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Milk coagulation ability of Rendena and Holstein-Friesian cattle breeds

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ABSTRACT

Aim of this study was to compare Holstein-Friesian (HF) and Rendena (RE) cattle breeds for milk coagulation and composition traits predicted by mid-infrared spectroscopy using official milk recording samples of 28 single-breed dairy herds of northeast Italy. Individual milk samples (n = 3,622) from 1,786 cows were analyzed for rennet coagulation time (RCT, min), curd firmness (a_{30}, mm), and composition traits. A linear mixed model was used to study the effect of breed and environmental factors on RCT and a_{30}. Breed was the most important source of variation for coagulation traits. In particular, milk from RE coagulated earlier and showed a firmer curd than milk from HF cows. Rennet coagulation time was shortest at the beginning of lactation, and a_{30} was better at the beginning and end of lactation. In conclusion, RE produced milk more suitable for cheese processing than that of HF. Clotting characteristics of RE breed should be considered when developing strategies useful for the valorization of this local genetic resource.
(Keywords: milk coagulation ability, dairy cattle breed, mid-infrared spectroscopy)

INTRODUCTION

Milk coagulation properties **(**MCP**)** are important in cheese-making production, especially in countries where dairy industry is based on traditional products and is market-oriented (*Cassandro*, 2003). Milk that aggregates and forms a firm curd soon after the addition of the clotting enzyme is expected to produce higher cheese yield than milk with poor coagulation properties (*Bynum and Olson*, 1982; *Riddell-Lawrence and Hicks*, 1989). Several studies have confirmed that MCP are useful information for cheese processing, yield and quality at the laboratory (*Alipanah and Kalashnikova*, 2007; *Penasa et al.*, 2010) and industrial level (*Bynum and Olson*, 1982; *Summer et al.*, 2003; *De Marchi et al.*, 2008). Moreover, MCP influence the sensory properties of cheese (*Martin et al.*, 1997).

Several approaches can be used to determinate MCP (*O'Callaghan et al.*, 2002; *Fagan et al.*, 2007; *Klandar et al.*, 2007). Among mechanical tools, the Formagraph and the Computerized Renneting Meter have been the most used to determine MCP (*Cassandro et al.*, 2008). The output are firmness/time graphs that report measures of rennet coagulation time (RCT), which is the interval, in minutes, between the addition of the rennet to milk and the beginning of coagulation, and curd firmness (a_{30}), which corresponds to the width of the graph 30 min after rennet addition. The main disadvantages of the aforementioned instruments are the limited number of samples processed per hour, the costs related to sample processing and the skilled personnel involved. Therefore, mid-infrared spectroscopy (MIRS) offers quick and low-cost analysis, minimal sample preparation, and the opportunity to be implemented routinely to predict economically important traits such as fat, protein, casein and MCP (*De Marchi et al.,* 2009, 2012).

Differences in MCP among breeds (*e.g., Macheboeuf et al.,* 1993; *Malacarne et al.,* 2006; *De Marchi et al.,* 2007) and among cows within the same breed *(e.g., Ikonen et al.,* 2004; *Cassandro et al.,* 2008*)* have been reported. Most studies have measured coagulation properties on milk from cosmopolitan breeds such as Holstein-Friesian (HF) and Brown Swiss, whereas few studies have focused on local breeds (*Chiofalo et al.,* 2000; *De Marchi et al.,* 2007*).*

Among the latter, Rendena (RE) is a dual-purpose (milk and meat) alpine breed mainly reared in northeast Italy, with 4,066 cows undergoing milk recording (*AIA*, 2013). Rendena is a small-sized cow that exhibits good grazing ability, longevity and fertility (*Mantovani et al.,* 1997). To our knowledge, no studies have attempted to predict the coagulation ability of milk from RE breed using MIRS and repeated records per cow. Therefore, the objective of this work is to compare two cattle breeds, one local (RE) and one cosmopolitan (HF), for predicted MCP using individual milk samples collected during routine milk recording.

MATERIAL AND METHODS

Data

The data consisted of 3,622 individual milk samples collected between September and December 2011 from 20 and 8 single-breed herds of Holstein-Friesian (HF; n = 1,330 cows) and Rendena (RE; n = 456 cows) cattle breeds, respectively. Farms were located in Veneto region (northeast Italy) and were enrolled in the official monthly test-day milk recording system.

