Genetics of the Mineral Contents in Bovine Milk Predicted by Mid-Infrared Spectrometry

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Introduction

- Why genetic evaluation for mineral contents in milk?
  - Human Health:
    - Calcium (Ca): Osteoporosis
  - Animal Health:
    - Ca: milk fever
    - Na: milk fever, alkalosis, indicator of mastitis?
  - Potential Economic Interest:
    - Potential added value for dairy products with high content of Ca because specific food with addition of Ca exist

State of Art

- Why not before?
  - Expensive and time-consuming chemical analysis
  - Mid-infrared (MIR) spectrometry:
    - Fast and cheap analysis (up to 500 samples/hour)
    - Used in routine milk recording

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    - Used in routine milk recording
    - First results published by Soyeurt et al. (2009)

mg/kg of milk	N	Mean	SD	SEC	R^2c	SECV	R^2cv	RPD
Na	87	403	107	48	0.80	64	0.65	1.68
Ca	87	1,333	260	78	0.91	95	0.87	2.74
P	87	1,093	127	42	0.89	50	0.85	2.54
Mg	61	110	18	7	0.85	11	0.65	1.68
K	61	1,336	168	82	0.76	136	0.36	1.24

SEC= standard error of calibration; R^2c= calibration coefficient of determination; SECV= standard error of cross-validation; R^2cv= cross-validation coefficient of determination; RPD=SD/SECV

New Equations

- Milk samples collected in Belgium, Luxembourg, and France from various breeds between March 2005 and February 2012
- Analyzed using mid-infrared spectrometry and by ICP-AES (inductively coupled plasma atomic emission spectrometry)
- First derivative pre-treatment + Partial least squared regressions + T-outlier test to detect potential outliers

mg/kg of milk	N	Mean	SD	SEC	R^2c	SECV	R^2cv	RPD
Na	389	466.19	247.39	63.17	0.93	68.72	0.92	3.60
Ca	426	1176.90	163.71	44.90	0.92	48.58	0.91	3.37
P	433	1028.37	127.40	57.69	0.79	62.65	0.76	2.03
Mg	409	103.39	14.06	6.40	0.79	6.86	0.76	2.05
K	409	1511.33	166.94	87.52	0.73	93.55	0.69	1.78

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Data

- Records from first-parity Holstein cows:
  - > 989,000 records for common production traits
    - > 124,000 cows
  - > 176,000 records for predicted minerals and fatty acids (FA)
    - > 44,000 cows
- 4 separated files to limit the computation time

Data

Variable	Dataset 1 (314 herds)			Dataset 2 (307 herds)			Dataset 3 (315 herds)			Dataset 4 (297 herds)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Milk yield *(kg/day)*	248,450	22.66	5.94	238,637	23.15	6.08	246,859	22.39	6.03	255,778	23.07	6.19
Fat yield *(kg/day)*	248,450	0.91	0.24	238,637	0.92	0.24	246,859	0.89	0.24	255,778	0.91	0.24
Protein yield *(kg/day)*	248,450	0.75	0.18	238,637	0.77	0.19	246,859	0.74	0.19	255,778	0.76	0.19
Saturated FA *(SAT : g/dl of milk)*	36,892	2.78	0.49	33,691	2.81	0.49	37,390	2.80	0.49	35,068	2.79	0.48
Monounsaturated *FA* *(MONO : g/dl of milk)*	36,892	1.14	0.23	33,691	1.14	0.23	37,390	1.14	0.23	35,068	1.13	0.23
Na *(mg/kg of milk)*	44,705	515.02	181.16	41,020	507.34	184.13	46,048	510.58	181.98	43,663	510.29	182.59
Ca *(mg/kg of milk)*	45,664	1221.69	119.39	41,997	1227.34	119.59	47,169	1222.25	120.40	44,437	1221.98	119.70
P *(mg/kg of milk)*	45,773	1088.04	101.83	42,088	1097.37	103.03	47,296	1089.94	102.29	44,659	1089.67	102.34
Mg *(mg/kg of milk)*	45,867	106.62	8.57	42,156	107.11	8.70	47,368	106.65	8.68	44,756	106.53	8.66
K *(mg/kg of milk)*	45,664	1483.76	122.17	41,979	1483.62	121.92	47,203	1480.09	123.49	44,618	1485.58	122.35

