

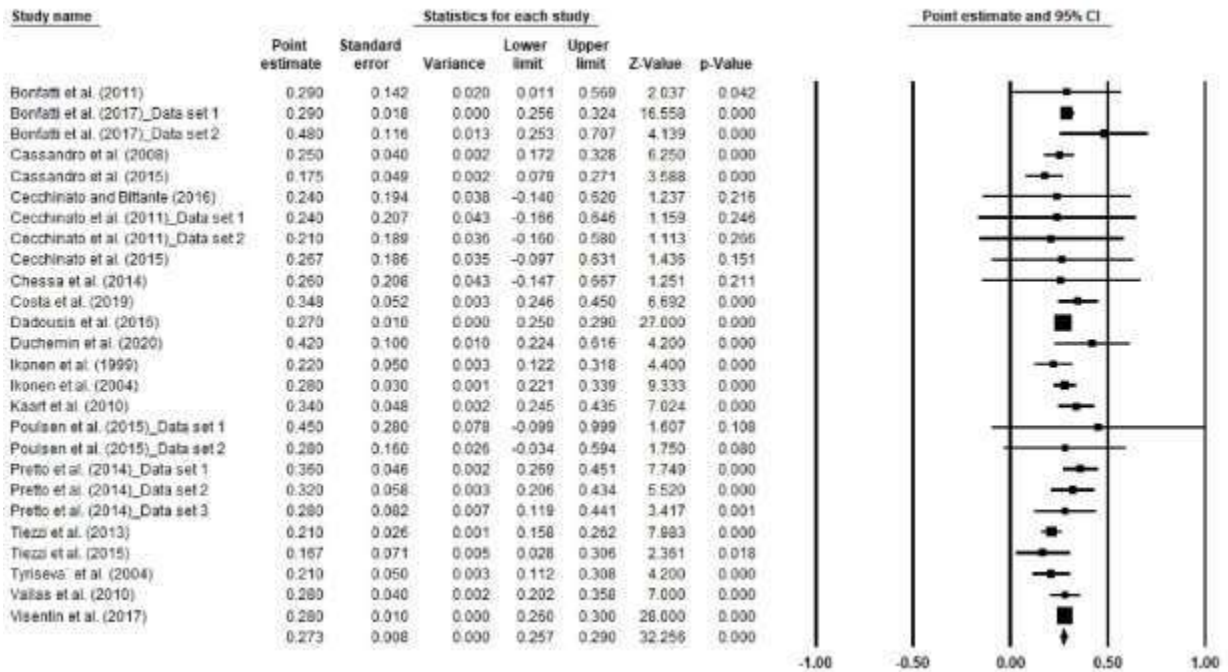
## Milk coagulation properties are moderately heritable in dairy cows: A meta-analysis using the random-effects model

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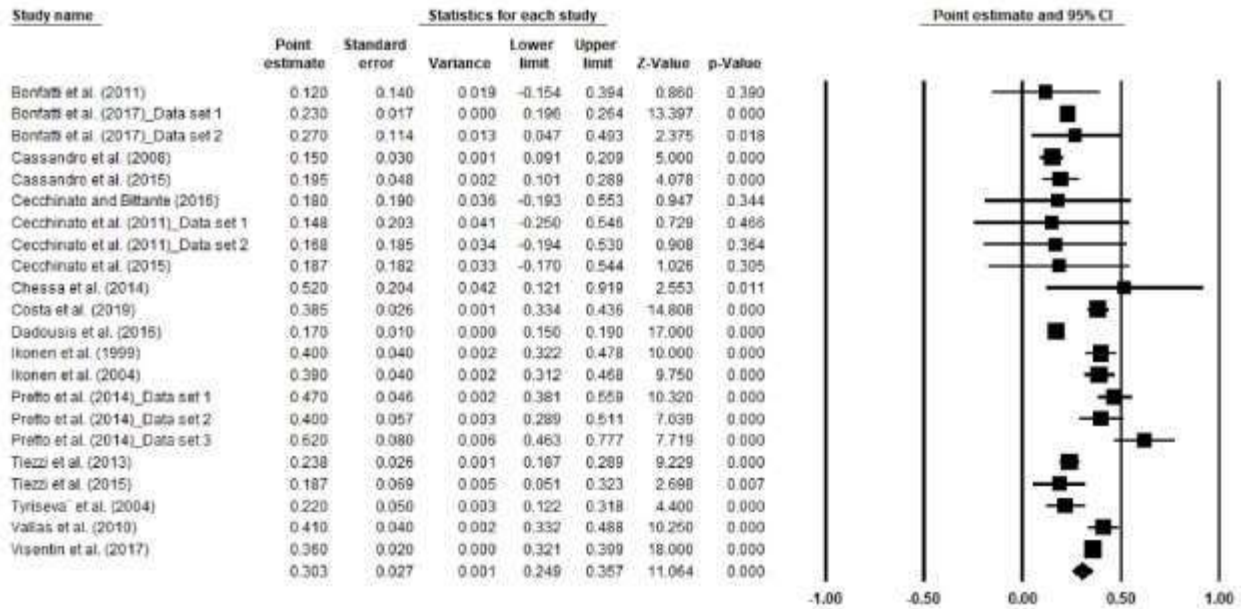
**Table S1.** The list of studies included in the database for conducting this meta-analysis

