components estimated for milk and fat yields

→ $dMONO = EBV_{MONO} - EBV_{MONO,expected}$

- $EBV_{MONO,expected}$ was estimated from the genetic variance components estimated for milk and fat yields


Relationship between the breeding value (EBV) for monounsaturated FA and the difference between monounsaturated FA and the predicted value for this FA
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
dMONO (g/dl of milk)
EBV for monounsaturated FA in milk (g/dl of milk)
Holstein bulls
Potential interesting bulls:
dMONO > 0

Heritability

- Heritability of studied traits for the 1st lactation

	h^2
Milk yield (kg/day)	0.31
Fat yield (kg/day)	0.33
Protein yield (kg/day)	0.25
Saturated FA (g/dl of milk)	0.61
Monounsaturated FA (g/dl of milk)	0.51
dUNSAT (g/dl of milk)	0.22
dMONO (g/dl of milk)	0.43

Correlations

- Genetic (above the diagonal) and phenotypic (below the diagonal) correlations among studied traits

	Milk	Fat	Protein	SAT	MONO	dUNSAT	dMONO
Milk yield		0.57	0.83	-0.42	-0.41	0.00	0.00
Fat yield	0.78		0.70	0.50	0.38	0.00	0.00
Protein yield	0.93	0.84		-0.11	-0.11	0.09	0.05
Saturated FA	-0.32	0.34	-0.12		0.80	-0.11	-0.11
Monounsaturated FA	-0.33	0.23	-0.16	0.75		0.48	0.51
dUNSAT	-0.03	0.00	-0.01	-0.14	0.37		0.93
dMONO	0.00	0.05	0.01	-0.03	0.62	0.60	

Correlations

- Genetic (above the diagonal) and phenotypic (below the diagonal) correlations among studied traits

	Milk	Fat	Protein	SAT	MONO	dUNSAT	dMONO
Milk yield		0.57	0.83	-0.42	-0.41	0.00	0.00
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Saturated FA	-0.32	0.34	-0.12		0.80	-0.11	-0.11
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dUNSAT	-0.03	0.00	-0.01	-0.14	0.37		0.93
dMONO	0.00	0.05	0.01	-0.03	0.62	0.60	

The negative correlations confirmed that dUNSAT and dMONO represent the desaturation of fat (positive correlations with MONO)

Not more strongly negatively correlated because SAT is expressed in milk (g/dl of milk) and not in fat (g/100g of fat)

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As expected dUNSAT and dMONO are positively correlated

Not equal to 1 because dUNSAT takes into account the contents of polyunsaturated FA and MONO in fat

Comparison

- Comparison of ranking of bulls among the 2 datasets
  - Only bulls with REL $\geq$ 0.40 were studied

1963 common bulls	EBV from the 1st dataset			EBV from the 2nd dataset		
	SD	Minimum	Maximum	SD	Minimum	Maximum
Milk yield (kg/day)	477.15	-452.27	3135.00	482.80	-436.15	3172.00
Fat yield (kg/day)	16.62	-9.00	110.79	16.67	-8.87	110.98
Protein yield (kg/day)	13.30	-9.85	87.79	13.47	-10.47	88.95
SAT (g/dl of milk)	0.20	-0.70	0.87	0.20	-0.70	0.86
MONO (g/dl of milk)	0.05	-0.16	0.22	0.05	-0.16	0.20
dUNSAT (g/dl of milk)	0.024	-0.056	0.112	0.024	-0.061	0.109
dMONO (g/dl of milk)	0.023	-0.061	0.092	0.024	-0.063	0.091

Similar results from the 2 datasets

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Co

- Comparison of ranki
  - Only bulls with REL ≥

1963 common bulls	Spearman correlation
Milk yield (kg/day)	> 0.99
Fat yield (kg/day)	> 0.99
Protein yield (kg/day)	> 0.99
SAT (g/dl of milk)	> 0.99
MONO (g/dl of milk)	> 0.99
dUNSAT (g/dl of milk)	0.96
dMONO (g/dl of milk)	0.96

