BREEDING VALUE ESTIMATION FOR MILK COAGULATION PROPERTIES IN THE ITALIAN HOLSTEIN FRIESIAN BULL POPULATION

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Objective

- The objective of this work was to define direct and indirect genetic indices for Milk Coagulation Properties in Italian Holstein Friesian sires

- >70% of Italian milk is used for cheese production

- Milk technological traits can be used for:
  - ✓ Quantity of milk products
  - ✓ Quality of milk products
  - ✓ Milk payment systems
  - ✓ Genetics and breeding

Mid-infrared spectroscopy (MIRS) papers

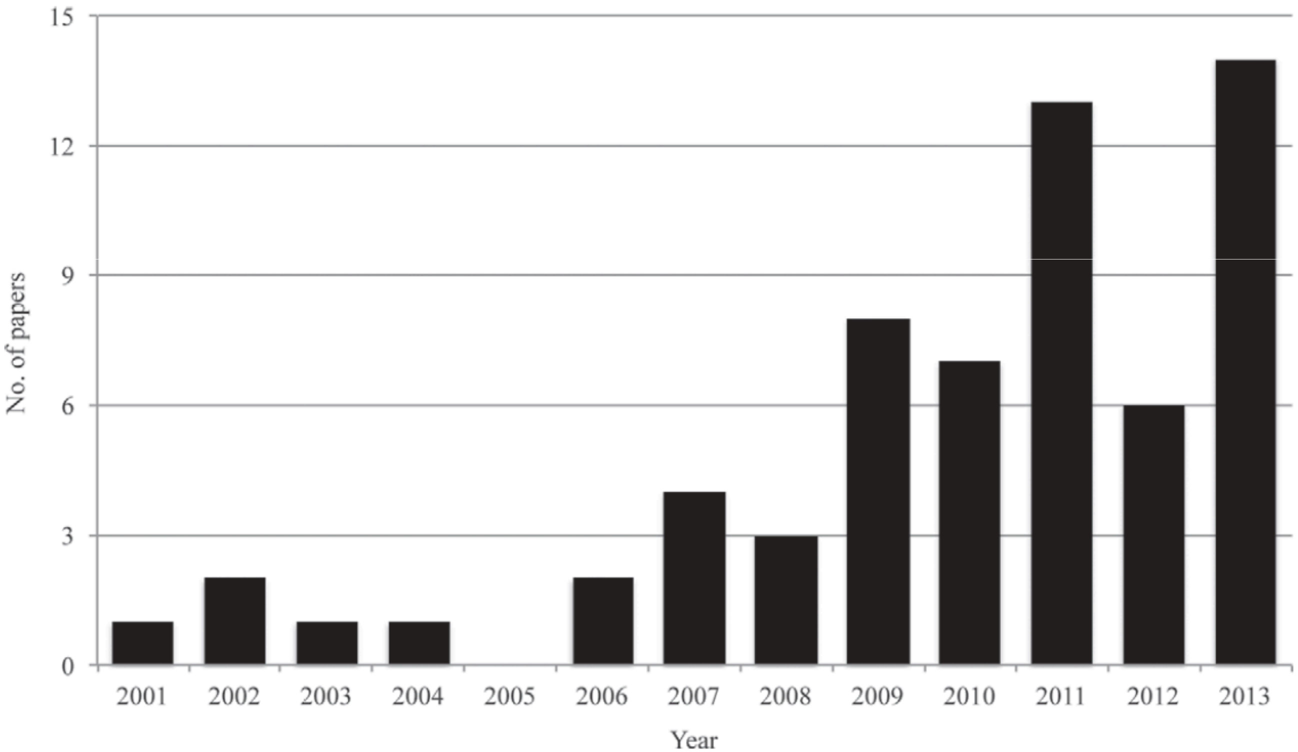


Figure 2. Published papers (retrieved from ISI Web of Science; http://thomsonreuters.com/web-of-science/) on mid-infrared spectroscopy (MIRS) and milk. For 2013, papers published up to October are reported.

Why mid-infrared spectroscopy (MIRS)?