Reference	Country	Breed	Method of analysis
Bonfatti et al. (2011)	Italy	Simmental	Bayesian
Bonfatti et al. (2017)	Italy	Simmental	REML
Cassandro et al. (2008)	Italy	Holstein	REML
Cassandro et al. (2015)	Italy	Holstein	REML
Cecchinato and Bittante (2016)	Italy	Brown Swiss	Bayesian
Cecchinato et al. (2011)	Italy	Holstein and Brown Swiss	Bayesian
Cecchinato et al. (2015)	Italy	Brown Swiss	Bayesian
Chessa et al. (2014)	Italy	Holstein	REML
Costa et al. (2019)	Italy	Holstein	REML
Dadousis et al. (2016)	Italy	Brown Swiss	REML
Duchemin et al. (2020)	Sweden	Swedish Red	REML
Ikonen et al. (1999)	Finland	Friesian	REML
Ikonen et al. (2004)	Finland	Ayrshire	REML
Kaart et al. (2010)	Estonia	Holstein	REML
Poulsen et al. (2015)	Denmark	Holstein and Jersey	REML
Pretto et al. (2014)	Estonia	Holstein	REML
Tiezzi et al. (2013)	Italy	Holstein	Bayesian
Tiezzi et al. (2015)	Italy	Holstein	REML
Toffanin et al. (2015)	Italy	Holstein	REML
Tyrisevä et al. (2004)	Finland	Holstein and Ayrshire	REML
Vallas et al. (2010)	Estonia	Holstein	REML
Visentin et al. (2017)	Ireland	Different breeds	REML
Visentin et al. (2019)	Italy	Holstein	REML

