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Breed of cow and herd productivity affect milk composition and modeling of coagulation, curd firming, and syneresis

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ABSTRACT

Milk coagulation properties (MCP) have been widely investigated in the past using milk collected from different cattle breeds and herds. However, to our knowledge, no previous studies have assessed MCP in individual milk samples from several multi-breed herds characterized by either high or low milk productivity, thereby allowing the effects of herd and cow breed to be evaluated independently. Multi-breed herds (n = 41) were classified into 2 categories based on milk productivity (high vs. low), defined according to the average milk net energy yielded daily by lactating cows. Milk samples were taken from 1,508 cows of 6 different breeds: 3 specialized dairy (Holstein-Friesian, Brown Swiss, Jersey) and 3 dual-purpose (Simmental, Rendena, Alpine Grey) breeds, and analyzed in duplicate (3,016 tests) using 2 lactodynamographs to obtain 240 curd firming (CF) measurements over 60 min (1 every 15 s) for each duplicate. The 5 traditional single-point MCP (RCT, k_{20}, a_{30}, a_{45}, and a_{60}) were yielded directly by the instrument from the available CF measures. All 240 CF measures of each replicate were also used to estimate 4 individual equation parameters: RCT estimated according to curd firm change over time modeling (RCT_{eq}), asymptotic potential curd firmness (CF_P), curd firming instant rate constant (k_{CF}), and syneresis instant rate constant (k_{SR}) and 2 derived traits: maximum curd firmness achieved within 45 min (CF_{max}) and time at achievement of CF_{max} (t_{max}) by curvilinear regression using a nonlinear procedure. Results showed that the effect of herd-date on traditional and modeled MCP was modest, ranging from 6.1% of total variance for k_{20} to 10.7% for RCT, whereas individual animal variance was the highest, ranging from 32.0% for t_{max} to 82.5% for RCT_{eq}. The repeatability of MCP was high (>80%) for all traits except those associated with the last part of the lactodynamographic curve (i.e., a_{60}, k_{SR}, k_{CF}, and t_{max}: 57 to 71%). Reproducibility, taking into account the effect of instrument, was equal to or slightly lower than repeatability. Milk samples collected in farms characterized by high productivity exhibited delayed coagulation (RCT_{eq}: 18.6 vs. 16.3 min) but greater potential curd firmness (CF_P: 76.8 vs. 71.9 mm) compared with milk samples collected from low-productivity herds. Parity and days in milk influenced almost all MCP. Large differences in all MCP traits were observed among breeds, both between specialized and dual-purpose breeds and within these 2 groups of breeds, even after adjusting for milk quality and yield. Milk quality and MCP of samples from Jersey cows, and coagulation time of samples from Rendena cows were better than in milk from Holstein-Friesian cows, and intermediate results were found with the other breeds of Alpine origin. The results of this study, taking into account the intrinsic limitation of this technique, show that the effects of breed on traditional and modeled MCP are much greater than the effects of herd productivity class, parity, and DIM. Moreover, the variance in individual animals is much greater than the variance in individual herds within herd productivity class. It seems that improvement in MCP depends more on genetics (e.g., breed, selection) than on environmental and management factors.
Key words: milk coagulation, curd firming, syneresis, breed, herd productivity

INTRODUCTION

Milk coagulation properties (**MCP**) have consequences for cheese making, cheese yields, and cheese quality. The major cheese-making problems are fast coagulation of milk (acid, fermented milk), late or absence of coagulation of milk (especially with some milk protein genetic variants), weak curd firmness at cutting and slow syneresis of curd. Recently, Cecchinato and Bittante (2016) found strong relationships between cheese yield and curd firming patterns. Milk renneting properties also affect cheese quality (Horne and Banks, 2004), and are therefore particularly important for Protected Designation of Origin (PDO) cheeses (Mariani

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and Battistotti, 1999; Bertoni et al., 2005; Bittante et al., 2011).

Several techniques can be used to assess MCP (Klandar et al., 2007), but the most common approach used in both the laboratory and industry is lactodynamography. Traditionally, 3 single-point traits are recorded: rennet coagulation time (**RCT**, min), time to a curd firmness (**CF**) of 20 mm (**k_{20}**, min), and CF 30 min after enzyme addition (**a_{30}**, mm).

The major limitations of the traditional MCP are the incidence of samples not coagulating (**NC**) within 30 min (no RCT, k_{20}, or a_{30} available), the much greater incidence of late-coagulating (**LC**) samples that fail to reach CF of 20 mm (no k_{20} available), and the high correlation between RCT and a_{30} (so that the latter trait has limited informative value).

