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Genetic parameters for milk coagulation properties in the first lactation Estonian Holstein cows

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ABSTRACT
Milk coagulation properties (MCP) are an important aspect in assessing cheese-making ability. In milk-to-cheese steps, coagulation of milk is important and sensitive because it is the first phase and affects the following phases in the process. Genetic factors play an important role in defining milk quality for cheese-making. MCP were found to be heritable, but little scientific literature is available about their genetic aspects. The aim of this study was to estimate heritability, repeatability and herd effect on MCP and milk production traits in first lactation Estonian Holstein dairy cattle. A total 10,722 measurements of 2,608 Estonian Holstein cows (progeny of 196 sires) reared in 92 herds in Estonia were sampled from April 2005 to August 2007 at least 3 times during the lactation (7 – 305 day in milk) and the database COAGEN™ of Bio-Competence Centre of Healthy Dairy Products was formed. Individual milk samples were analyzed for milk coagulation time (RCT), curd firmness (E_{30}), milk yield, fat percentage, protein percentage and somatic cell count. Only 0.3% of individual milk samples did not coagulate in 31 min and were excluded from analyses. Estimates of heritability for RCT and E_{30} were 0.34 ± 0.06 and 0.43 ± 0.01, respectively.
Key words: dairy cattle, milk coagulation ability, milk production traits, herd effect, heritability

INTRODUCTION
Milk coagulation properties (MCP) are an important aspect in cheese-making production, especially in those countries where the dairy industry is based on traditional products and is market-oriented (Cassandro et al., 2008). For this reason, milk composition and coagulation traits and cheese quality represent the most important tools for economic development of dairy sector (Dalvit et al., 2007; Marchi et al., 2008). In milk-to-cheese steps, coagulation of milk is important and sensitive because it is the first phase and affects the following phases in the process. Genetic factors play an important role in defining milk quality for cheese-making (Ikonen et al., 1999; Ikonen, 2000; Martin et al., 2003; NG-Kwai-Hang & Grosclaude, 2003; Coulon et al., 2004; Tyrisevä et al., 2004; Ojala et al., 2005; Malacarne et al., 2006; Cassandro et al., 2007; Pärna et al., 2008). The additive genetic variance of milk coagulation traits was estimated to be about 30-40% (Ikonen et al., 1997; Bittante et al., 2002). The recording data and genetic evaluation of milk for cheese production can be effectively done by using MCP (Comin et al., 2008). The objective of this study was to estimate heritability, repeatability and herd effect on MCP and milk production traits.

MATERIAL AND METHODS

Data collection

First lactation milk samples were collected during the period April 2005 – August 2007 from 92 herds across the country. After exclusion of non-coagulated milk samples (n = 37; 0.3% of the total), there are 10,722 observations from 2,608 Estonian Holstein cows that are daughters of 196 sires. Number of daughters per sire varies from 1 to 164. Each cow has 3 – 6 measurements collected during different stages of the lactation period (7 – 305 day in milk (DIM)). Milk samples utilized in this study were collected as a part of development project of Bio-Competence Centre of Healthy Dairy Products. Milk samples on cows from herds belonging to the Estonian milk recording system were collected during the test milking pick-up route. Milk coagulation properties (milk coagulation time (RCT) in minutes and firmness of curd (E_{30}) in millimetres) were determined at the Laboratory of Milk Quality of the Estonian University of Life Sciences using the Optigraph (Ysebaert, Frepillon, France, Optigraph system recipes were: R slope = 1.784 and R offset = -2.303) at 35°C. Milk coagulation time was recorded directly based on the maximum first derivative of the signal. To determine the firmness of the curd, the Optigraph signal 30 minutes after the addition of the rennet was converted into millimeters using a calibration equation (Kübarsepp et al., 2005). Individual milk samples were analyzed also for milk yield, fat percentage, protein percentage and SCC at the Milk Analysis Laboratory of the Estonian Animal Recording Centre (EARC). Values of SCC were log-transformed to SCS as: SCS = $\log_2$(SCC/100,000) + 3.

Information about the cows, herds and pedigree data was obtained from national milk recording datasets of the EARC.