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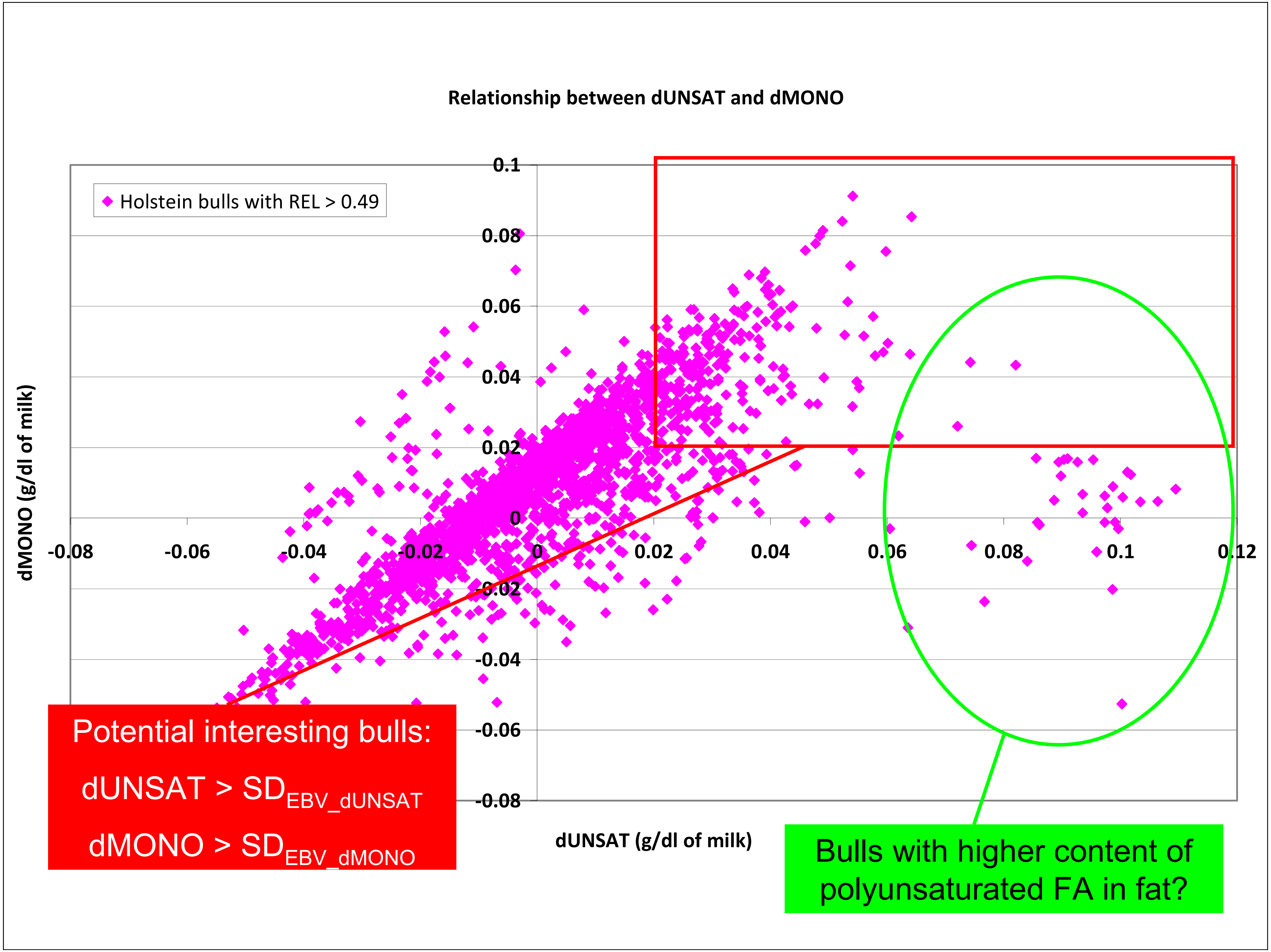
