MILK COAGULATION ABILITY AND PREVALENCE OF NONCOAGULATING MILK IN FINNISH DAIRY COWS

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INTRODUCTION
During the 1990s domestic consumption of cheese has increased about 20% in Finland. Nowadays about 40% of the milk produced is used for cheese production and about 30% of the net sales of the major Finnish dairy companies come from cheese production (http://www.finfood.fi/; http://www.etl.fi/). Because minor part of the milk produced is nowadays used as liquid product, milk quality and its technological properties have become more important to dairy industry.

Ayrshire (Fay) is the main dairy breed in Finland (73%). The proportion of the Holstein-Friesian (Ho-Fr) is about 25% and the rest of the dairy cattle population consists mainly of Finncattle (FC). A wide variation exists in milk coagulation ability (MCA) between different breeds. Based on several studies, FC and Ho-Fr cows are superior to Fay cows (Ikonen, 2000). Some of the differences in MCA between breeds can be caused by noncoagulation phenomenon of Fay. In the data set of 4,600 Fay cows, 13% of the cows produced milk which did not coagulate at all in 30 min testing time (Tyrisevä et al., 2000a). So far this phenomenon has only been observed in the Fay. However the samples of the FC and Ho-Fr cows have been quite limited in size (Ikonen, 2000).

Many systematic environmental factors, e.g. stage of lactation and parity, influence MCA, but major part of the variation (39%) in MCA is genetic (Tyrisevä et al., 2000b). Farmers can to some extent influence MCA of the cows by feeding and management. Based on many studies, energy level of the diet and udder health of the cows both influence cheese quantity and quality (e.g. Green and Grandison, 1987; Machebouef et al., 1993; Malossini et al., 1996).

The objectives of this research were to study 1) the differences in milk coagulation ability (MCA) between the different dairy breeds in Finland, and 2) the effects of environmental and genetic factors on MCA.

MATERIAL AND METHODS
A total of 1,435 cows from 85 herds were sampled from the region of Lammi co-operative dairy in April and May 1999. Milk renneting properties; renneting time (R, min) and curd firmness (E30, min) were measured with CRM 40 (Polo Trade, Italy) at 35°C and pH with 744 pH Meter (Metrohm, Switzerland) from one milk sample per each cow. A 305-day milk production traits from the year 1999 were obtained from Agricultural Data Processing Centre of Finland. Farmers also filled the background information form about feeding and management of their herd. The sampled data represented well the distribution of the different dairy breeds in Finland: 68% of the cows were Fay, 28% Ho-Fr, 1% FC and 3% of the cows were crossbreds.

Session 09. Lactation and milk quality  Communication N° 09-02
Estimation of variance components was based on REML methodology and an animal model. Pedigree information included parents and grandparents of the animals. Variance components for the random effects were obtained by REML VCE4.0 -package (Groeneveld, 1997). Heritability estimates and herd effects were analysed using an univariate model. Statistical significance of the fixed effects was tested by F-test of PEST sofware (Groeneveld, 1990). Renneting time, curd firmness, pH, 305-day milk, fat and protein yields, and protein and fat content were analysed with the following linear mixed model:

\[ y_{ijklmn} = \mu + \text{breedi} + \text{parj} + \text{lack} + \text{unitl} + c_m + a_n + \epsilon_{ijklmn} \]

where:

- \( y_{ijklmn} \) = studied trait
- \( \mu \) = overall mean
- \( \text{breedi} \) = fixed effect of breed, \( i = 1, \ldots, 4 \)
- \( \text{parj} \) = fixed effect of parity, \( j = 1, \ldots, 4 \)
- \( \text{lack} \) = fixed effect of stage of lactation, \( k = 1, \ldots, 11 \) (for R, E30 and pH only)
- \( \text{unitl} \) = fixed effect of a measuring unit, \( j = 1, \ldots, 20 \) (for R and E30 only)
- \( c_m \) = random effect of herd, \( m \), N \((0, \text{I} \sigma^2_c)\)
- \( a_n \) = random effect of animal, \( n \), N \((0, A \sigma^2_a)\)
- \( \epsilon_{ijklmn} \) = random residual effect, N \((0, \text{I} \sigma^2_\epsilon)\)

Covariances between factors \( c, a \) and \( \epsilon \) were assumed to be zero. Heritabilities were calculated using a formula \( h^2 = \frac{\sigma^2_a}{\sigma^2_a + \sigma^2_c + \sigma^2_\epsilon} \) and herd effects using a formula \( c^2 = \frac{\sigma^2_c}{\sigma^2_a + \sigma^2_c + \sigma^2_\epsilon} \).

RESULTS AND DISCUSSION

**Breed differences in the studied traits.** Large differences existed in the milk coagulation ability (MCA) between Fay and Ho-Fr (figure 1). About 30% of the Fay cows produced poorly coagulating milk (curd firmness < 20 mm), whereas the equivalent proportion of the Ho-Fr cows was only 12%. A total of 8.4% of the Fay milk samples were noncoagulating (nc). Further, first Finnish Ho-Fr cows producing nc-milk were detected. Based on the present sampling, the prevalence of the phenomenon is 1.3% in the Finnish Ho-Fr population. Cows producing noncoagulating milk has been detected in Italian Friesian population as well (e.g. Malossini et al., 1996).