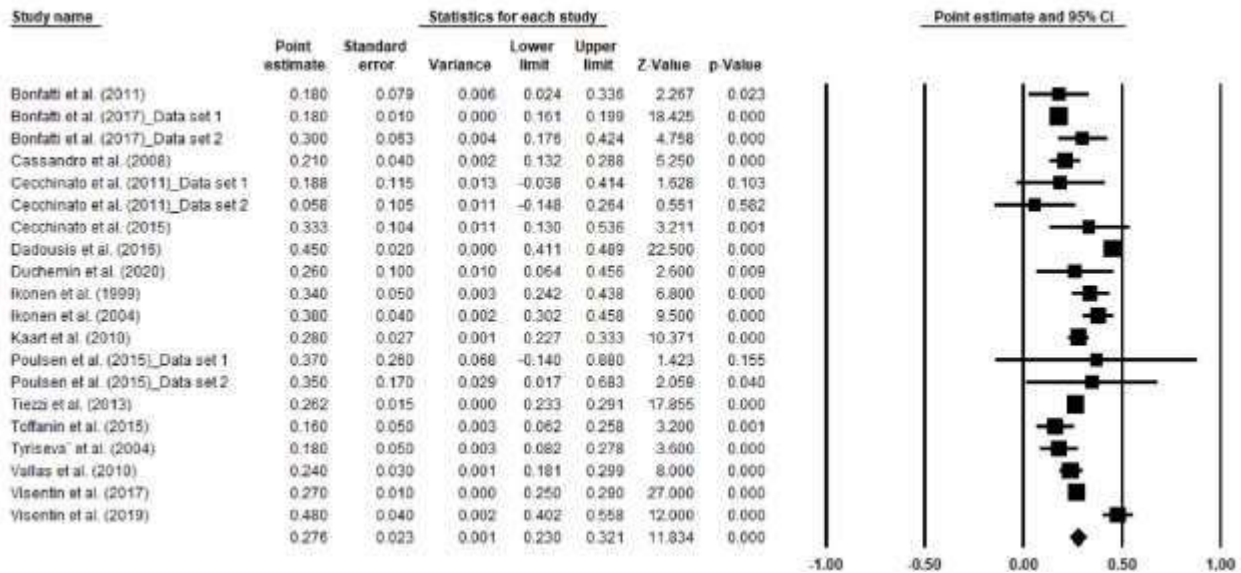
REML: Restricted maximum likelihood



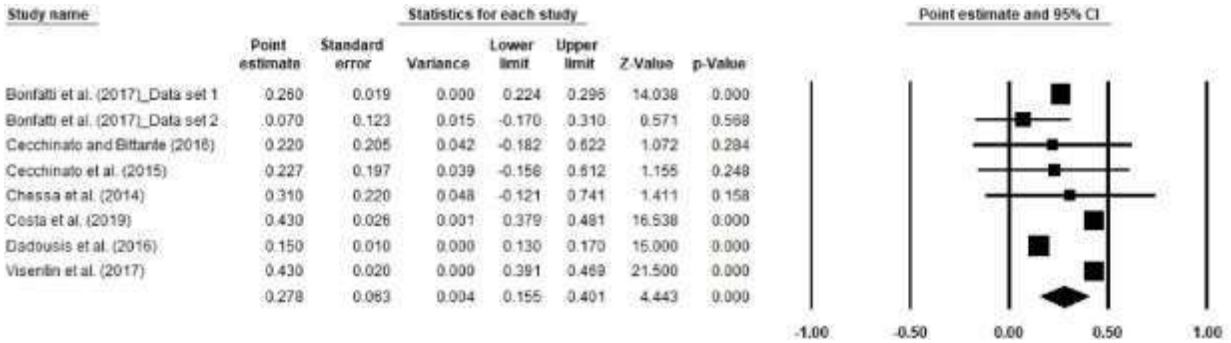
**Fig. S1.** The forest plot of individual studies and the overall outcome for heritability estimate of RCT. The mean effect size, calculated according to a random-effects model, is indicated by the diamond at the bottom of each plot. The size of the squares illustrates the weight of each study relative to the mean effect size. Smaller squares represent less weight. The horizontal bars represent the 95% confidence intervals for the study.



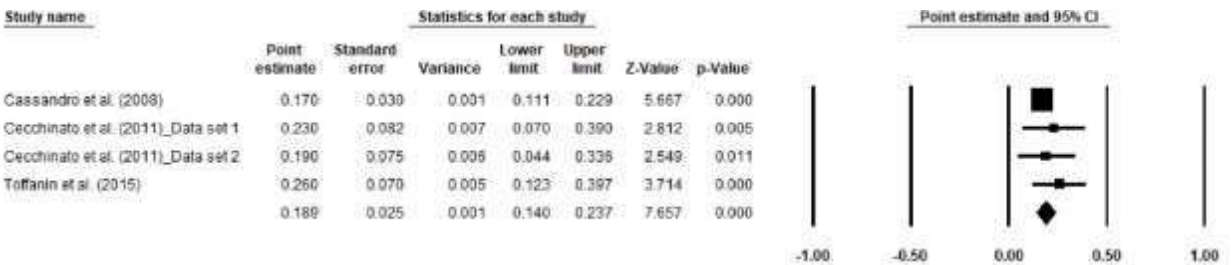
**Fig. S2.** The forest plot of individual studies and the overall outcome for heritability estimate of a30. Detailed information is provided in Fig. S1.



