Genetic parameters for major milk proteins in three French dairy cattle breeds

M. Brochard, M.P. Sanchez, A. Govignon-Gion, M. Ferrand, M. Gelé, D. Pourchet, G. Miranda, P. Martin, D. Boichard

Cniel · Institut de l'Elevage · INRA · France Conseil Elevage · Actilait · UNCEIA · Capgenes · CNBL · LABOGENA

www.phenofinlait.fr
phenofinlait@idele.fr

PhénoFinlait

Context

Expectations of consumers evolve:
Improve the human nutritional value and functionalities of cow milk
Common interest for Dairy industry, breeding and genetic sectors

Fine milk composition
Global approach (feeding, genetics…) to develop tools for breeders

Basis for genomic selection

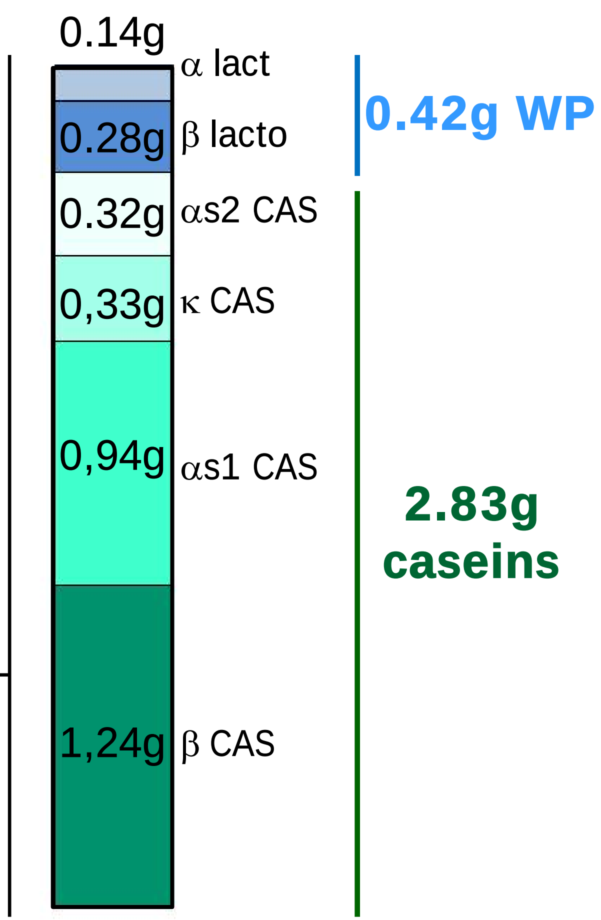
Record the data and estimate the genetic variability

A French dairy R&D project on fine milk composition PhénoFinlait

Protein composition (Montbeliard)

