Food Quality symposium: Milk and meat product quality

Modeling and genetics of milk technological properties

Giovanni Bittante

Summary:

Introduction:

Importance of milk coagulation properties (MCP)
Defining MCP
Differences among breeds
Effect of genetic variants of milk proteins

Questions on heritability of MCP:

How much MCP are heritable?
Protein genetic variants affect heritability?
Instruments can affect estimates?
Which is the role of non-coagulating milk?
Which model for genetic evaluation?

Questions on correlations with other milk traits:

Are MCP phenotipically related to other traits?
Are MCP genetically related to other traits?

Problems and future prospects:

Molecular basis and genome wide applications
Summary of open problems
New modeling of curd firmness and new parameters
Prolonging and modeling observation time
MCP prediction by MIR spectra

Conclusions

Cheese making in brief...

1. PREPARATION OF MILK (heating and inoculum)
2. COAGULATION
3. DRAIN OF WHEY AND CURD CUTTING
4. (COOKING)
5. SOURING (brine bath or "dry")
6. MATURING & RIPENING

Cheese processing

Cheese yield

Cheese composition

Cheese quality

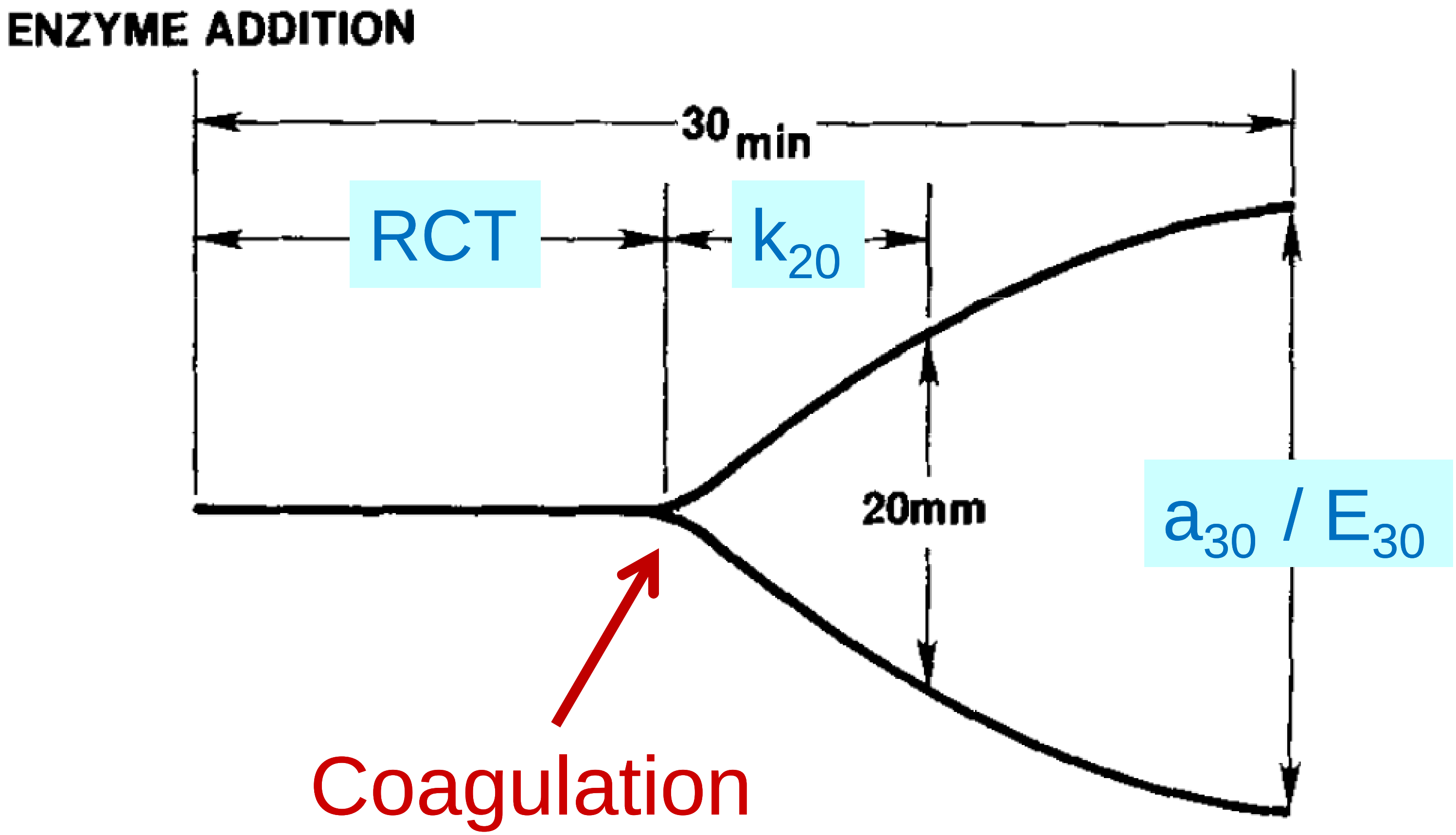
Cheese defects

PAYMENT SYSTEM

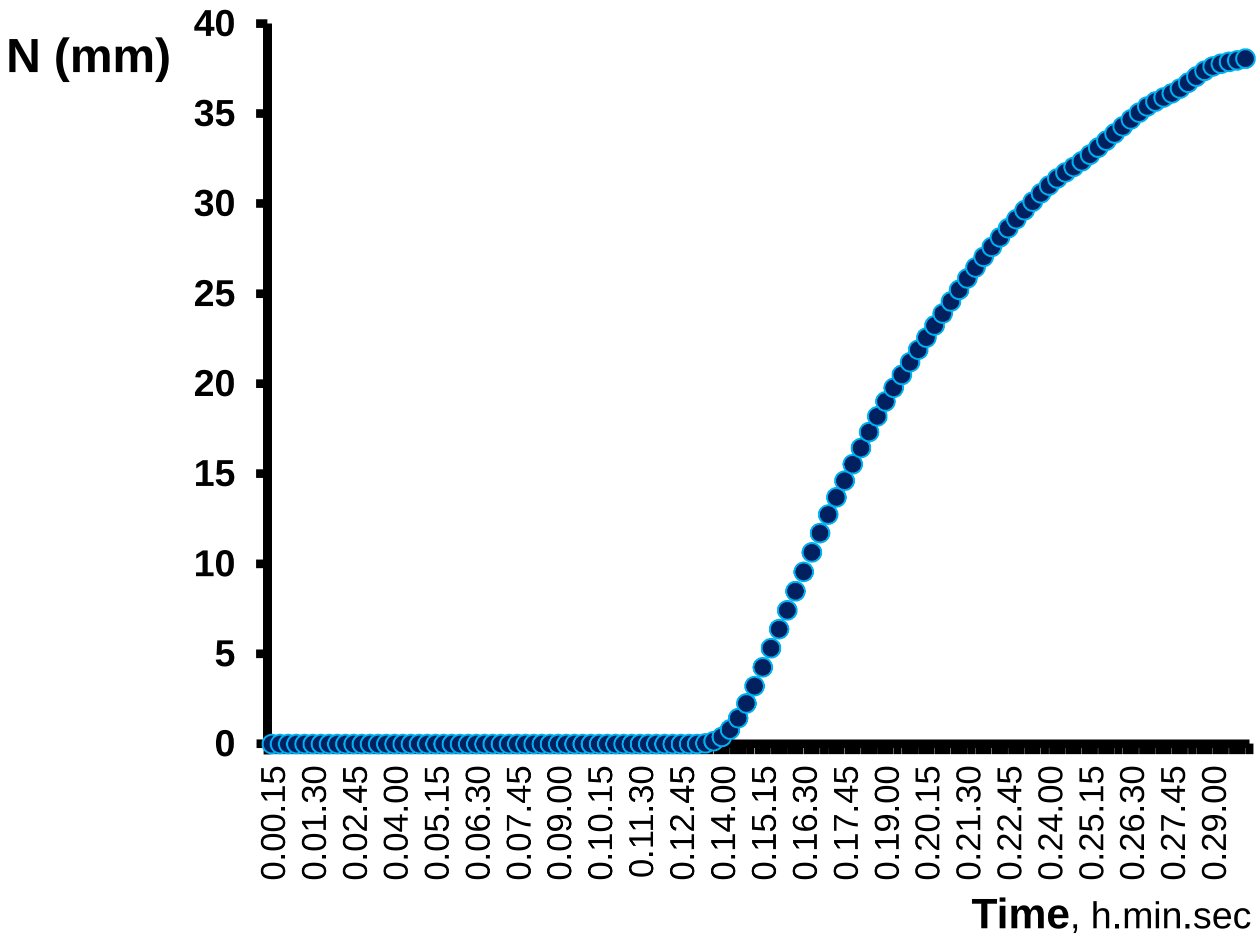
Computerized Renneting Meters

Diagram of coagulation and curd firmness

McMahon and Brown, 1982, J. Dairy Sci. 65:1639-1642



Output of CRM



Effect of breed on MCP

Breed:	Papers n	RCT min	k_{20} min	a_{30} min
Holstein Friesian	19	**14,7**	10,7	**29,6**
respect to HF:				
Ayrshire (Finnish)	6	**1,00**	1,09	**0,84**
Brown Swiss	6	**0,80**	0,70	**1,40**
Simmental/Montbeliarde	4	**0,74**	0,75	**1,18**
Jersey	2	**0,90**	0,80	**1,44**
Finncattle	3	**0,88**	1,01	**1,01**
Tarentaise	2	**0,80**	0,88	**1,08**
Rendena	2	**0,89**	0,72	**1,54**
Alpine Grey	1	**0,89**	0,93	**1,21**
Normande	1	**0,68**	0,45	**1,32**

Effect of protein genetic variants on MCP

Protein fraction:	Alleles n	Best allele for MCP
Caseins:		
α_{s1}-casein	9	-
α_{s2}-casein	4	-
β-casein	12	B