The majority of the Fay cows producing nc-milk were descendants of the widely used Fay and Norwegian Red Breed ancestors both from the sire and dam line. An evidence exists that noncoagulation of milk in Fay is caused by a gene mutation (Ikonen et al., 1999; Tyrisevä et al., 2000a). The five Ho-Fr cows producing nc-milk shared partly two common ancestors, both foreign bulls. Based on this fact, there is a possibility that noncoagulation of milk in Ho-Fr is also caused by genetic factors. However, the prevalence of the phenomenon is much lower than in Finnish Ayrshire population.

Milk began to aggregate almost 3 min earlier and curd was about 5mm firmer in Ho-Fr and FC cows than in Fay cows (P < 0.001). Results from the FC are only suggestive because the number of the cows was only 15. All FC cows produced coagulating milk. Ho-Fr cows were also superior to Fay in 305-day milk, protein and fat yields (P < 0.001) and pH (P = 0.002), but

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**Session 09. Lactation and milk quality**

Communication No 09-02
Fay cows had higher protein and fat content of milk (P < 0.001). Based on a recent large data set, moderate genetic correlations existed between pH and MCA, but genetic correlations between milk production traits and MCA were almost zero (Tyrisevä et al., 2000b). A variation exists also in milk protein genotypes between different dairy breeds in Finland. The K-casein B-allele is more common in FC and Ho-Fr than in Fay and it has a favourable effect on MCA (Ikonen, 2000). Thus, differences in pH, milk protein genotypes and prevalence of the nc-milk may, in part, explain the differences in MCA between the Fay and Ho-Fr.

Figure 1. Distribution of the milk coagulation ability (curd firmness, mm) of the Ayrshire and Holstein-Friesian cows. Zero refers to noncoagulating milk samples

Table 1. Means and variation, herd effects ($c^2$) and heritabilities ($h^2$) with their standard errors ($se$) for the milk coagulation traits, pH and milk production traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>$N$</th>
<th>$\bar{x}$</th>
<th>Sd</th>
<th>CV</th>
<th>$c^2 \pm se$</th>
<th>$h^2 \pm se$</th>
</tr>
</thead>
<tbody>
<tr>
<td>R (min)</td>
<td>1346</td>
<td>11.1</td>
<td>5.0</td>
<td>45</td>
<td>0.06 $\pm$ 0.01</td>
<td>0.36 $\pm$ 0.07</td>
</tr>
<tr>
<td>$E_{30}$ (mm)</td>
<td>1435</td>
<td>26.6</td>
<td>11.8</td>
<td>44</td>
<td>0.09 $\pm$ 0.02</td>
<td>0.31 $\pm$ 0.06</td>
</tr>
<tr>
<td>pH</td>
<td>1434</td>
<td>6.65</td>
<td>0.08</td>
<td>1.2</td>
<td>0.12 $\pm$ 0.02</td>
<td>0.17 $\pm$ 0.07</td>
</tr>
<tr>
<td>MY (kg)</td>
<td>1287</td>
<td>7350</td>
<td>1605</td>
<td>22</td>
<td>0.48 $\pm$ 0.03</td>
<td>0.15 $\pm$ 0.03</td>
</tr>
<tr>
<td>FY (kg)</td>
<td>1287</td>
<td>317</td>
<td>70.7</td>
<td>22</td>
<td>0.42 $\pm$ 0.03</td>
<td>0.17 $\pm$ 0.04</td>
</tr>
<tr>
<td>Fat-%</td>
<td>1287</td>
<td>4.35</td>
<td>0.62</td>
<td>14</td>
<td>0.48 $\pm$ 0.03</td>
<td>0.11 $\pm$ 0.03</td>
</tr>
<tr>
<td>Prot.-%</td>
<td>1287</td>
<td>2.37</td>
<td>0.22</td>
<td>6.7</td>
<td>0.21 $\pm$ 0.02</td>
<td>0.26 $\pm$ 0.05</td>
</tr>
</tbody>
</table>

$^a$ R = milk renneting time, $E_{30}$ = curd firmness

MY, FY, PY = 305-day milk, fat and protein yields, respectively.

Herd and genetic effects. Herd explained less than 10 % of the variation in MCA, whereas the corresponding proportion in milk production traits was over 40 %. Heritability estimates for the milk coagulation traits were over 0.30, and for the milk production traits they were much
lower, about 0.11 to 0.26. (table 1). Results were in a good agreement with the previous estimates from a more extensive set of data (Tyrisevä et al., 2000b). Minor influence of the herd in MCA was also confirmed, when the herds were divided into the best and poorest ones based on the 305-day milk protein yield. Differences between the two groups were 120 kg in 305-day protein yield and 3500 kg in milk yield, but there was only 1 mm difference in curd firmness.

REFERENCES