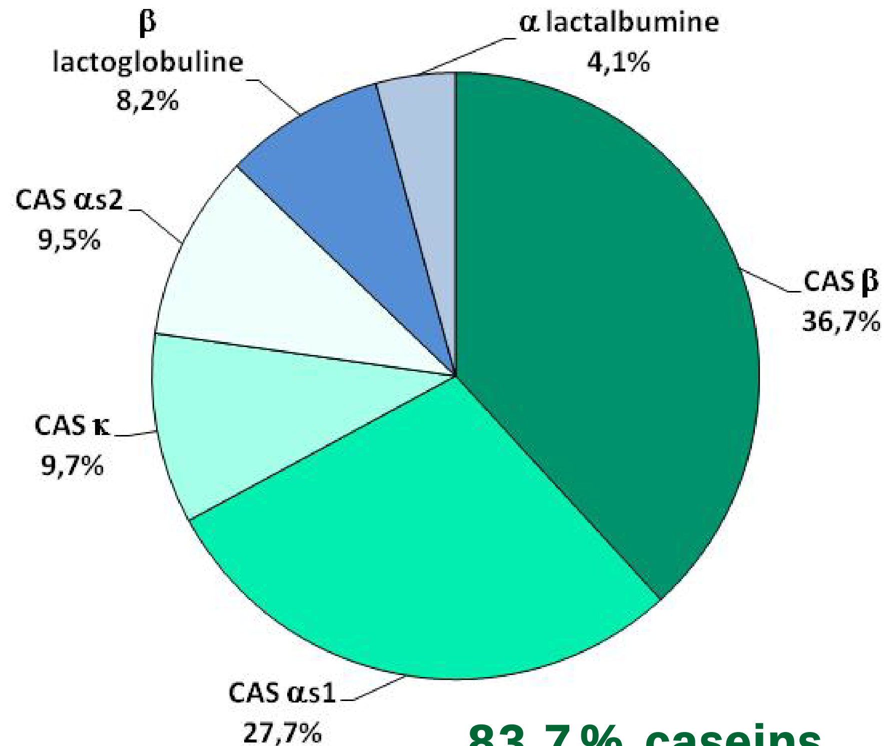
100g milk

3.37g proteins



100g proteins

12.3 % WP

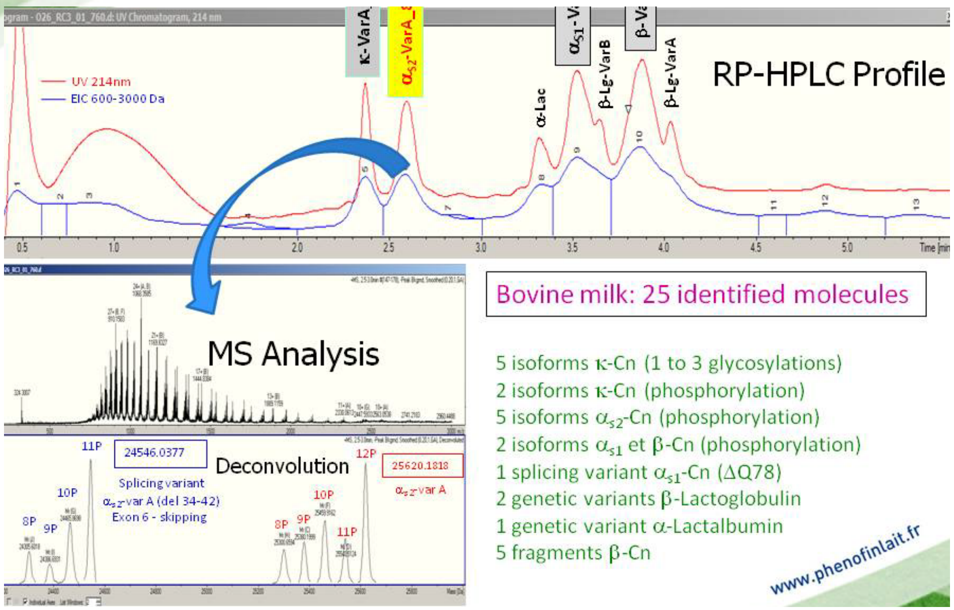


83.7 % caseins

Total Casein + Whey protein (WP) = 96% (≠100%) due to proteolyse
(10%, partly distributed over native proteins)

Broch

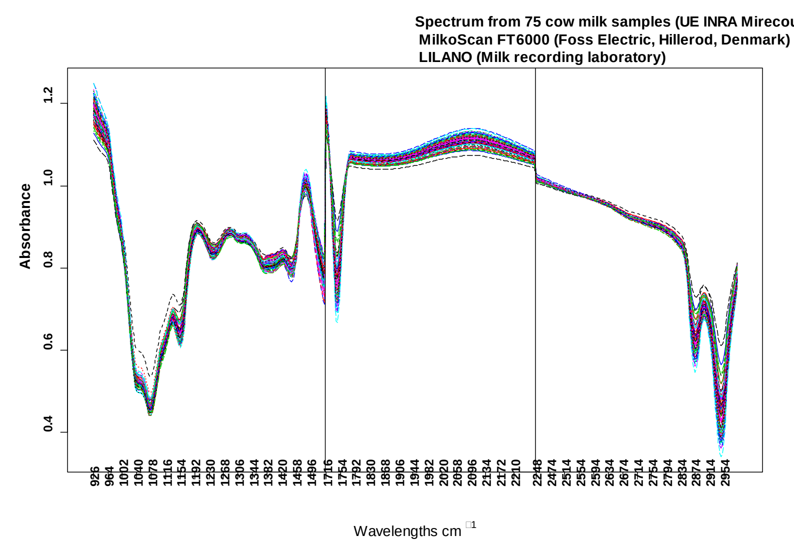
Main protein milk composition: analysis tools



« Reference » method (*Miranda et Martin, Inra-GABI*):
LC-MS: *liquid chromatography coupled with mass spectrometry*

Mid infrared spectra (**MIR**)
= large scale use for milk analysis (DHI): Fat and protein content.
« Easy » to implement, very few additionnal cost

(*Ferrand et al*)



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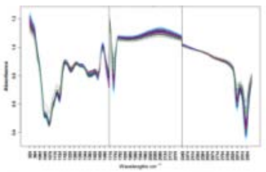
Milk protein composition at a large scale