Recently, a more informative method to overcome, at least in part, the above-mentioned limitations and acquire detailed information is to model the curd-firming process over time (**CF_t**) using the hundreds of single-point pieces of information automatically available for each milk sample analyzed (Bittante, 2011), and to extend the lactodynamographic test period beyond 30 min (Bittante et al., 2013).

Traditional MCP obtained from lactodynamographs have been used in several studies to compare milk from cows of different breeds, as reviewed by Bittante et al. (2012). Comparisons are difficult, however, because they are often based on a small number of cows of 2 to 3 different breeds reared in one (experimental) farm (Auldist et al., 2002; Jõudu et al., 2008), or on a large number of cows from many single-breed farms (Poulsen et al., 2013), so that the effect of breed is confounded with the effects of farm, feeding strategy, and sampling date, or they are based on bulk milk samples from different single-breed farms (Mariani et al., 1984; De Marchi et al., 2007). In addition, the effect of feeding strategy is not well known as experimental trials focus on some specific diet ingredient (Kreuzer et al., 1996; Malossini et al., 1996), and very few studies have been carried out at the population level (Tyrisevä et al., 2003).

Over time, dairy farms have moved toward larger and more industrialized setups in which cows are fed high-energy diets, and dairy herds have changed in terms of the proportions and productivity of breeds, and dairy breeds have been assiduously selected to improve productivity and milk quality.

We have carried out a large study involving several multi-breed herds characterized by variable levels of productivity, which allows for independent evaluation of the effects of farm and of different cattle breeds. The specific aims of this study were (1) to quantify and characterize the effects on MCP of high or low herd productivity (defined according to the milk net energy yielded daily by the cows); (2) to quantify the variability of herds within herd productivity class; (3) to make a within-herd comparison of 3 dairy and 3 dual-purpose breeds for their milk quality, traditional MCP, and modeled CF_t; and (4) to quantify the effects of DIM and parity, and assess the repeatability and reproducibility of traditional MCP and CF_t modeled and derived traits.

MATERIALS AND METHODS

Multi-Breed Herds

The present study is part of the Cowplus project. A total of 1,508 cows from 41 multi-breed herds (2 to 5 breeds, with an average of 3.0) located in the Trentino Alto Adige region of the northeastern Italian Alps, were controlled once for daily milk production and sampled during the evening milking for milk quality analyses. A total of 6 breeds were sampled—3 specialized dairy breeds: Holstein Friesian (**HF**, 31 herds and 471 cows), Brown Swiss (**BS**, 36 herds, 663 cows), and Jersey (**Je**, 7 herds, 40 cows); and 3 dual-purpose breeds: Simmental (**Si**, 20 herds, 158 cows), and 2 autochthonous breeds, Alpine Grey (**AG**, 13 herds, 73 cows) and Rendena (**Re**, 8 herds, 103 cows). The herds comprised 15 combinations of breeds: HF + BS + Si (n = 8 herds), HF + BS (n = 7 herds), BS + Si + AG (n = 6 herds), HF + BS + Re (n = 3 herds), HF + BS + Je (n = 3 herds), BS + AG (n = 3 herds), HF + BS + Si + AG (n = 2 herds), HF + AG (n = 2 herds), BS + Je (n = 1 herds), HF + BS + Si + AG + Re (n = 1 herd), BS + Si + AG + Re (n = 1 herd), HF + Si + Re (n = 1 herd), BS + AG + Re (n = 1 herd), HF + Si (n = 1 herd), and HF + Re (n = 1 herd).

Dairy and Dual-Purpose Breeds

The 41 mixed-breed dairy farms selected for the study had only cows enrolled in the Italian Herd Books of the 6 breeds studied and were practicing almost exclusively AI using national or imported semen from proven bulls or progeny testing young bulls.

The dairy large-framed Holstein Friesian cows in the province of Trento were obtained from semen mainly from Italian, German, American, and Dutch bulls (Cecchinato et al., 2015a). In this study, the cows were characterized by a BW of 654 ± 45 kg, a parity of 2.4 ± 1.6, and DIM of 197 ± 140.

The dairy large-framed Brown Swiss cows were obtained from semen from Italian, Austrian, German, American, and Swiss bulls. Body size was very close to that of Holstein Friesians (656 ± 46 kg), as was parity (2.6 ± 1.6) and DIM (188 ± 139).