Statistical analysis

Statistical analysis was carried out in ASReml (Gilmour et al., 2002), using following univariate repeatability animal model:

$$Y_{ijklm} = \mu + dim_i + e^{-0.05 \times dim_i} + season_j + herd_k + animal_l + pe_m + e_{ijklm},$$

where Y_{ijklm} - dependent variable (log-transformed RCT, E_{30}, milk yield, milk protein and fat percentage, SCS); μ - overall mean; dim_i - day in milk, modelled with a Wilmink curve (Wilmink, 1987); $season_j$ - fixed effect of year-season (j = 1,… 10): spring 2005 (April – May 2005), summer 2005 (June – August 2005), fall 2005 (September – November 2005), winter 2006 (December 2005 – February 2006), spring 2006 (March – May 2006), summer 2006 (June – August 2006), fall 2006 (September – November 2006), winter 2007 (December 2006 – February 2007), spring 2007 (March – May 2007), summer 2007 (June – August 2007); $herd_k$ - random effect of herd (k = 1,..., 92); $animal_l$ - random effect of animal (l = 1,…, 3,439); pe_m - random permanent environmental term (m = 1, …, 2,608); e_{ijklm} - residual random error term.

For genetic estimation all sires and two generation of paternal grandparents of the cows with records in the data were included in the pedigree file. A total of 3,439 animals were included in the relationship matrix.

Heritability was calculated as:

$$\mathrm{h}^2 = \sigma_a^2 / (\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2),$$

where σ_a^2 - additive genetic variation; σ_{pe}^2 - permanent environmental variation; σ_e^2 - residual variation.
Repeatability was calculated as:

$$r^2 = (\sigma_a^2 + \sigma_{pe}^2)/(\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2).$$

The proportion of herd variation was calculated as:

$$c^2 = \sigma_h^2 /(\sigma_h^2 + \sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2),$$

where σ_h^2 - herd variation.

RESULTS AND DISCUSSION

Table 1 shows the descriptive statistics of MCP and milk production traits. The average of log-transformed RCT was 2.3 and E_{30} was 27.2 mm on average. Milk yield averaged 25.8 kg/d. There was substantial variation in milk coagulation properties as indicated by the coefficient of variation 26% for E_{30} and 10% for log-transformed RCT. Coefficient of variation was highest for SCS (66%) and lowest for protein percentage (9%).

Table 1. Number of observations (N), means, standard deviations (SD) and coefficients of variation (CV) for milk coagulation and production traits.

Variable	N	Mean	SD	CV
Coagulation time[1]	10722	2.3	0.23	10
Curd firmness, mm	10722	27.2	7.07	26
Milk yield, kg	10722	25.8	7.13	28
Fat %	10703	4.0	0.69	17
Protein %	10717	3.4	0.31	9
SCS	10717	2.8	1.87	66

[1]Log-transformed

Effect of DIM was significant ($P<0.05$) for all traits. MCP were better at the beginning of lactation and worst during mid lactation (Figure 1). Curd firmness improved also in the second part of lactation. These results are in agreement with changes in MCP reported in previous studies (Jõudu, 2008; De Marchi et al., 2007; Tyrisevä et al., 2003; Ostersen et al., 1997).