κ-casein	11	B
Whey proteins:		
β-lactoglobulin	11	B
α-lactoalbumin	3	-

Effect of β–κ casein on breed difference

Ikonen et al. 1999 J. Dairy Sci. 82:205-214

Finnish Ayrshire (789) - Holstein Friesian cows (86), 51 herds.

Model 1: MCP = DIM + Parity + Breed + Herd + a + e

Model 2: MCP = DIM + Parity + Breed + Herd +β–κcasein + a + e

Trait:	***Model 1***	***Model 2***	***Δ***
RCT, min	3,2**	2,0*	-38 %
a_{30}, mm	-9,8**	-7,8**	-20 %
Milk yield, kg	-2,5**	-2,3*	-8 %
Fat, %	0,36**	0,29*	-19 %
Protein, %	$0,01^{ns}$	$0,02^{ns}$	-
SCS	$-0,17^{ns}$	$-0,19^{ns}$	-
pH	0.02*	$0,01^{ns}$	-

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Model 2: MCP = DIM + Parity + Breed + Herd + β–κcasein + a + e

Trait:	***Model 1***	***Model 2***	***Δ***
RCT, min	Auldist et al., 2002: -37%		-38 %
a_{30}, mm	Auldist et al., 2002: -30%		-20 %
Milk yield, kg	Auldist et al., 2002; k_{20}: -55%		
Fat, %	0,36**	0,29*	-19 %
Protein, %	$0,01^{ns}$	$0,02^{ns}$	-
SCS	$-0,17^{ns}$	$-0,19^{ns}$	-
pH	0.02*	$0,01^{ns}$	-

