Associations between milk quality traits and coagulation properties and fertility in Estonian Holstein heifers and first lactation cows

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Introduction

Genetic improvement of milk coagulation properties (MCP) would be an effective way to increase the efficiency of cheese production (Ikonen *et al.* (1999)). To develop the best possible breeding strategies to improve cheese manufacturing efficiency, studies are focused on the genetic improvement of MCP: milk coagulation time (RCT) and firmness of curd (A_{30}). Except for the weak correlations between short RCT and low protein and casein contents, MCP did not correlate genetically with milk production traits (Ikonen *et al.* (2004)), and therefore selection for milk coagulation properties is not expected to result in a strong deterioration in milk production and composition. With the aim to avoid substantial economic losses for milk producers, it is also important to know how selection for MCP would affect fertility of heifers and dairy cows. No studies quantifying the associations between RCT and A_{30} and fertility are available in the scientific literature that the authors are aware of.

The objective of this study was to estimate the associations between milk quality traits and MCP and fertility traits of Estonian Holstein heifers and first lactation cows.

Material and methods

Production and female fertility data. The dataset of milk production and quality traits consisted of 18,825 test-day records from 5,007 first lactation Estonian Holstein cows collected during routine milk recording as part of a development project for the Bio-Competence Centre of Healthy Dairy Products in Estonia during the period April 2005 - June 2009. Each cow had 3-6 measurements from individual milk samples collected during the different stages (7-305 days in milk) of the first lactation.

The milk samples were analyzed for fat, protein and urea concentrations using the MilkoScan 4000 and MilcoScan FT6000, and for somatic cell count (SCC) using the Fossomatic 4000 and Fossomatic 5000 cell counters at the Milk Analysis Laboratory of the Estonian Animal Recording Centre (EARC), using methods suggested by the International Committee for Animal Recording.

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The pH level and milk coagulation properties were determined at the Laboratory of Milk Quality of the Estonian University of Life Sciences on an average 3.5 (SD=1.6) days after sampling. The proportion of milk samples with an age over seven days was less than 1%. The pH level of the milk was determined using a pH meter (Seven Multi; Mettler Toledo GmbH, Greifensee, Switzerland) at 20 ˚C. MCP were milk coagulation time (RCT) in minutes and firmness of curd (A_{30}) in volts. Prior to the assessment of the MCP, milk samples were heated to the renneting temperature (35 ˚C). The rennet (Milase MRS 750 IMCU/ml; CSK Food Enrichment B.V., The Netherlands) used in the analyses was diluted 1:100 (v/v) with distilled water and 0.2 ml of the solution was added to 10 ml milk. The MCP were determined using the Optigraph (Ysebaert (2009)), developed by Ysebaert Dairy Division in partnership with the INRA (LGMPA, lab. G. CORRIEU). Milk samples with a pH lower than 6.5 and non-coagulated milk samples were excluded from the analysis (n=80).

Six fertility traits were selected for analyses (Jorjani (2006)): heifer's age at first insemination (AF), heifer's conception rate at first insemination (hCR), days between calving and first insemination (CF), cow's conception rate at first insemination (cCR), dry period length (DP) and calving interval (CI).

Information about the cows, herds, pedigree and recorded production, milk quality and fertility traits was obtained from the Estonian Animal Recording Centre, from the Animal Breeders' Association of Estonia and from the database COAGEN®.

Statistical analysis. Statistical analysis was carried out in VCE (Groeneveld *et al.* (2008)). The production traits were modelled following the repeatability animal model considering fixed effects of calving year-season and sampling year-season, linear regressions on age at calving and on sample age, 3rd order regression on days in milk and random effects of herd, animal and permanent environment.

The fertility traits were modelled following the animal model considering random effects of farm and animal. Additionally the models for conception rates contained random effects of service sire and technician and fixed effects of birth year, insemination year-season and heifer's age at first insemination (for hCR) or interval between calving and first insemination (for cCR). Model for heifer's age at first insemination contained additionally the fixed effect of birth year-season and random effect of technician; model for days between calving and first insemination contained additionally the fixed effects of birth year and calving year-season and random effect of technician; models for dry period and calving interval contained additionally the fixed effects of birth year and calving year-season and linear regression on age at calving.

Milk coagulation time and fertilitry traits (except conception rates) were log-transformed before analyses. Values of SCC were log-transformed to somatic cell score (SCS) as: $SCS = \log_2(SCC/100{,}000) + 3$. Heritabilities were estimated with univariate models, genetic correlations were derived from bivariate models. Three generations of ancestors were included in the analysis and a total of 20,665 animals were included in the relationship matrix.

Results and discussion

The descriptive statistics of the studied traits are presented in Table 1.