Milk samples were analyzed in the laboratory of the Breeders Association of Veneto region (Padova, Italy) using Milko-Scan FT6000 (Foss Electric A/S, Hillerod, Denmark) for fat, protein, casein and lactose contents, somatic cell count (SCC) and pH. Milk coagulation traits, namely rennet coagulation time (RCT, min) and curd firmness ($a_{30,}$ mm), were predicted by MIRS using models developed by *De Marchi et al. (*2012*)* and implemented on the Milko-Scan FT6000; those authors obtained coefficients of determination of cross-validation of 0.76 and 0.70 for RCT and a_{30}, respectively *(De Marchi et al.,* 2009, 2012*)*. Somatic cell score (SCS) was obtained via base-2 log-transformation of SCC as: SCS = 3 + $\log_2$(SCC/100,000).

Statistical analysis

Data were analyzed using the MIXED procedure of SAS (*SAS Institute*, 2012) according to the following linear model:

$$y_{ijklmno} = \mu + B_i + H_j(B_i) + M_k + DIM_l + P_m + (B \times DIM)_{il} + (B \times P)_{im} + cow_n(B_i) + \varepsilon_{ijklmno},$$

where $y_{ijklmno}$ is the dependent variable (RCT or a_{30}); μ is the overall intercept of the model; B_i is the fixed effect of the *i*th breed of the cow (*i* = HF, RE); $H_j(B_i)$ is the fixed effect of the *j*th herd (*j* = 1 to 28) nested within the *i*th breed; M_k is the fixed effect of the *k*th month of sampling (*k* = September, October, November, December); DIM_l is the fixed effect of the *l*th class of stage of lactation of the cow (*l* = 1 to 12, the first being a class from 5 to 35 d, followed by 10 classes of 30 d each, a class of 45 d, and an open class beyond 350 d, respectively); P_m is the fixed effect of the *m*th parity of the cow (*m* = first, second, third, fourth, and fifth and later parities); $(B \times DIM)_{il}$ is the fixed interaction effect between breed and DIM; $(B \times P)_{im}$ is the fixed interaction effect between breed and parity; $cow_n(B_i)$ is the random effect of the *n*th cow (*n* = 1 to 1,786) nested within the *i*th breed N ~ (0, $\sigma^2_{cow(B)}$); and $\varepsilon_{ijklmno}$ is the random residual N ~ (0, σ^2_{ε}). Significance of breed effect was tested on the cow within breed variance.

RESULTS AND DISCUSSION

Descriptive statistics and significance of fixed effects

Table 1 shows descriptive statistics of MCP, composition traits, and milk yield. Rennet coagulation time and a_{30} averaged 20.59 ± 3.99 min and 22.00 ± 8.81 mm, respectively.

Table 1

Descriptive statistics

Trait[a]	Mean	SD	P1[b]	P99[b]
RCT (min)	20.59	3.99	10.62	29.11
a_{30} (mm)	22.00	8.81	5.11	46.39
Fat content (%)	3.80	0.70	2.35	5.67
Protein content (%)	3.47	0.44	2.65	4.68
Casein content (%)	2.75	0.37	2.04	3.75
Lactose content (%)	4.79	0.22	4.16	5.20
SCS	4.75	1.36	2.30	8.31
pH	6.61	0.08	6.43	6.79
Milk yield (kg d^{-1})	25.68	9.96	5.80	49.60

[a]RCT, rennet coagulation time; a_{30}, curd firmness 30 min after rennet addition; SCS somatic cell score

[b]P1, 1st percentile; P99, 99th percentile

Significance of fixed effects included in the analysis of RCT and a_{30} are reported in *Table 2*.

Table 2

***F*-values and significance of fixed effects included in the analysis for milk coagulation traits (RCT, rennet coagulation time; a_{30}, curd firmness 30 min after rennet addition)**

Effect[a]	RCT, min	a_{30}, mm
Breed (B)	111.60^{***}	95.72^{***}
Herd(B)	6.45^{***}	5.00^{***}
Month	55.63^{***}	77.29^{***}
DIM	36.11^{***}	16.22^{***}
Parity (P)	4.63^{***}	8.99^{***}
B x DIM	1.81^{*}	1.43^{ns}
B x P	2.24^{ns}	2.78^{*}
RSD	3.39	7.84

[a]DIM, days in milk; RSD, residual standard deviation; ns = not significant; $^{*}P<0.05$; $^{***}P<0.001$

Breed, herd within breed, month, DIM and parity were highly significant (P<0.001) in explaining the variability of MCP. The interaction effect between breed and DIM was significant (P<0.05) in explaining the variation of RCT but not of a_{30}. Finally, the interaction effect between breed and parity was found significant (P<0.05) for a_{30} but not for RCT.