Heritability of MCP and other milk traits

Trait:	Paper n	Average h^2 %	SD	Herd %
RCT, min	16	**29**	12	**5**
a_{30}, all samples	8	**28**	11	**7**
a_{30}, without NC	8	**29**	17	**5**
k_{20}, min	4	**35**	30	**2**
Milk yield, kg	11	**14**	8	**33**
Fat, %	10	**27**	13	**27**
Protein, %	10	**31**	7	**14**
Casein, %	7	**34**	9	**16**
pH	12	**20**	10	**11**
TA	4	**19**	3	**-**
SCS	9	**12**	11	**6**

Effect of β–κ casein on h^2 estimation

Penasa et al. 2010 J. Dairy Sci. 93:3346-3349
1,042 Holstein Friesian cows, 34 herds.
Model 1: MCP = Herd + DIM + Parity + a + e
Model 2: MCP = Herd + DIM + Parity + β–κcasein + a + e

Trait:	Δ σ^2_a %	h^2 % Model 1	h^2 % Model 2	h^2 % β–κ CN
Milk yield, kg	-4	7.0	6.9	0.1
Fat, %	+1	40.3	40.6	-0.3
Protein, %	-5	31.2	29.8	1.4
Casein, %	-4	34.4	33.3	1.1
SCS	-1	4.5	4.4	0.1
pH	-18	21.6	18.1	3.5
TA, SH°/50 ml	-23	19.5	15.4	4.1
RCT, min	-47	24.8	14.3	10.5
a_{30}, mm	-68	12.3	4.3	8.0

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Milk yield, kg	-4	7.0	6.9	0.1
Fat, %	+1	40.3	40.6	-0.3
Protein, %	-5	31.2	29.8	1.4
Casein, %	-4	34.4	33.3	1.1
SCS	-1	4.5	4.4	0.1
pH	-18	21.6	18.1	3.5
TA, SH°/50 ml	-23	[illegible]	[illegible]	1
RCT, min	-47	[illegible]	[illegible]	.5
a_{30}, mm	-68	[illegible]	[illegible]	0

-20% Ikonen et al. 1999

-24% Ikonen et al. 1999

MCP measurement by NIRS

Cecchinato et al. 2011 ADSA-ASAS JAM

913 Brown Swiss cows, 65 herds.

Form: RCT, k_{20} and a_{30} measured by Formagraph

Opti: RCT, k_{20} and a_{30} measured by Optigraph (NIRS)

Trait:	RCT:		a_{30} :		k_{20} :	
	Form	Opti	Form	Opti	Form	Opti
NC at 30 min, %	6,6	2,7				
Average value	19,9	19,0	28,2	26,6	5,6	8,2
σ^2_a	6,7	4,5	25,7	24,4	2,1	3,5
σ^2_h	3,9	1,9	7,0	10,3	0,4	0,5
σ^2_e	19,5	10,8	91,3	80,3	10,2	5,2
h^2, %	22	25	20	21	16	38
r_p	80		70		56	
r_g	96		87		83	