1. We need "new phenotypes" - the concept of quality is changing (in relation to market requirements)
2. Fast, cheap, and high-throughput method
3. It is widely used to predict traditional traits in official milk-recording schemes worldwide
4. Several laboratories have been storing spectral data to predict *a posteriori* several phenotypes
5. MIRS phenotypes show good to optimal accuracy of prediction

Why mid-infrared spectroscopy (MIRS)?

1. Fatty acid composition (Soyeurt et al., 2006, 2008, 2011; Rutten et al., 2009; De Marchi et al., 2011; Ferrand et al., 2011; Maurice-Van Eijndhoven et al., 2013)
2. Milk protein composition (Luginbühl, 2002; Sørensen et al., 2003; Etzion et al., 2004; De Marchi et al., 2009; Bonfatti et al., 2011; Rutten et al., 2011)
3. Melamine content (Balabin and Smirnov, 2011)
4. Ketone bodies (Heuer et al., 2001; de Roos et al., 2007; van Knegsel et al., 2010; van der Drift et al., 2012)
5. Body energy status (McParland et al., 2011)
6. Free amino acid (McDermott et al., 2015)
7. ... and milk technological traits

Milk features related to cheese production

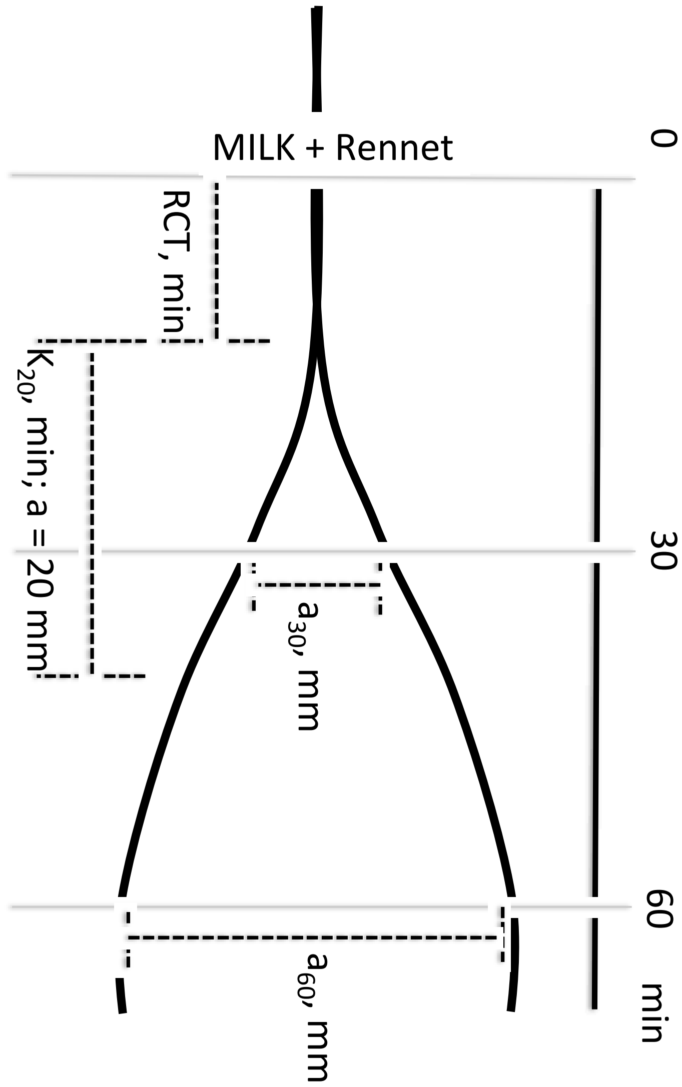
- ✓ The volume of milk processed for cheese manufacturing is growing worldwide (annually by 2% - FAOSTAT, 2014)
- ✓ Milk coagulation properties (MCP) affect the efficiency of the cheese-making process (Bynum and Olson, 1982; Riddell-Lawrence and Hicks, 1989)
- ✓ Milk acidity [pH and titratable acidity (TA)], milk mineral composition [Calcium (Ca) and Phosphorus (P)] (Toffanin et al., 2015)
- ✓ Cheese yield (what is the reference trait for cheese yield?)