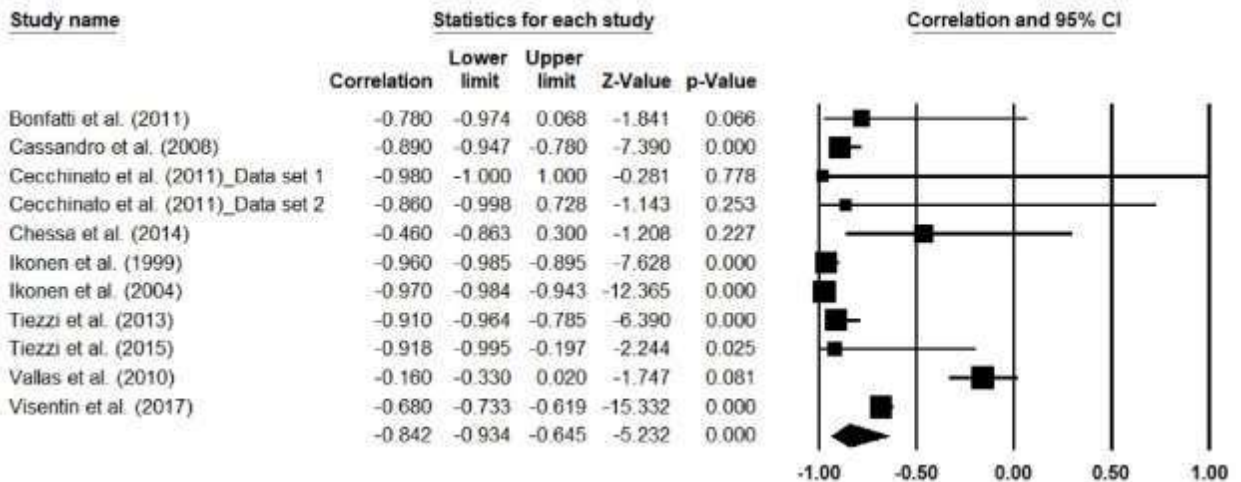
**Fig. S3.** The forest plot of individual studies and the overall outcome for heritability estimate of pH. Detailed information is provided in Fig. S1.



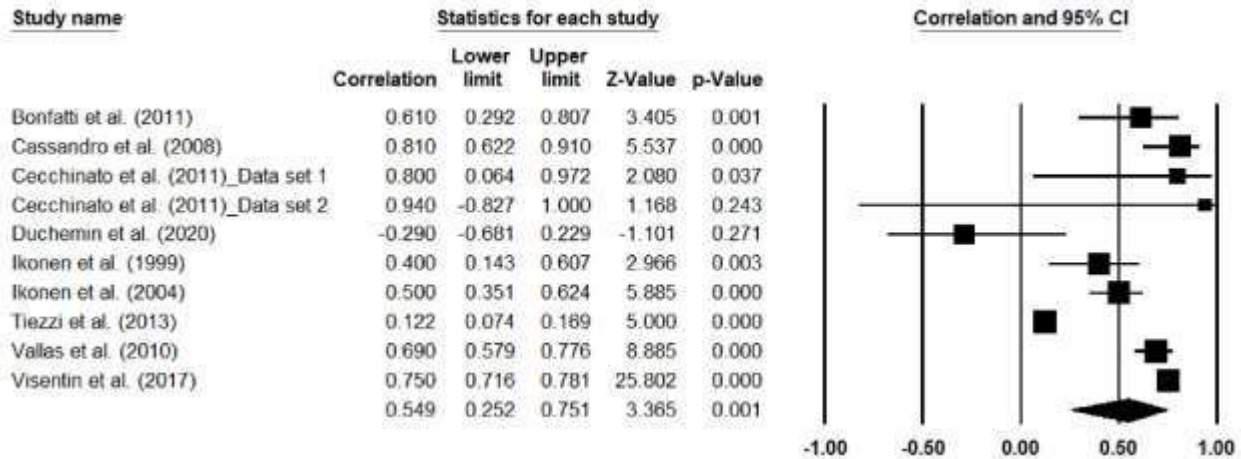
**Fig. S4.** The forest plot of individual studies and the overall outcome for heritability estimate of k20. Detailed information is provided in Fig. S1.



