Implementation of a routine genetic evaluation of milk coagulation properties in Italian Holstein breed

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The importance of cheesemaking in Italy

- 56 geographical indications and traditional specialties
- 2021 production value: €4.7B (+12.8% annual basis)
- 2021 export value: €2.4B (+15.4% annual basis)

(Retort ISMEA, 2022)
Aims

• Study genetic aspects of milk coagulation properties (MCP) in the Italian Holstein breed

• Develop and implement a routine genetic evaluation of MCP in the Italian Holstein breed in order to identify the animals with the highest genetic potential for producing the most suitable milk for cheesemaking

• Add females to training population for the studied traits
What are MCP?

MCP traits have been already described and analyzed in several previous studies (Annibaldi, et al. 1977; Aleandri et al., 1989; Ikonen, 2000; Comin et al., 2005; Cassandro et al, 2008; De Marchi et al., 2009; Pretto et al., 2013; Penasa et al., 2015)
Data & data editing (1)

6.7M test-day (TD) records from 2017 onwards (AIA, «LEO project», 2023) – Milkoscan MIR spectra.

- Kept only records from regions that provide a consistent data flow (10/20)
- Max parity: 5
- DIM range: 5-405
- Removed obvious errors
- Min contemporaries (herd-year-season of recording): 20

Observations after edits: 4M
Data & data editing (2): isolation forest  
(Pedregosa et al, 2011)

Reference phenotypic correlations:

- RCT – A30: -0.73
- RCT – K20: 0.80
- A30 – K20: -0.79

(Visentin et al, 2015, JDS)

Correlations computed within herd-testday 
in order to detect anomalies in lab measurements
### Descriptive statistics

<table>
<thead>
<tr>
<th>N = 4,001,769</th>
<th>CAS</th>
<th>RCT</th>
<th>A30</th>
<th>K20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.72</td>
<td>25.40</td>
<td>20.73</td>
<td>7.29</td>
</tr>
<tr>
<td>SD</td>
<td>0.33</td>
<td>6.56</td>
<td>8.93</td>
<td>2.00</td>
</tr>
<tr>
<td>CV</td>
<td>12.13</td>
<td>25.83</td>
<td>43.08</td>
<td>27.44</td>
</tr>
<tr>
<td>MIN</td>
<td>1.06</td>
<td>5.00</td>
<td>5.00</td>
<td>1.00</td>
</tr>
<tr>
<td>MAX</td>
<td>6.21</td>
<td>60.00</td>
<td>60.00</td>
<td>20.00</td>
</tr>
</tbody>
</table>

- **RCT**: rennet coagulation time [minutes] – optimal range: 11-18
- **K20**: curd firming time [minutes] – optimal range: 5-9
- **A30**: curd firmness [millimeters] – optimal range: 40-50

22% of the samples didn’t coagulate before 30min. 1% of them had an RCT > 45min
Statistical model: MT repeatability linear animal model

\[ \text{CAS}_{ijklmnopq} = hys_i + S_j \times Y_k + \text{DIM}_l \times \text{PARC}_m \times Y_k + \text{AGEC\_PAR}_n \times Y_k + a_o + p e_p + e_{ijklmnopq} \]

\[ \text{MCP}_{ijklmnopqr} = hys_i + S_j \times Y_k + b\text{SCS}_l + \text{DIM}_m \times \text{PARC}_n \times Y_k + \text{AGEC\_PAR}_o \times Y_k + a_p + p e_q + e_{ijklmnopqr} \]

- MCP: 3 traits (RCT, A30, K20) with the same model
- DIM: 10 classes of 30 days
- PARC (3 classes): 1, 2, 3+
- AGEC\_PAR (9 classes): 1 (<24mon), 1 (24-27mon), 1 (>27mon), 2 (<36mon), 2 (36-40mon), 2 (>40mon), 3, 4, 5
- hys & YS are relative to the recording
Variance components

Software: THRGIBBS1F90 (*Misztal et al*, 2014)
Obs: 64,720 (150 herds)
Convergence: R package BOA (*Smith*, 2007)

Diagonal: PM (PSD)
Above diagonal: genetic correlations

<table>
<thead>
<tr>
<th>CAS</th>
<th>RCT</th>
<th>A30</th>
<th>K20</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33 (0.01)</td>
<td>-0.04</td>
<td>0.51</td>
<td>-0.67</td>
</tr>
<tr>
<td>0.11 (0.01)</td>
<td>-0.87</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>0.16 (0.01)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.15 (0.01)</td>
</tr>
</tbody>
</table>
Genomic validation

Multi-step genomic evaluation (EDPs as pseudo-phenotypes)
MiX99 (MiX99 Development Team, 2022) + GS3 (Legarra et al, 2011)
Full run and reduced run (YYYY-3)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Training</th>
<th>N_training</th>
<th>b</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS</td>
<td>Bulls</td>
<td>3,276</td>
<td>1.205</td>
<td>0.452</td>
</tr>
<tr>
<td>CAS</td>
<td>Bulls+Cows</td>
<td>43,754</td>
<td>0.898</td>
<td>0.790</td>
</tr>
<tr>
<td>RCT</td>
<td>Bulls</td>
<td>3,276</td>
<td>1.359</td>
<td>0.421</td>
</tr>
<tr>
<td>RCT</td>
<td>Bulls+Cows</td>
<td>43,754</td>
<td>0.925</td>
<td>0.737</td>
</tr>
<tr>
<td>A30</td>
<td>Bulls</td>
<td>3,276</td>
<td>1.319</td>
<td>0.478</td>
</tr>
<tr>
<td>A30</td>
<td>Bulls+Cows</td>
<td>43,754</td>
<td>0.911</td>
<td>0.767</td>
</tr>
<tr>
<td>K20</td>
<td>Bulls</td>
<td>3,276</td>
<td>1.246</td>
<td>0.459</td>
</tr>
<tr>
<td>K20</td>
<td>Bulls+Cows</td>
<td>43,754</td>
<td>0.895</td>
<td>0.763</td>
</tr>
</tbody>
</table>

\[ EDP_{full} = a + bDGV_{red} + e \]

Average reliability increase with females: 60%
(+40,478 individuals in training population)
Genetic trend (bulls by birthyear)
Approximate genetic correlations

Approximate genetic correlations for Casein % and MCP

GEBVs of 87.569 females born after 2016
Take home massage(s)

- Selection for MCP is feasible
- No negative effects on other traits highlighted by approximate genetic correlations, except milk yield
- Indirect selection for protein kg and % was effective
- The developed model is stable enough and suitable for routine genetic evaluation
- Adding females to training population is beneficial for MCP

These traits will be available in Italy from April ‘24 run (after CTC approval) with the perspective of being included in the national breeding goal for Parmigiano-Reggiano producers (ICS-PR)
Thank you

Ferdinando Galluzzo  
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Milk Coagulation Properties: scheme (Cassandro et al, ICAR 2012)

1) Lactodinamograph - LDG

<table>
<thead>
<tr>
<th>RCT (min)</th>
<th>Rennet coagulation time</th>
</tr>
</thead>
<tbody>
<tr>
<td>K20 (mm)</td>
<td>Curd firming time</td>
</tr>
<tr>
<td>A30 (mm)</td>
<td>Curd firmness</td>
</tr>
</tbody>
</table>

Good coagulation properties

A
B
C
D
E
F