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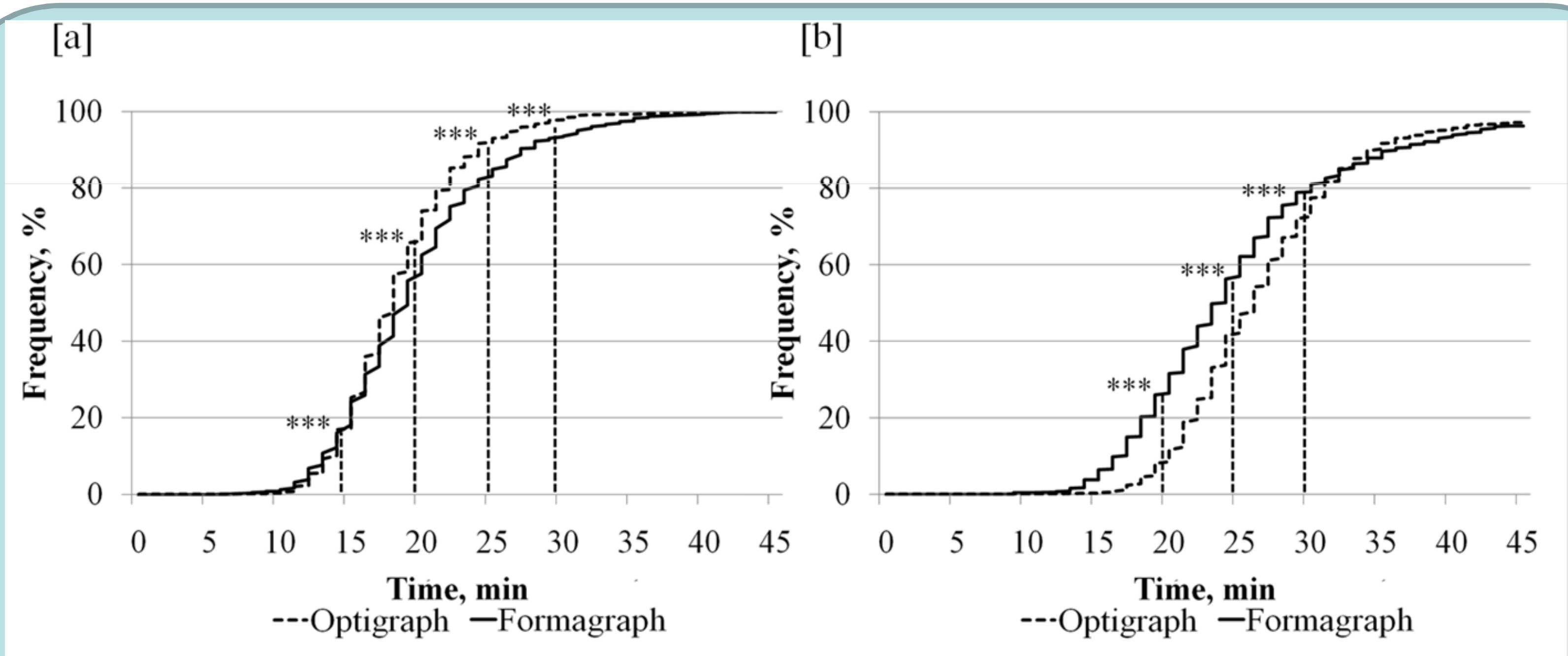

Effect of NC samples on h^2 estimation of a_{30}

Ikonen et al. 2004 J. Dairy Sci. 87:458-467

4,664 Finnish Ayrshire cows, 91 sires, 693 herds.

CO: Samples that coagulated within 31 min.

NC: Samples that did not coagulate within 31 min.

Trait:	**Samples**	**N**	**h^2 %**
RCT, min	CO	4038	28
a_{30}, binary	ALL	4664	26
a_{30}, mm	CO	4046	22
a_{30}, mm	ALL	4664	39