Methods

- Single trait random regression test-day animal models inspired by the one used for the Walloon genetic evaluation for dairy production traits
- Variance components were estimated by REML (Misztal, 2009)
- Showed results were the average of obtained estimates

Heritability & Correlations

- Heritability (on the diagonal), correlations between breeding values (upper the diagonal) and observed correlations (below the diagonal)

	Ca	Na	Mg	K	P	Milk	Fat	Prot	SAT	MONO
Ca	**0.50**	-0.22	0.51	-0.42	0.43	-0.17	0.12	-0.05	0.27	0.25
Na	-0.21	**0.34**	-0.08	0.09	-0.44	0.09	-0.08	0.05	-0.16	-0.15
Mg	0.55	0.00	**0.52**	0.22	0.70	-0.18	0.05	-0.04	0.21	0.24
K	-0.46	0.49	-0.06	**0.48**	0.14	0.08	-0.10	0.03	-0.16	-0.14
P	0.51	-0.28	0.60	-0.06	**0.55**	-0.21	0.07	-0.07	0.25	0.29
Milk yield	-0.31	-0.04	-0.29	0.29	-0.05	**0.24**	0.43	0.90	-0.55	-0.55
Fat yield	-0.03	-0.07	-0.05	0.15	0.15	0.84	**0.19**	0.61	0.51	0.38
Prot yield	-0.14	-0.05	-0.03	0.22	0.18	0.93	0.85	**0.18**	-0.29	-0.25
SAT	0.52	0.00	0.40	-0.13	0.37	-0.29	0.20	-0.14	**0.59**	0.82
MONO	0.28	0.03	0.29	-0.38	0.11	-0.26	0.07	-0.22	0.26	**0.26**

Heritability & Correlations

- Daily heritability (on the diagonal), correlations between breeding values (upper the diagonal) and observed correlations (below the diagonal)

	Ca	Na	Mg	K	P	Milk	Fat	Prot	SAT	MONO
Ca	**0.50**									
Na		**0.34**								
Mg			**0.52**							
K				**0.48**						
P					**0.55**					
Milk yield						**0.24**				
Fat yield							**0.19**			
Prot yield								**0.18**		
SAT									**0.59**	
MONO										**0.26**

Relatively high daily heritability for predicted minerals compared to the common dairy production traits

Heritability & Correlations

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K	-0.46	0.49	-0.06	**0.48**	0.14					
P	0.51	-0.28	0.60	-0.06	**0.55**					
Milk yield										
Fat yield										
Prot yield										
SAT										
MONO										

High correlations among Ca and P or Mg.
Ca, Mg and P are involved in the casein structure

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Fat yield	-0.03	-0.07	-0.05	0.15	0.15	0.84	**0.19**	0.61		
Prot yield	-0.14	-0.05	-0.03	0.22	0.18	0.93	0.85	**0.18**		
SAT										
MONO										

Stronger phenotypic relationship between milk and minerals compared to the genetic link

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SAT										
MONO										

No strong relation with fat yield

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Prot yield	-0.14	-0.05	-0.03	0.22	0.18	0.93	0.85	**0.18**		
SAT										
MONO										

Surprisingly, no strong relation between protein yield and Ca or Mg or P

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Prot yield	-0.14	-0.05	-0.03	0.22	0.18	0.93	0.85	**0.18**		
SAT										
MONO										

Smoothed by the negative correlation with milk for Ca, Mg, and P → positive link with protein content