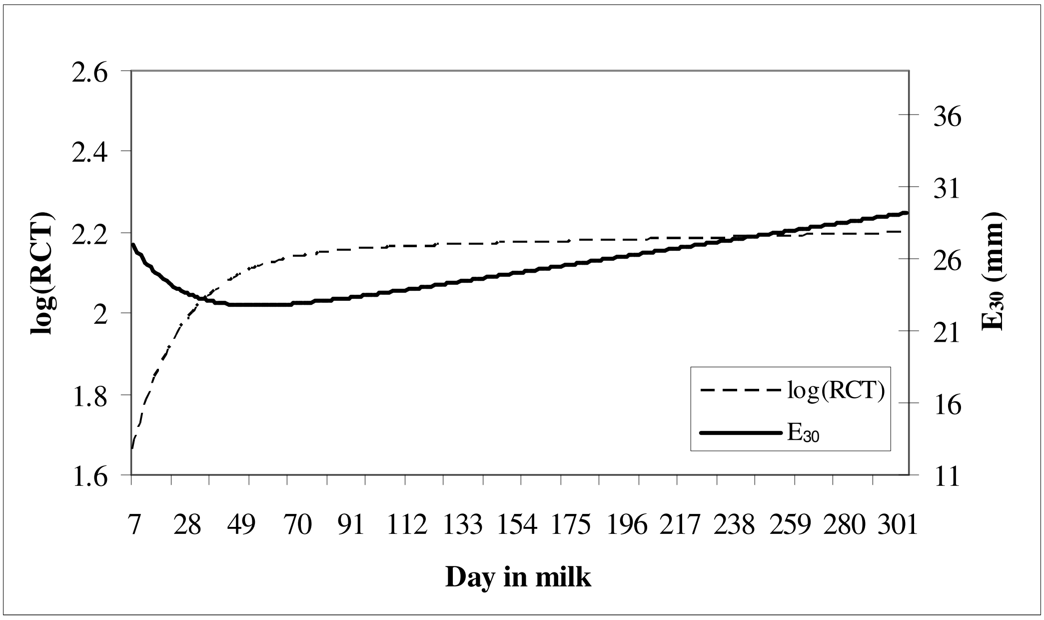

Figure 1. Lactation curve of milk coagulation properties during the lactation period 7 – 305 DIM.

Year-season effects were significant for all studied traits, except SCS.
Table 2 shows the genetic parameters for each trait. The highest heritability was estimated for E_{30} and protein percentage (0.43). Heritability for other milk coagulation property RCT was also somewhat higher (0.34) than for milk production traits, except protein percentage.
Repeatabilities for RCT (0.44) and E_{30} (0.43) were slightly lower than that for milk yield and protein percentage, but moderately higher than that for fat percentage and SCS. There was no permanent environmental variation for E_{30}. Repeatability for this milk coagulation trait was therefore equal to heritability. Repeatability estimates for MCP were somewhat lower than reported by Ikonen et al. (1999) and Tyrisevä et al. (2003), but slightly higher than those reported by Cassandro et al. (2008).
Heritabilities and repeatabilities for milk production traits and SCS are also moderately lower than reported in other studies (Stoop et al., 2007; Tyrisevä et al., 2003).
Contribution of herd variability to total variance was very low, except for milk yield (0.2).

Table 2. The estimates of heritability (h^2), repeatability (r), herd effect (c^2) and total variance (σ_P^2) with their standard errors (se) for milk coagulation properties and milk production traits[1]

Variable	h^2	±	se	r	±	se	c^2	±	se	σ_P^2
Coagulation time[2]	0.34	±	0.06	0.44	±	0.01	0.04	±	0.01	0.04
Curd firmness, mm	0.43	±	0.01	0.43	±	0.01	0.04	±	0.01	45.59
Milk yield, kg	0.20	±	0.04	0.49	±	0.02	0.20	±	0.03	35.27
Fat %	0.24	±	0.05	0.31	±	0.01	0.06	±	0.01	0.45
Protein %	0.43	±	0.07	0.46	±	0.02	0.08	±	0.02	0.06
SCS	0.05	±	0.02	0.36	±	0.01	0.04	±	0.01	3.41

[1] $\sigma_P^2 = \sigma_A^2 + \sigma_{pe}^2 + \sigma_e^2$; $h^2 = \sigma_A^2 / (\sigma_A^2 + \sigma_{pe}^2 + \sigma_e^2)$; $r = (\sigma_A^2 + \sigma_{pe}^2)/(\sigma_A^2 + \sigma_{pe}^2 + \sigma_e^2)$;
$c^2 = \sigma_h^2 / (\sigma_h^2 + \sigma_A^2 + \sigma_{pe}^2 + \sigma_e^2)$
[2] Log-transformed

CONCLUSIONS

Our study with overall 10,722 measurements from 2,608 cows showed moderately high heritabilities for milk coagulation time and curd firmness. Based on these results we can conclude that there is a substantial genetic variation for milk coagulation traits.

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