Effect of NC samples on h^2 estimation of a_{30}

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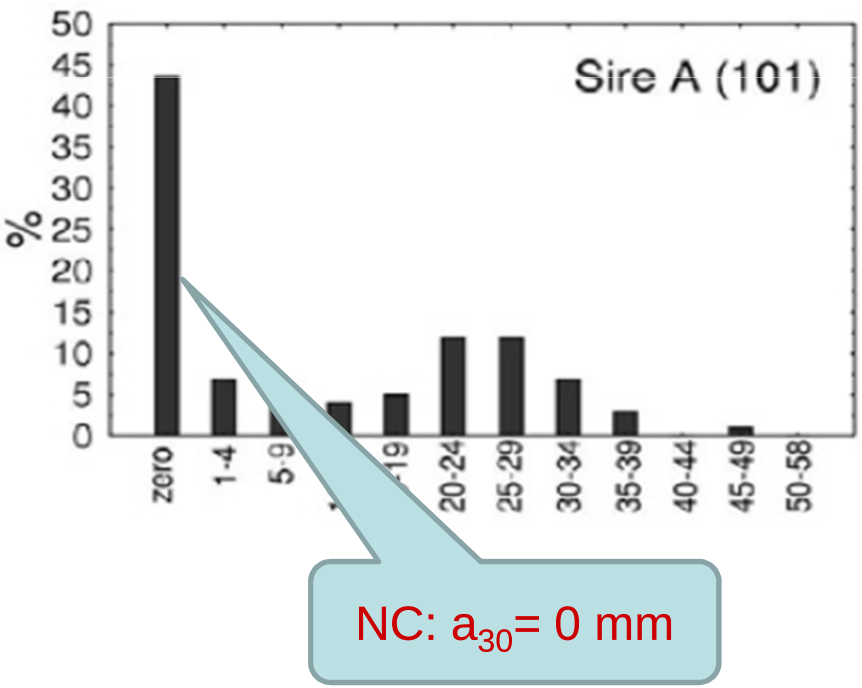

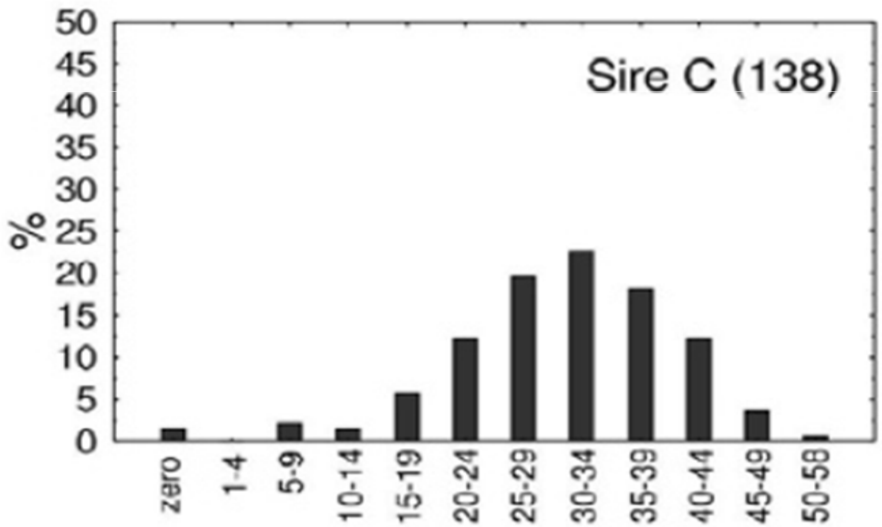

Effect of NC and method on h^2 estimation of RCT

Cecchinato and Carnier 2011 J. Dairy Sci. 94:4214-4219

1,025 Holstein Friesian cows, 54 sires, 34 herds.

LIN: Standard linear model

CEN: Right censored linear model

SUR: Survival sire model

THR: Threshold sire model

	LIN	CEN	SUR	THR
s^2_a	4.97	9.97	0.15	0.16
s^2_h	3.41	7.28	0.22	0.30
s^2_ε	12.86	25.97	1.00	1.00
h^2	23	23	11	12
he^2	16	17	17	22
Sires rank correlation:				
LIN	-	82	73	24
CEN	-	-	88	64
SUR	-	-	-	71

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LIN: Standard linear model

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	LIN	CEN	SUR	THR
s^2_a	4.97	9.97	0.15	0.16
s^2_h	3.41	7.28	[illegible]	[illegible]
s^2_ε	12.86	25.97	[illegible]	[illegible]
h^2	23	23	11	12
h^2	20	25	11	12
Sires rank correlation:				
LIN	-	82	73	24
r within method	60	88	84	52
SUR	-	-	-	71