MIR routinely collected



Equations

α-lactalbumin
β-lactoglobulin

αs1-casein
αs2-casein
β-casein
κ-casein

Whey proteins (WP)

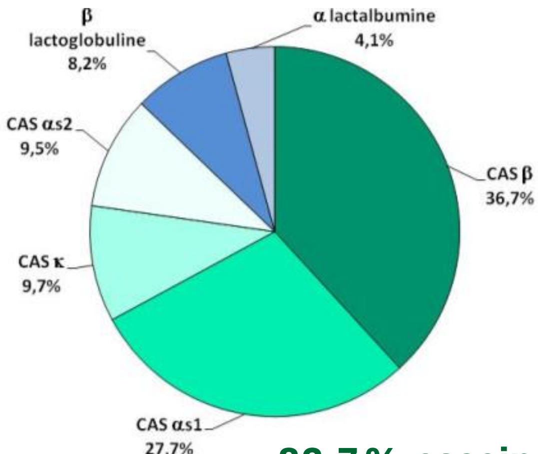
Caseins

in g/100g milk
= *% milk*

in g/100g protein
= *% protein*

12.3 % WP

100g proteins
ex. in Montbéliarde



83.7 % caseins

	R^2	Relative error
Caseins	80 - 92%	4 - 8%
WP	60 - 70%	12 - 14%

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Data

Breed	All lactations	1st lactations	
	MIR spectra	MIR spectra	Cow
Montbéliarde (MO)	589 016	181 515	36 042
Normande (NO)	117 323	37 668	9 668
Holstein (HO)	150 285	47 325	11 767
Total	856 624	266 508	57 477

Data for genetic parameters estimation

2 models & 2 softwares

Model 1
Test-day records

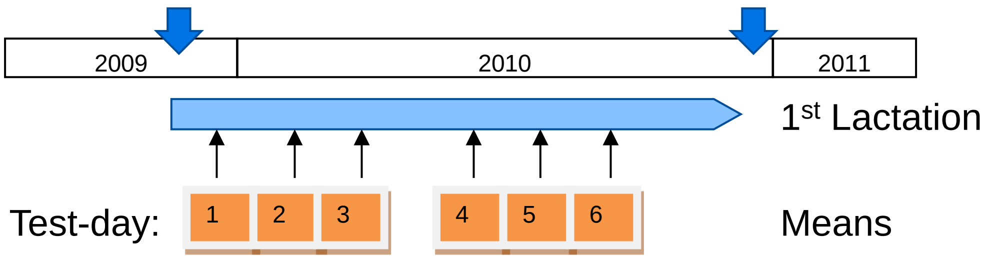
Model 2
Means over 1st lactation

WOMBAT
(Meyer et al., 2006)

REML
(Boichard et al., 1989)

Very similar results between models X softwares
→ model2 * REML is the fastest combination, efficient for genetic correlation computations (results shown thereafter)

Model 2 – means over 1st lactation



Means
At least 3 test-day NO & HO
At least 7 test-day MO

$$y = X\beta + Za + e$$

Fixed effects
herd
calving month_year
spectrometer

Random effects
animal $(0, \mathbf{G}\,\sigma_a^2)$
residual $(0, \mathbf{I}\,\sigma_e^2)$

Heritability estimates (%) – Montbéliard

	g /100g milk	g /100g prot
Total Casein	**57**	**73**
αs1 casein	54	67
αs2 casein	54	58
β casein	66	42
κ casein	48	61
Whey protein	**61**	**61**
α lactalbumin	57	72
β lactoglobulin	86	79

High h^2 estimates especially for β–lactoglobulin

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Heritability estimates (%) – Holstein

	g /100g lait	*g /100g prot*	*Schopen* et al. 2008 g / 100g prot*
αs1 casein	30	53	*47*
αs2 casein	29	31	*73*
β casein	27	39	*25*
κ casein	32	54	*64*
α lactalbumin	31	44	*55*
β lactoglobulin	61	71	*80*

** LC analysis method*

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Genetic coefficient of variation (σ_g/μ) % - Montbéliard

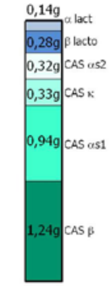
	g /100g prot	*g /100g milk*
Total Casein	**0,3**	**3,7**
αs1 casein	0,6	3,5
αs2 casein	0,9	4,2
β–casein	0,6	3,7
κ–casein	2,1	4,3
Whey protein	**3,0**	**5,6**
α-lactalbumin	2,8	4,5
β-lactoglobulin	6,4	8,6