Least square means

Milk from RE cows coagulated 2.37 min earlier and curd was 5.17 mm firmer than milk from HF cows (P<0.001). The HF breed had the worst coagulation properties as reported by *De Marchi et al. (*2007*)* who studied the variation of MCP determined by Formagraph in bulk milk. It is important to emphasize that these are the first results for MCP predicted by MIRS at individual level in RE breed.

Figure 1 shows the least squares means of MCP for HF and RE breeds across DIM. Rennet coagulation time was shortest in early lactation, and RE performed better than HF across DIM. Curd firmness exhibited the best values at the beginning and end of lactation, and it was higher in milk of RE than HF cows. The DIM effect was an important source of variation for MCP (P<0.001), and the trend of RCT and a_{30} during the first part of lactation is very similar to those reported by several authors (*Ostersen et al.,* 1997; *Tyrisevä et al.,* 2004; *De Marchi et al.,* 2007; *Penasa et al.,* 2014).

Figure 1

Least square means (with standard errors) of (a) rennet coagulation time (RCT, min) and (b) curd firmness 30 min after rennet addition (a_{30}, mm) of cows of different days in milk (DIM) and breeds (– – = Holstein-Friesian; —— = Rendena)

a) b)

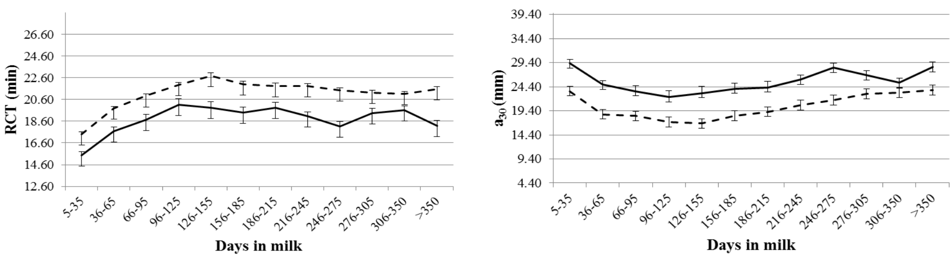
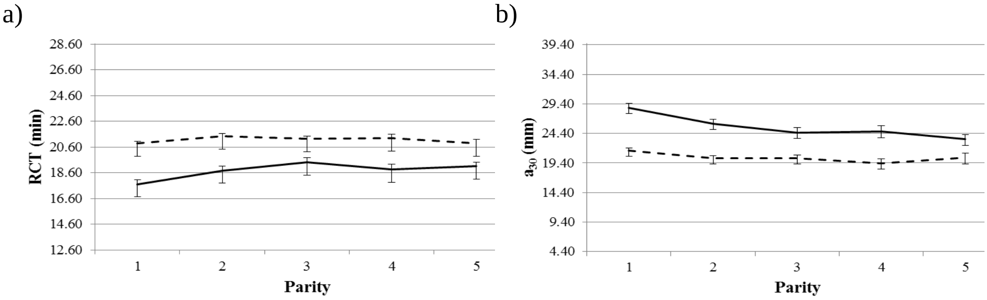


Figure 2 depicts the least squares means of MCP for HF and RE breeds across parities. Overall, RCT and a_{30} were better in primiparous than multiparous cows, and RE performed better than HF. Parity had a strong effect on MCP (P<0.001). However, the effects of parity on RCT and a_{30} are contradictory. Milk coagulation properties deteriorated with parity in the study of *Tyrisevä et al.* (2003) and *Penasa et al.* (2014), confirming findings of the present work, whereas *Ikonen et al.* (2004) reported lower values of curd firmness for primiparous than multiparous cows. Finally, *Ikonen et al.* (1999) and *Tyrisevä et al.* (2004) did not observe any effects of parity on milk clotting ability.

Figure 2

Least square means (with standard errors) of (a) rennet coagulation time (RCT, min) and (b) curd firmness 30 min after rennet addition (a30, mm) of cows of different parities and breeds (– – = Holstein-Friesian; —— = Rendena)



CONCLUSION

Milk coagulation properties were affected by several factors, especially cow breed and environmental factors. Rendena produced milk which coagulated earlier and exhibited a firmer curd than that of HF. This result suggests that small-sized local breeds such as RE are often interesting for traits of economic importance. Besides cow breed, month, stage of lactation and parity were also important on MCP. Further research is needed to investigate the effects of farm characteristics on the variation of MCP to identify technical solutions which could help farmers to improve MCP and the opportunity for the conservation of endangered resources.

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