Simulating RCT>18min=NC

Phenotypic correlations of MCP

Trait:	Papers n	RCT %	SD %	a_{30} %	SD %
RCT	5			**-71**	**29**
Milk yield, kg	4	-6	8	-3	4
Fat, %	4	-7	5	6	9
Protein, %	5	3	8	**30**	15
Casein, %	3	-8	13	**32**	18
pH	6	**45**	12	**-27**	12
TA	1	**-43**		**41**	13
SCS	5	15	10	-5	8

Genetic correlations of MCP

Trait:	Paper n	RCT %	SD %	a_{30} %	SD %
RCT	7			**-94**	5
Milk yield, kg	11	-16	18	4	22
Fat, %	9	-6	**36**	13	14
Protein, %	11	6	**30**	21	25
Casein, %	8	-10	**29**	**44**	24
pH	8	**72**	18	**-54**	**36**
TA	4	**-51**	13	**74**	13
SCS	10	16	**34**	**-38**	27

Role of genomics

Co
D

Genome wide association

depends

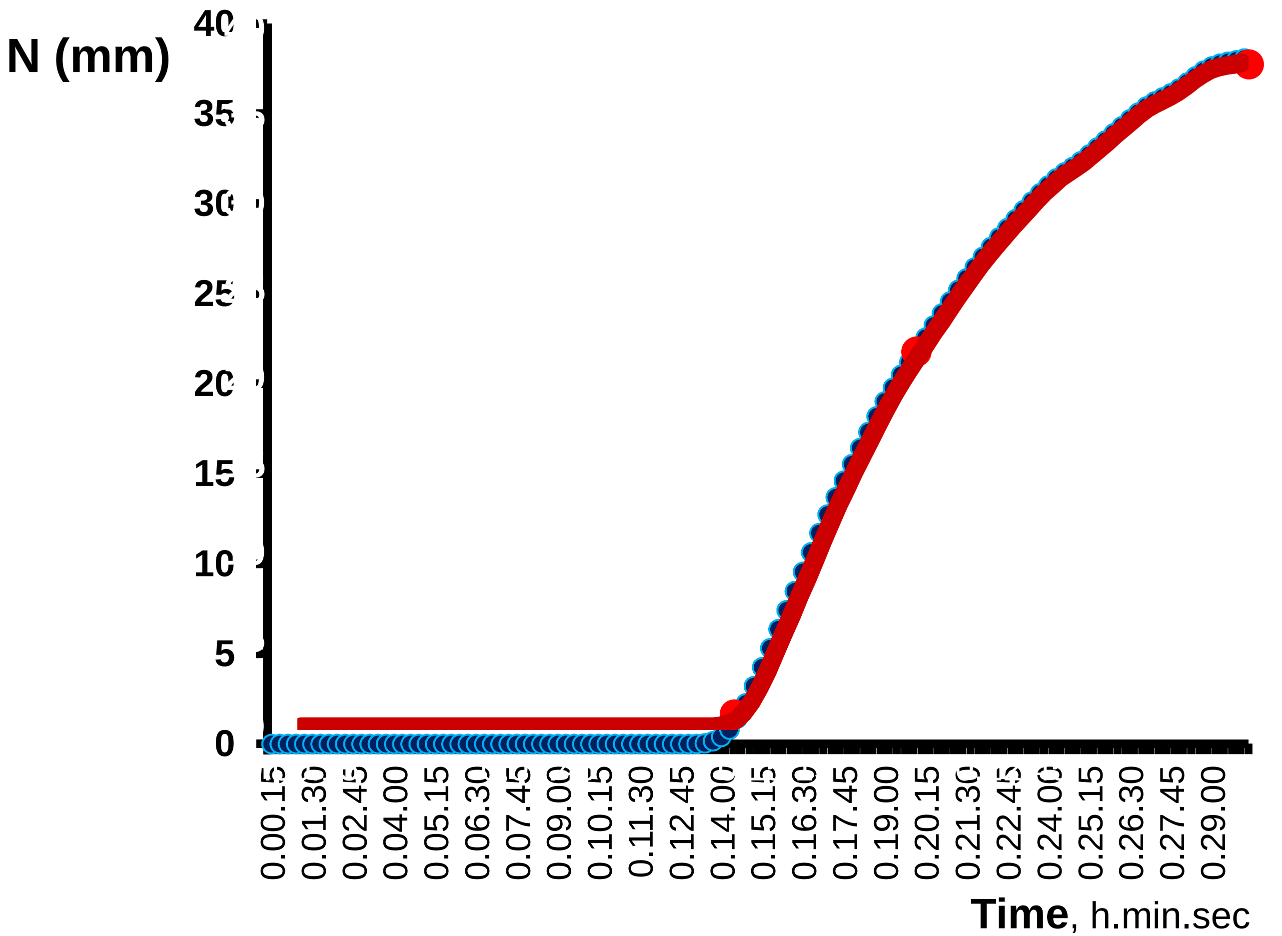
on quantity and quality
of phenotypes

Summary of open problems

TRAIT:	PROBLEM	
RCT	NC – late coagulating	
k_{20}	no time enough	
a_{30}	high correlation with RCT	

Modeling MCP

Bittante 2011 J. Dairy Sci. 2011. doi:10.3168/jds.2011-4514



Modeling MCP

Bittante 2011 J. Dairy Sci. 2011. doi:10.3168/jds.2011-4514

$$CF_t = CF_P*(1-e^{-k_{CF}*(t-RCT)})*$$

where:

CF_t = curd firmness at a given time after coagulation (mm);

CF_P = asymptotical potential value of curd firmness (mm);

k_{CF} = curd firming rate constant (/min);

RCT = rennet coagulation time (min).

Summary of open problems

TRAIT:	PROBLEM	
RCT	NC – late coagulating	-
k_{20}	no time enough	++
a_{30}	high correlation with RCT	++

MCP prediction by MIRS