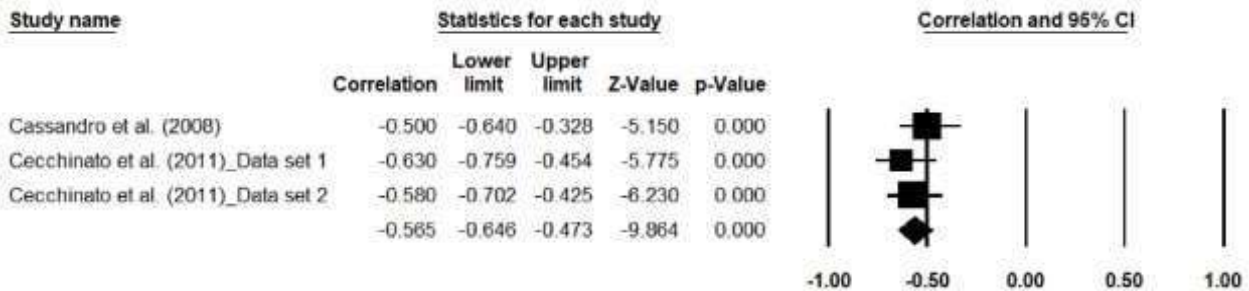
**Fig. S5.** The forest plot of individual studies and the overall outcome for heritability estimate of TA. Detailed information is provided in Fig. S1.



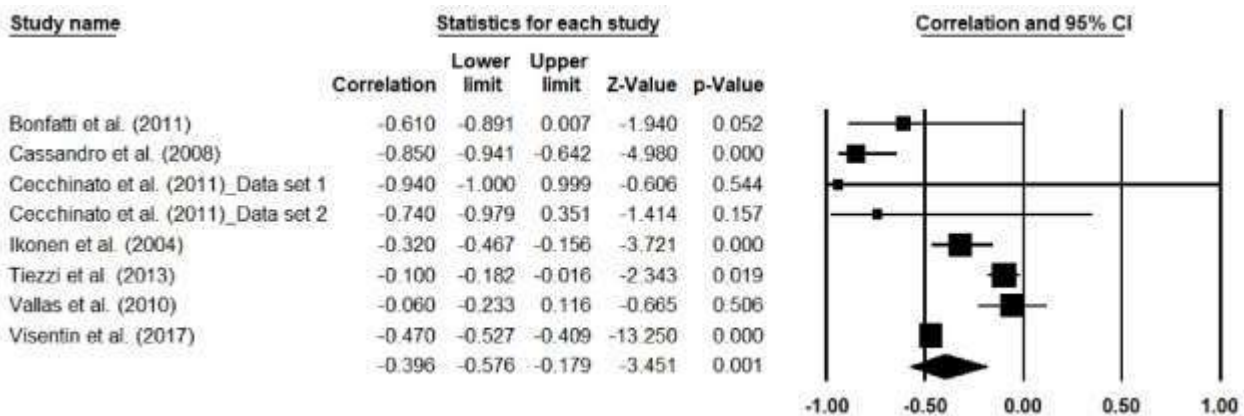
**Fig. S6.** The forest plot of individual studies and the overall outcome for the mean genetic correlation estimate between RCT-a30. Detailed information is provided in Fig. S1.



**Fig. S7.** The forest plot of individual studies and the overall outcome for the mean genetic correlation estimate between RCT-pH. Detailed information is provided in Fig. S1.

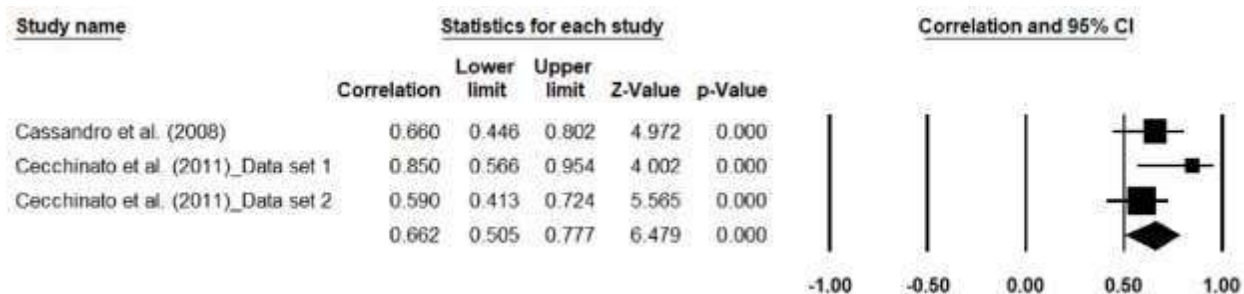


**Fig. S8.** The forest plot of individual studies and the overall outcome for the mean genetic correlation estimate between RCT-TA. Detailed information is provided in Fig. S1.



**Fig. S9.** The forest plot of individual studies and the overall outcome for the mean genetic correlation estimate between a30-pH. Detailed information is provided in Fig. S1.