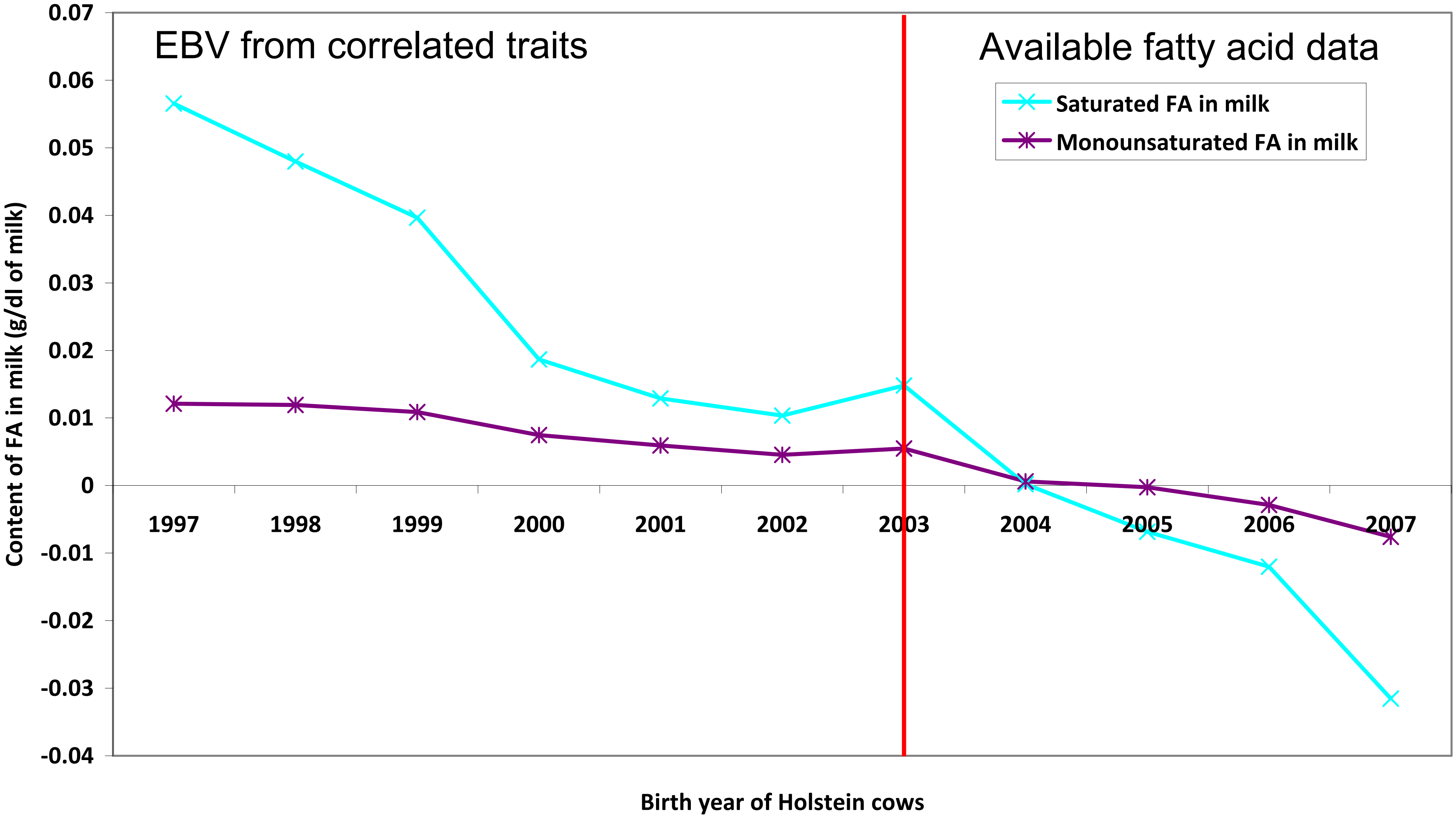
Large range of variation