Cecchinato et al. 2009 J. Dairy Sci. 92:5304-5313

1,200 Brown Swiss cows, 50 sires, 30 herds.

Measured MCP: RCT and a_{30} measured by renneting meter (CRM)

Predicted MCP: RCT and a_{30} predicted by MIRS (Foss FT 6000)

Repeatability of conventional MCP and MIRS predictions:

Dal Zotto et al. 2008 J. Dairy Sci. 91:4103-4112

Calibration of MIRS predictions:

De Marchi et al. 2009. J. Dairy Sci. 92:423-432

Calibration R^2, %	-	64	-	49
Average value	15,1	14,9	41,5	41,7
σ^2_a	4,9	3,7	19,4	17,2
σ^2_h	1,7	1,5	9,4	5,3
σ^2_e	8,5	4,6	50,6	20,0
H^2, %	32	37	24	40
r_p	67		51	
r_g	94		77	

Conclusions:

Milk coagulation properties are:

- ✓ important !
- ✓ dependent more from genetics then herd
- ✓ strongly influenced by breed
- ✓ strongly influenced by protein genetic variants
- ✓ strongly influenced by many other genes
- ✓ heritable like milk contents
- ✓ not much related to milk yield and contents
- ✓ related to pH and TA (and SCS)

…

Conclusions:

Milk coagulation properties require:

- ✓ a standardized methodology (IMCU,etc.)
- ✓ a comparison of techniques
- ✓ a proper statistical treatment of data
- ✓ a longer observation period

…

Conclusions:

Milk coagulation properties prospects:

- ✓ new modeling
- ✓ new parameters
- ✓ new interpretation tools for cheesemaking
- ✓ new MIRS calibrations for rapid, inexpensive, and effective predictions for their genetic improvement at population level.

Thank you !