**Fig. S10.** The forest plot of individual studies and the overall outcome for the mean genetic correlation estimate between a30-TA. Detailed information is provided in Fig. S1.

## References

- Bonfatti V, Cecchinato A, Gallo L, Blasco A, Carnier P. Genetic analysis of detailed milk protein composition and coagulation properties in Simmental cattle. *J Dairy Sci.* 2011 Oct;94(10):5183-93. doi: 10.3168/jds.2011-4297. PMID: 21943768.
- Bonfatti V, Vicario D, Lugo A, Carnier P. Genetic parameters of measures and population-wide infrared predictions of 92 traits describing the fine composition and technological properties of milk in Italian Simmental cattle. *J Dairy Sci.* 2017 Jul;100(7):5526-5540. doi: 10.3168/jds.2016-11667. Epub 2017 May 4. PMID: 28478002.
- Cassandro M, Comin A, Ojala M, Dal Zotto R, De Marchi M, Gallo L, Carnier P, Bittante G. Genetic parameters of milk coagulation properties and their relationships with milk yield and quality traits in Italian Holstein cows. *J Dairy Sci.* 2008 Jan;91(1):371-6. doi: 10.3168/jds.2007-0308. PMID: 18096961.
- Cassandro M, Battagin M, Penasa M, De Marchi M. Short communication: Genetic relationships of milk coagulation properties with body condition score and linear type traits in Holstein-Friesian cows. *J Dairy Sci.* 2015 Jan;98(1):685-91. doi: 10.3168/jds.2014-8153. Epub 2014 Nov 20. PMID: 25465560.
- Cecchinato A, Bittante G. Genetic and environmental relationships of different measures of individual cheese yield and curd nutrients recovery with coagulation properties of bovine milk. *J Dairy Sci.* 2016 Mar;99(3):1975-1989. doi: 10.3168/jds.2015-9629. Epub 2016 Jan 21. PMID: 26805996.
- Cecchinato A, Penasa M, De Marchi M, Gallo L, Bittante G, Carnier P. Genetic parameters of coagulation properties, milk yield, quality, and acidity estimated using coagulating and noncoagulating milk information in Brown Swiss and Holstein-Friesian cows. *J Dairy Sci.* 2011 Aug;94(8):4205-13. doi: 10.3168/jds.2010-3913. PMID: 21787956.
- Cecchinato A, Chessa S, Ribeca C, Cipolat-Gotet C, Bobbo T, Casellas J, Bittante G. Genetic variation and effects of candidate-gene polymorphisms on coagulation properties, curd firmness modeling and acidity in milk from Brown Swiss cows. *Animal.* 2015 Jul;9(7):1104-12. doi: 10.1017/S1751731115000440. Epub 2015 Mar 31. PMID: 25823422.