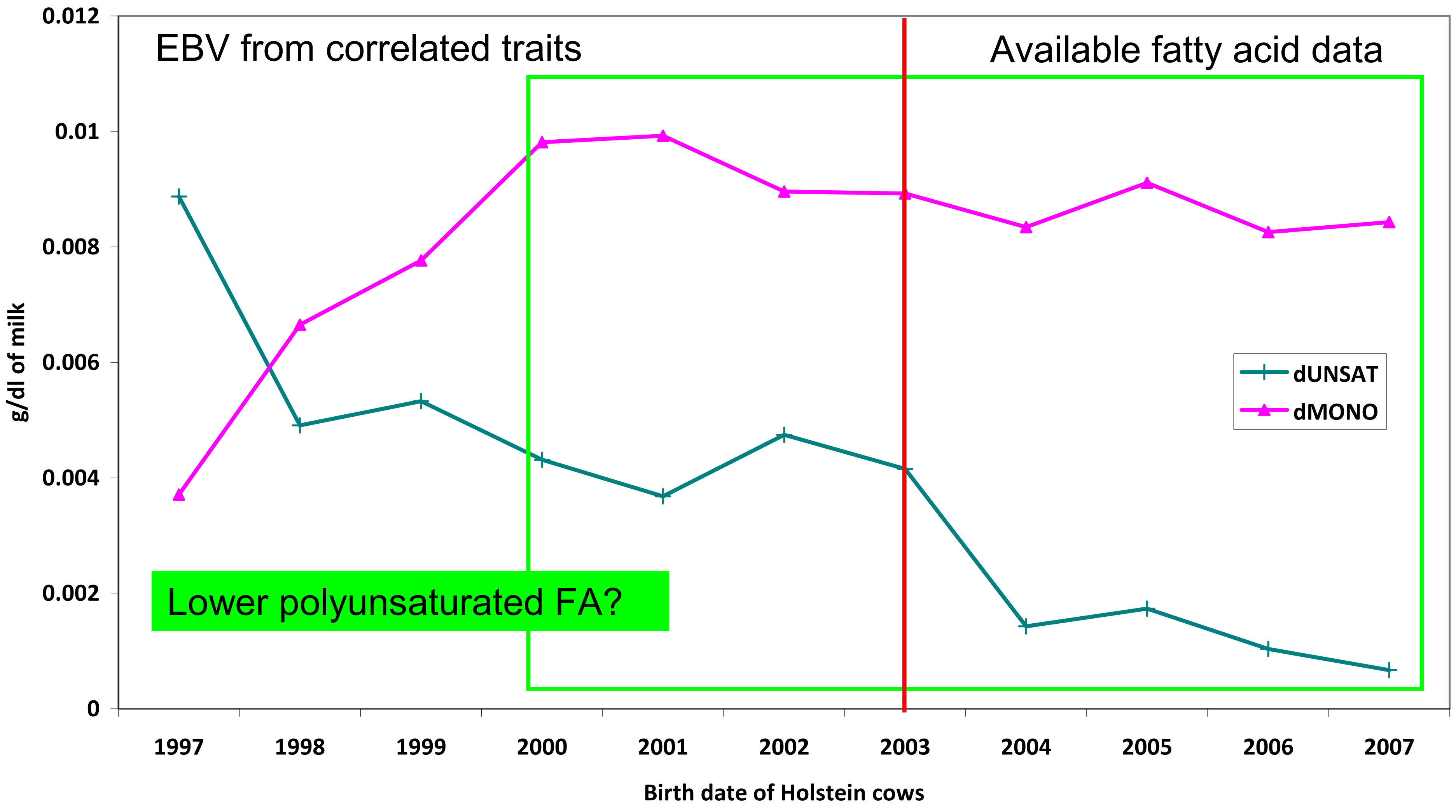

Relationship between dUNSAT and dMONO
Holstein bulls with REL > 0.49
dMONO (g/dl of milk)
dUNSAT (g/dl of milk)
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
Potential interesting bulls:
dUNSAT > SD_{EBV_dUNSAT}
dMONO > SD_{EBV_dMONO}
Bulls with higher content of polyunsaturated FA in fat?

Genetic trend of studied FA in milk from cows with production data



The decrease of SAT and MONO in milk is related to the decrease of %fat

Genetic trend for dUNSAT and dMONO from cows with production data



The increase of unsaturated FA in fat could be mainly related to the decrease of %fat

Conclusions

- Feasable selection for FA
  - Sufficient heritability
  - Sufficient existing variability
- What is the interest?
  - Improve the selection of bulls by taking into account the milk fat composition
  - By decreasing the fat content, the current genetic evaluation decreased the total content of UNSAT in milk but increased MONO in fat
    - However, polyunsaturated FA in milk fat decreased…

Future

- Increase the data available and re-run the calculation:
  - All spectral data generated by the Walloon routine milk recoring are recorded (on average 65,000 /month)
  - Addition of data for the second and third lactations
- Observe the impact of these new FA traits on traits with non-productive economic interest
  - First results showed a negative impact of dMONO on female fertility and a negative effect of dUNSAT on the longevity

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- Ministry of Agriculture of the Walloon Region of Belgium (projects D31-1207 and D31-1224/S1)
- European Commission, Directorate-General for Agriculture and Rural Development, under Grant Agreement 211708 (project Robustmilk).

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