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SAT										
MONO										

Not so clear at the phenotypic level…

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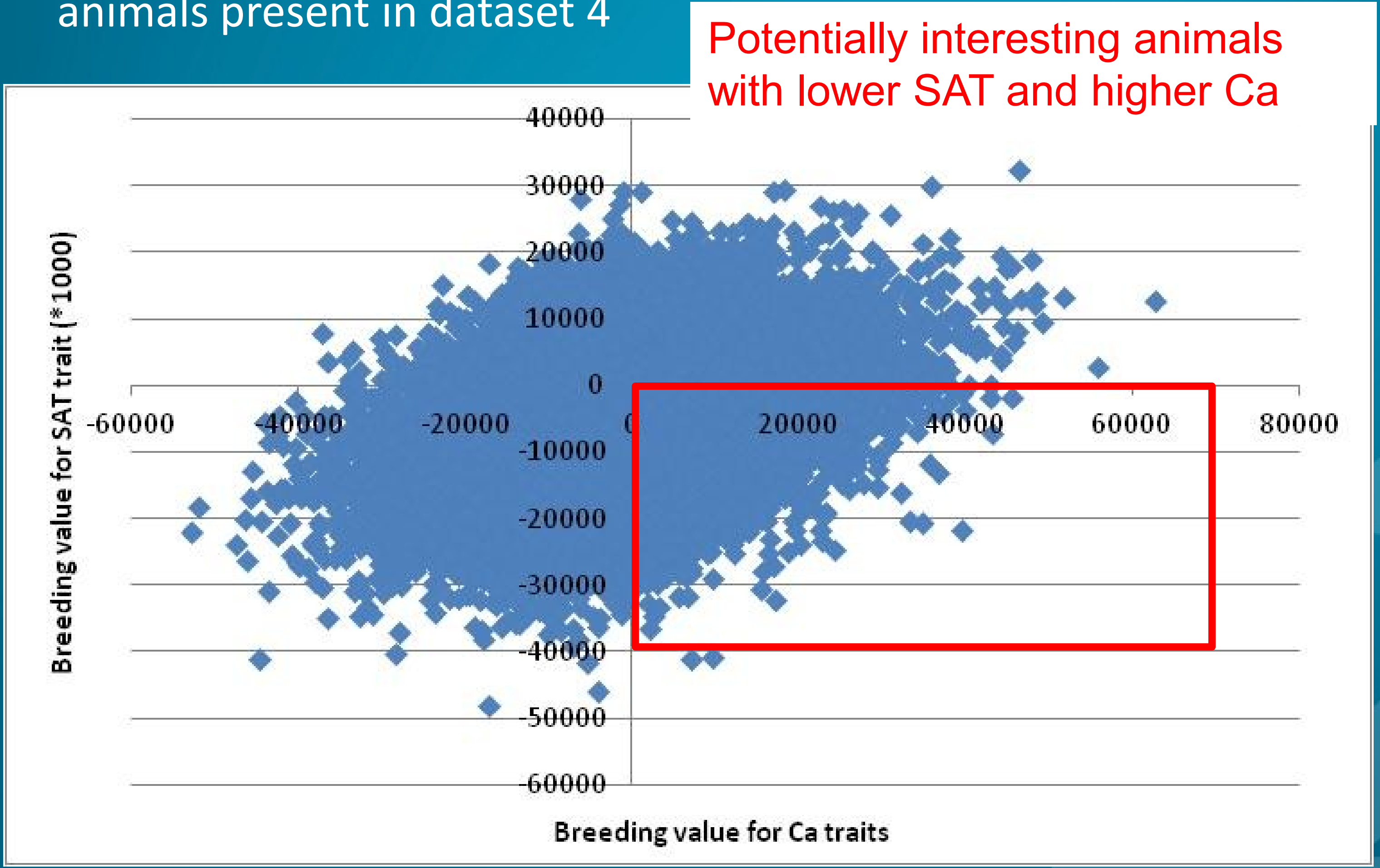
P									0.25	0.29
Milk yield									-0.55	-0.55
Fat yield									0.51	0.38
Prot yield									-0.29	-0.25
SAT	0.52	0.00	0.40	-0.13	0.37	-0.29	0.20	-0.14	**0.59**	0.82
MONO	0.28	0.03	0.29	-0.38	0.11	-0.26	0.07	-0.22	0.26	**0.26**

Positive correlations with SAT and MONO for Ca, Mg and P
→ increase of fat content

Heritability & Correlations

- Relationship between Ca and SAT breeding values obtained for studied animals present in dataset 4



Conclusions

- Calibration of major mineral by MIR spectrometry is feasible
- Mineral contents are heritable
- If we select to increase the Ca content in milk, we can expect:
  - A short decrease in milk yield
  - An increase of fat content
    - Stronger increase for the SAT content in milk compared to MONO BUT the correlation was not close to 1

Acknowledgement

- Walloon Breeding Association (AWE) and Milk Committee of Battice
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  - Organisme de Contrôle Laitier du Doubs et du Territoire de Belfort (OCL25)
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If you want to joint the consortium to improve the mineral equations:

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