Milk features related to cheese production

- Milk with a medium-to high casein content, good colloidal calcium phosphate content, the correct degree of titratable acidity (TA), moderate SCC, and an adequate fat-to-casein ratio was shown to be ideal for cheese-making
- Increasing milk yield might deteriorate milk coagulation and result in a lower than proportional increase in cheese production
- Milk coagulation properties are important for:
  - Time needed for cheese production
  - Cheese yield
  - Cheese quality

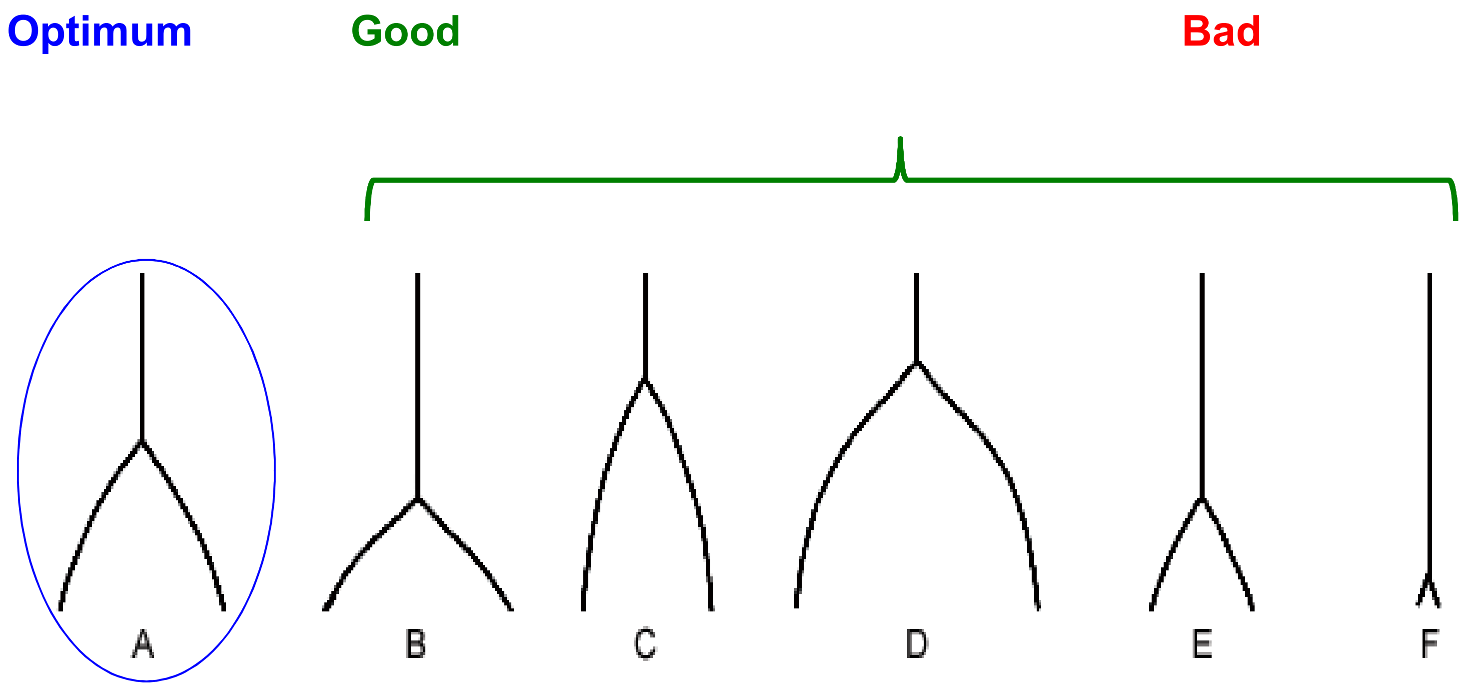
Milk coagulation properties

- Lactodynamograph (Formagraph)
- Three measures:
  - Rennet Coagulation Time (RCT) (in min) measures the amount of time between rennet addition and the beginning of the coagulation process
  - a_{30} measures curd firmness at 30 min after rennet addition. The longer the milk takes to start coagulating, the softer the curd will be at the end of the test, and vice versa
  - k_{20} measures curd-firming time minutes necessary for the curd to reach 20 mm thickness