Higher CV for proteins expressed in milk and for β–lactoglobulin

Genetic correlations – Normande

	α s1 cas	α s2 cas	β cas	κ cas	αlact	β lacto
α s1 casein		0.98	0.95	0.89	0.71	0.59
α s2 casein			0.96	0.92	0.69	0.57
β casein				0.85	0.68	0.58
κ casein					0.74	0.31
α lacta						0.27
β lacto						

g / 100 g milk



All genetic correlations >0

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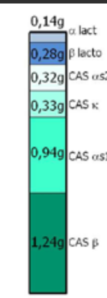
Genetic correlations – Montbéliard

	α s1 cas	α s2 cas	β cas	κ cas	αlact	β lacto
α s1 casein		0.94	0.96	0.84	0.69	0.51
α s2 casein			0.95	0.88	0.72	0.46
β casein				0.83	0.70	0.47
κ casein					0.80	0.10
α lacta						0.18
β lacto						

g / 100 g milk



The different caseins are highly correlated to each other
Co-regulations through BTA6 genes cluster?

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Genetic correlations – Montbéliard

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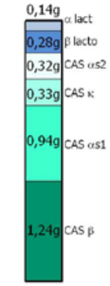
g / 100 g milk

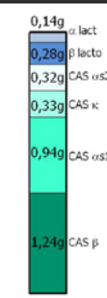


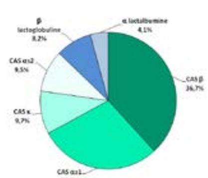
Moderate correlations between β lactoglobulin et caseins

Genetic correlations – Holstein

	α s1 cas	α s2 cas	β cas	κ cas	αlact	β lacto
α s1 casein		0.96	0.94	0.87	0.72	0.39
α s2 casein	0.04		0.95	0.88	0.71	0.39
β casein	-0.48	-0.37		0.84	0.75	0.39
κ casein	0.14	0.36	-0.31		0.80	0.07
α lacta	-0.01	-0.09	0.25	0.46		-0.01
β lacto	-0.19	-0.22	-0.20	-0.66	-0.52	

g / 100 g milk





g / 100 g proteins

Correlations = 0 or < 0 due to mathematical relationships (Σ = 100%!)

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Genetic correlations – Holstein

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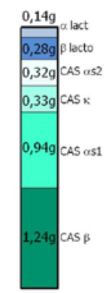
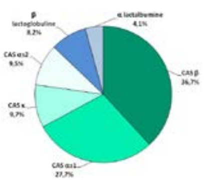
g / 100 g milk





g / 100 g proteins

β Lacto and caseins negatively correlated

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Conclusions

h^2 from MIR sepctra ≈ h^2 ref. meth. (LC)

→ **MIR spectra useful « phenotypes » for genetic selection**

High h^2 and genetic variability available

→ **For all proteins and especially for β lacto.**

Correlations >0 or <0 regarding unit

→ **All proteins linked to each other**

Genetic selection can modulate protein composition of cow milk, for instance it is possible to

↘ β lactoglobulin and ↗ several caseins at the same time

Next step

Genetic parameters estimation
Model improvement: Random Regression model to account for variation of genetic parameters along the lactation

QTL detection → SANCHEZ Marie-Pierre et al presentation,
"*Whole genome scan to detect QTL for major milk proteins in three French dairy cattle breeds*"

~8 000 cows in 3 breeds genotyped (Labogena)

7 500
54K snp chip
(Illumina)

+

500 7K snp chip (Illumina)
and imputation

Authors

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D Pourchet, P Martin, G Miranda, D Boichard

Acknowledgements:

to the **breeders** who participated to the project,

to the partners of the project, laboratories, manufacturers (Foss and Bentley), DHI and AI organizations which provided data and samples.

PARTNERS

Cniel · INSTITUT DE L'ELEVAGE · INRA · France Contrôle Laitier · Actilait · UNCEIA · Capgenes · CNBL Comité National Brebis Laitières · LABOGENA

FUNDINGS

ANR AGENCE NATIONALE DE LA RECHERCHE · APIS-GENE · FranceAgriMer · Liberté · Égalité · Fraternité République Française CasDAR

France Génétique Elevage · Liberté · Égalité · Fraternité RÉPUBLIQUE FRANÇAISE MINISTÈRE DE L'ALIMENTATION DE L'AGRICULTURE ET DE LA PÊCHE · IBiSA INFRASTRUCTURES BIOLOGIE SANTÉ ET AGRONOMIE

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