Table 1: Descriptive statistics of studied traits

	n	Mean	SD	Min*	Max*
Milk yield, kg	18,825	26.0	7.24	2.0	57.8
Fat, %	18,774	4.03	0.72	1.51	8.61
Protein, %	18,813	3.37	0.32	1.68	6.67
SCS	18.817	2.91	1.92	-2.64	10.85
Urea, mg/ml	18,451	26.47	8.31	0.3	107.6
pH	18,799	6.65	0.06	6.5	7.4
A_{30}, volt	18,749	13.63	3.99	3.06	36.66
RCT, min	18,749	10.43	2.36	4.36	27.02
AF	5,007	529.3	95.5	190	808
hCR	4,829	0.60	0.49	0	1
CF	4,760	92.0	33.2	40	210
cCR	3,799	0.43	0.50	0	1
DP	3,738	66.1	19.2	1	150
CI	3,706	423.1	74.4	305	660

AF – heifer's age at first insemination, days; hCR – heifer's conception rate; CF – days between calving and first insemination; cCR – cow's conception rate; DP – dry period length, days; CI – calving interval, days;
SCS = $\log_2$(SCC/100,000) + 3; * limits put on fertility traits

Table 2: Estimates of heritability (h^2) and genetic correlations with standard errors in parentheses for the milk production and quality traits and fertility traits

Trait	Ln(AF) $h^2 = 0.24$	hCR $h^2 = 0.04$	Ln(CF) $h^2 = 0.10$	cCR $h^2 = 0.02$	Ln(DP) $h^2 = 0.07$	Ln(CI) $h^2 = 0.04$
Milk yield, kg $h^2 = 0.16$	-0.11 (0.05)	-0.30 (0.12)	0.47 (0.07)	-0.88 (0.09)	-0.64 (0.07)	0.87 (0.06)
Fat, % $h^2 = 0.25$	0.03 (0.03)	0.14 (0.03)	-0.09 (0.05)	0.57 (0.25)	0.24 (0.07)	-0.21 (0.12)
Protein, % $h^2 = 0.30$	-0.01 (0.03)	-0.08 (0.09)	-0.26 (0.06)	0.45 (0.16)	0.39 (0.06)	-0.46 (0.11)
SCS $h^2 = 0.06$	-0.12 (0.07)	-0.20 (0.14)	0.42 (0.10)	-0.36 (0.22)	0.57 (0.08)	0.74 (0.17)
Urea, mg/ml $h^2 = 0.09$	0.12 (0.05)	0.15 (0.12)	-0.10 (0.07)	-0.12 (0.17)	-0.18 (0.09)	0.09 (0.12)
pH $h^2 = 0.28$	0.01 (0.03)	-0.01 (0.08)	-0.10 (0.06)	-0.33 (0.17)	0.11 (0.07)	0.22 (0.12)
A_{30}, volt $h^2 = 0.44$	0.02 (0.03)	0.01 (0.07)	-0.13 (0.04)	0.51 (0.18)	0.19 (0.07)	-0.35 (0.09)
Ln(RCT, min) $h^2 = 0.34$	0.03 (0.03)	-0.06 (0.08)	-0.02 (0.05)	-0.74 (0.17)	0.26 (0.05)	0.63 (0.14)

AF – heifer's age at first insemination, days; hCR – heifer's conception rate; CF – days between calving and first insemination; cCR – cow's conception rate; DP – dry period length, days; CI – calving interval, days;
SCS = $\log_2$(SCC/100,000) + 3

Heritability estimates of the studied traits and genetic correlations between milk production and quality traits and fertility traits are presented in Table 2. About 24 % of the variation in heifer's age at first insemination was additive genetic. Most of the fertility traits had heritability estimates lower than 10%. RTC and A_{30} showed large genetic variation and moderately high heritability estimates. The SCS and urea had the lowest heritability estimates among milk quality traits.

The genetic correlations between heifer's age at first insemination and production traits were negligible. Heifer's conception rate was moderately and negatively correlated only with milk yield. The interval between calving and first insemination had moderate and positive genetic correlations with milk yield and SCS. The cows having genetic superiority to produce more milk had also genetic potential for longer calving interval, shorter dry period and lower conception rate. The genetic correlations of milk quality and coagulation properties with fertility traits showed eligible genetic relationships, which means that selecting cows for higher fat and protein content, shorter coagulation time and stronger firmness of curd should increase conception rate and decrease calving interval.

Conclusion

The milk coagulation time and firmness of curd had higher heritability estimates than milk production traits and therefore a good potential for breeding. Selection of cows for better coagulation properties, higher fat and protein content would have favourable effect and selection for lower SCS and higher milk yield would have unfavourable effect on fertility.

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