Milk coagulation properties

Lactodynamograph (Formagraph)



Link milk coagulation with cheese yield

Effect of milk composition and coagulation traits on Grana Padano cheese yield under field conditions

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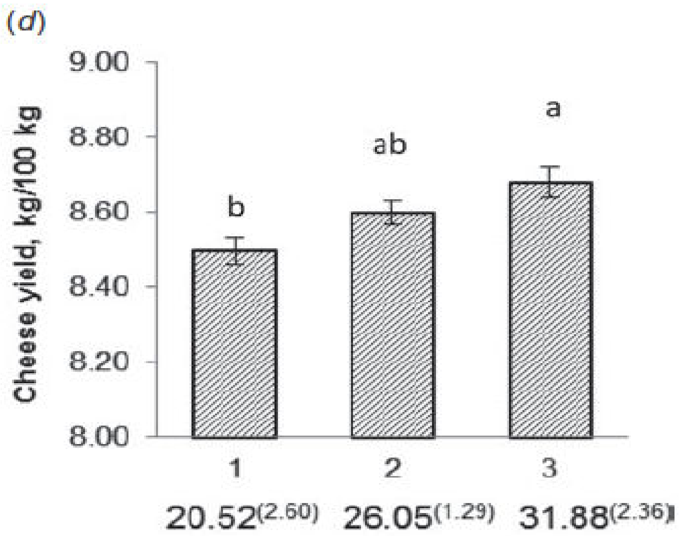
Table 2. Results from ANOVA for cheese yield ($R^2=0{\cdot}905$, RMSE = 0·153)

Effect†	df	Sum of squares	*P*-value
Cheese-making day	11	1·246	<0·0001
Fat, g/100 g	2	0·525	<0·0001
Protein, g/100 g	2	0·446	0·0002
TA, SH°/50 ml	2	0·383	0·0006
a_{30}, mm	2	0·175	0·0277
Residual	76	1·770	

† TA = titratable acidity; a_{30} = curd firmness 30 min after coagulant addition



Direct index for milk coagulation

$$IAC = 100 + \left[\left(\frac{A_{30} - mean_{A_{30}}}{SD_{A_{30}}} \right) \times 2.5 - \left(\frac{RCT - mean_{RCT}}{SD_{RCT}} \right) \times 2.5 \right]$$

- Uses standardized measures of a_{30} and RCT
- Weighted combination of 50% a_{30} and 50% RCT
- Heritability
  - Tiezzi et al 2013

Trait	h^2
RCT	0.210
a_{30}	0.238
IAC	>0.200

Indirect index for milk coagulation

- Temporary solution until more laboratories provide MCP measures
- Use of correlated traits to predict MCP as established in direct index
- Predictors:
  - Somatic cell score
  - K-casein
  - % protein
  - % fat

ITC = 30% GRS% + 22% PRT% + 32% SCS + 16% K-casein

Various indirect indices tested

	1	2	3	4	5	6	7	8	9	10	11
Fat %	X	X	X	X	X	X	X	X	X	X	X
Prot %	X	X	X	X	X	X	X	X	X	X	X
Udder depth	X								X		
SCS		X	X	X	X	X	X	X	X	X	
ICM		X	X	X	X	X					
K-casein		X				X	X	X	X	X	
Fat kg				X	X						
Prot kg				X	X	X					
Milking speed						X	X				
Longevity						X					
Fertility							X	X			

10 - Highest correlation with direct index (0.30)