- Chessa S, Bulgari O, Rizzi R, Calamari L, Bani P, Biffani S, Caroli AM. Selection for milk coagulation properties predicted by Fourier transform infrared spectroscopy in the Italian Holstein-Friesian breed. *J Dairy Sci.* 2014 Jul;97(7):4512-21. doi: 10.3168/jds.2013-7798. Epub 2014 May 2. PMID: 24792799.
- Costa A, Visentin G, De Marchi M, Cassandro M, Penasa M. Genetic relationships of lactose and freezing point with minerals and coagulation traits predicted from milk mid-infrared spectra in Holstein cows. *J Dairy Sci.* 2019 Aug;102(8):7217-7225. doi: 10.3168/jds.2018-15378. Epub 2019 May 31. PMID: 31155264.
- Dadousis C, Cipolat-Gotet C, Bittante G, Cecchinato A. Inferring genetic parameters on latent variables underlying milk yield and quality, protein composition, curd firmness and cheese-making traits in dairy cattle. *Animal.* 2018 Feb;12(2):224-231. doi: 10.1017/S1751731117001616. Epub 2017 Jul 17. PMID: 28712368.
- Duchemin SI, Nilsson K, Fikse WF, Stålhammar H, Buhelt Johansen L, Stenholdt Hansen M, Lindmark-Månsson H, de Koning DJ, Paulsson M, Glantz M. Genetic parameters for noncoagulating milk, milk coagulation properties, and detailed milk composition in Swedish Red Dairy Cattle. *J Dairy Sci.* 2020 Sep;103(9):8330-8342. doi: 10.3168/jds.2020-18315. Epub 2020 Jun 26. PMID: 32600755.
- Ikonen T, Ahlfors K, Kempe R, Ojala M, Ruottinen O. Genetic parameters for the milk coagulation properties and prevalence of noncoagulating milk in Finnish dairy cows. *J Dairy Sci.* 1999 Jan;82(1):205-14. doi: 10.3168/jds.S0022-0302(99)75225-2. PMID: 10022022.
- Ikonen T, Morri S, Tyrisevä AM, Ruottinen O, Ojala M. Genetic and phenotypic correlations between milk coagulation properties, milk production traits, somatic cell count, casein content, and pH of milk. *J Dairy Sci.* 2004 Feb;87(2):458-67. doi: 10.3168/jds.S0022-0302(04)73185-9. PMID: 14762089.
- Kaart, T., M. Vallas, A. Waldmann, H. Kiiman, K. Pärna, and E. Pärna. 2010. Associations between milk quality traits and coagulation properties and fertility in Estonian Holstein heifers and first lactation cows. Page 212 in *Proceedings of the 9th World Congress on Genetics Applied to Livestock Production*, Leipzig, Germany. German Society for Animal Science.
- Poulsen NA, Buitenhuis AJ, Larsen LB. Phenotypic and genetic associations of milk traits with milk coagulation properties. *J Dairy Sci.* 2015 Apr;98(4):2079-87. doi: 10.3168/jds.2014-7944. Epub 2015 Feb 11. PMID: 25682130.
- Pretto D, Vallas M, Pärna E, Tänavots A, Kiiman H, Kaart T. Short communication: Genetic correlation and heritability of milk coagulation traits within and across lactations in Holstein cows using multiple-lactation random regression animal models. *J Dairy Sci.* 2014 Dec;97(12):7980-4. doi: 10.3168/jds.2014-8270. Epub 2014 Oct 11. PMID: 25306280.
- Tiezzi F, Pretto D, De Marchi M, Penasa M, Cassandro M. Heritability and repeatability of milk coagulation properties predicted by mid-infrared spectroscopy during routine data recording, and their relationships with milk yield and quality traits. *Animal.* 2013 Oct;7(10):1592-9. doi: 10.1017/S1751731113001195. Epub 2013 Jul 2. PMID: 23816365.
- Tiezzi F, Valente BD, Cassandro M, Maltecca C. Causal relationships between milk quality and coagulation properties in Italian Holstein-Friesian dairy cattle. *Genet Sel Evol.* 2015 May 13;47(1):45. doi: 10.1186/s12711-015-0123-7. PMID: 25968045; PMCID: PMC4429925.

- Toffanin V, Penasa M, McParland S, Berry DP, Cassandro M, De Marchi M. Genetic parameters for milk mineral content and acidity predicted by mid-infrared spectroscopy in Holstein-Friesian cows. *Animal*. 2015 May;9(5):775-80. doi: 10.1017/S1751731114003255. Epub 2015 Jan 13. PMID: 25584638.
- Tyrisevä AM, Vahlsten T, Ruottinen O, Ojala M. Noncoagulation of milk in Finnish Ayrshire and Holstein-Friesian cows and effect of herds on milk coagulation ability. *J Dairy Sci*. 2004 Nov;87(11):3958-66. doi: 10.3168/jds.S0022-0302(04)73536-5. PMID: 15483181.
- Vallas M, Bovenhuis H, Kaart T, Pärna K, Kiiman H, Pärna E. Genetic parameters for milk coagulation properties in Estonian Holstein cows. *J Dairy Sci*. 2010 Aug;93(8):3789-96. doi: 10.3168/jds.2009-2435. PMID: 20655449.
- Visentin G, McParland S, De Marchi M, McDermott A, Fenelon MA, Penasa M, Berry DP. Processing characteristics of dairy cow milk are moderately heritable. *J Dairy Sci*. 2017 Aug;100(8):6343-6355. doi: 10.3168/jds.2017-12642. Epub 2017 May 30. PMID: 28571984.
- Visentin G, Niero G, Berry DP, Costa A, Cassandro M, De Marchi M, Penasa M. Genetic (co)variances between milk mineral concentration and chemical composition in lactating Holstein-Friesian dairy cows. *Animal*. 2019 Mar;13(3):477-486. doi: 10.1017/S1751731118001507. Epub 2018 Jul 6. PMID: 29976269.