Correlations milk coagulation with milk traits

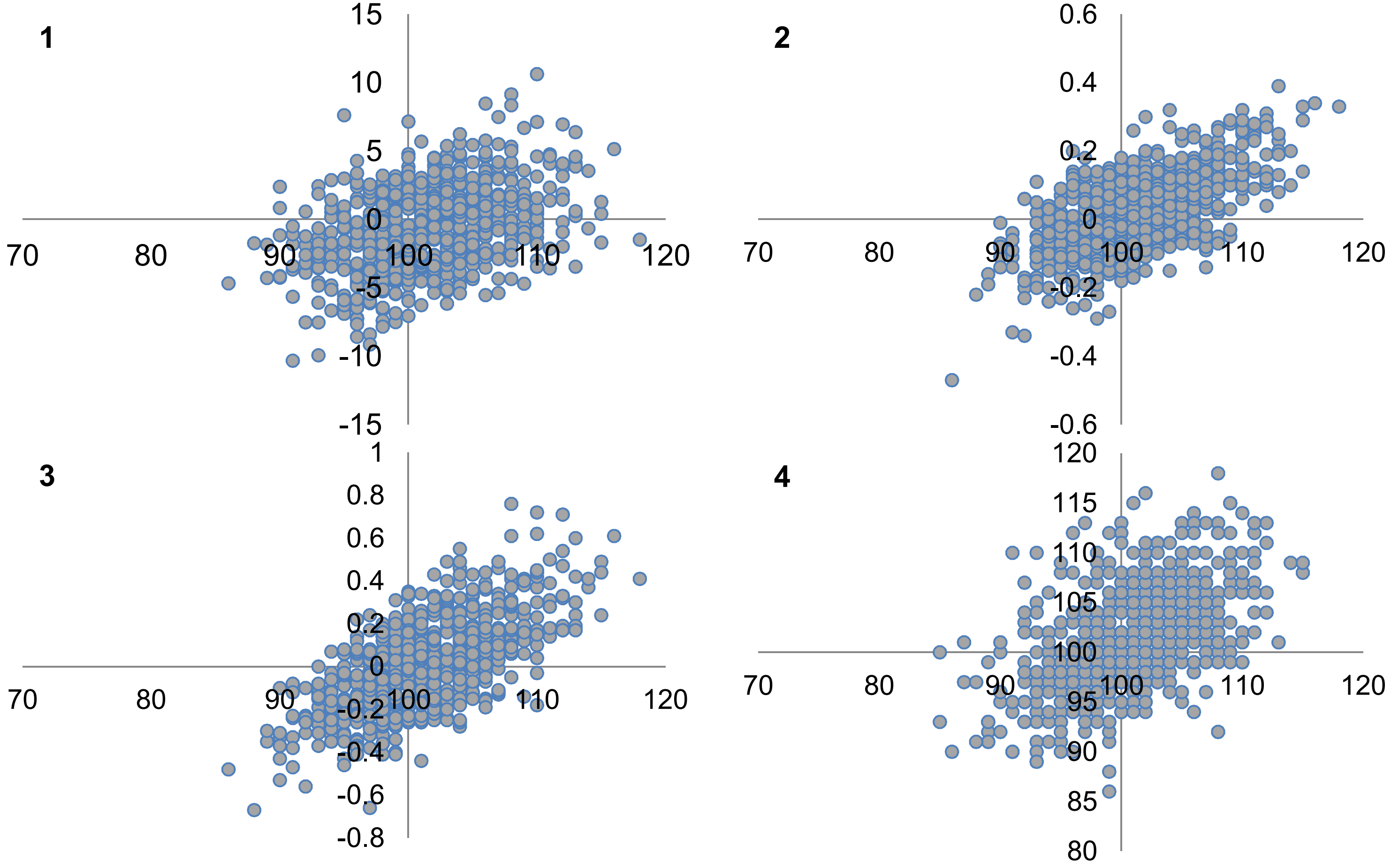
- Genetic correlations among milk coagulation, production, and quality and udder traits

Trait	RCT (min)	a_{30} (mm)	IAC
RCT (min)	-	**-0.900**	**-0.977**
a_{30} (mm)	-0.900	-	**0.972**
IAC	-0.977	0.972	-
Italian selection index (PFT)	-0.103	0.153	0.130
Milk (kg)	0.036 [ns]	-0.152	-0.093
Fat (%)	**-0.157**	**0.258**	**0.210**
Protein (%)	**-0.012 [ns]**	**0.285**	**0.145**
Fat (kg)	-0.126	0.125	0.129
Protein (kg)	0.030 [ns]	0.041 [ns]	0.004 [ns]
SCS	**-0.211**	**0.170**	**0.197**
Udder composite (ICM)	-0.032	-0.002 [ns]	0.016 [ns]

[ns] not significantly different from zero

Dispersion plots between EBVs

Dispersion plots between EBVs of a_{30} (1), protein content (2), fat content (3) and SCS (4) with the indirect selection index



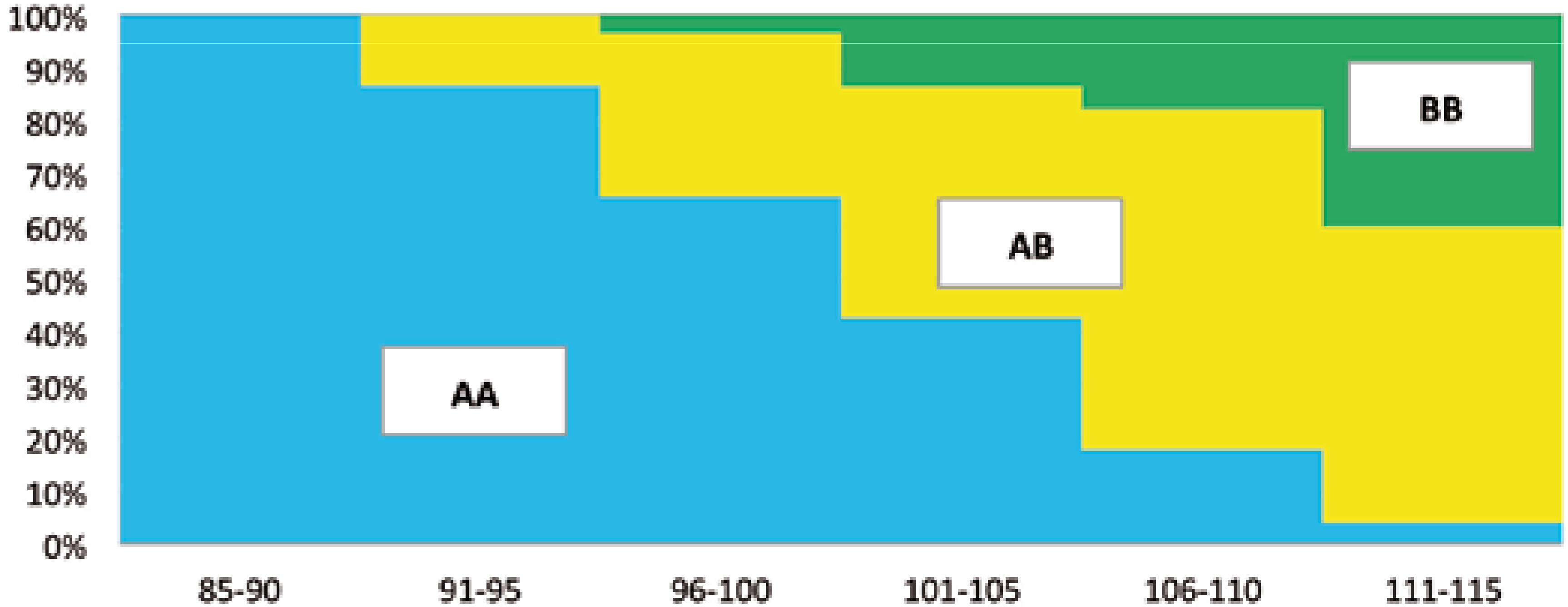
Relation milk coagulation with milk content EBVs

- Mean bull EBVs for top and bottom of milk coagulation

EBV	ITC ≤ 95	ITC ≥ 105
Protein %	-0.08	0.11
Fat %	-0.21	0.23
Somatic cell index	95	102

Relation milk coagulation with Kappa-casein genotype

- Frequency of bull genotypes for various levels of ITC breeding value



Conclusions

1. MIRS is able to predict milk technological traits
2. New opportunities for dairy industry to improve the efficiency of cheese and milk powder production
3. New opportunities to improve milk payment systems
4. "New phenotypes" can be used for breeding purposes to improve milk technological aspects and other new important traits (nutritional, healthy features, ...) – addressing consumers requirements
5. Direct index can be predicted partly by correlated traits