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Phenotypic factors affecting coagulation properties of milk from Sarda ewes

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ABSTRACT

In this study, milk-coagulation properties (MCP) were characterized in the Sarda sheep breed. Milk composition and MCP [rennet-coagulation time (RCT), curd-firming time [time to reach a curd firmness of 20 mm (k_{20})], and curd firmness (a_{30}), (a_{45}), and (a_{60})] were obtained extending the lactodynamographic analysis from 30 to 60 min from a population of 1,121 ewes from 23 different farms. Managerial characteristics of farms and parity, individual daily milk yields and stage of lactation of ewes were recorded. Data were analyzed using a mixed-model procedure with fixed effects of days in milk, parity, daily milk yield, and flock size and the random effect of the flock/test day nested within flock size. Sampled farms were classified as small (<300 ewes) and medium (300 to 600 ewes), and these were kept by family operations, or as large (>600 ewes), often operated through hired workers. Daily milk yield was, on average, 1.58 ± 0.79 L/d and variability for this trait was very high. The average content of fat, protein, and casein was respectively 6.41, 5.39, and 4.20%. The class of flock size had a significant effect only on curd firmness, whereas days in milk affected RCT and k_{20}. The flock test day, parity, and daily milk yield were important sources of variation for all MCP. The mean value of RCT (8.6 min) and the low occurrence of noncoagulating samples (0.44%) confirmed the excellent coagulation ability of sheep milk compared with cattle milk. A more rapid coagulation was observed in midlactating, primiparous, and high-yielding ewes. The k_{20} was usually reached in less than 2 min after gelation, with the most favorable values at mid lactation. The mean value of curd firmness 30 min after rennet addition (a_{30}) was, on average, 50 mm and decreased to 46 and 42 mm respectively after 45 (a_{45}) and 60 min (a_{60}). The decreasing value of curd-firmness traits was likely to be caused by curd syneresis and whey expulsion. The correlation between RCT and a_{30} was much lower than in dairy cows and about null for a_{45} and a_{60}. This means that curd firmness in dairy ewes is almost independent of gelation time and this can provide specific information for this species. In conclusion, this study showed that milk from Sarda sheep is characterized by an earlier gelation, a faster increase in curd firmness with time, and greater curd firmness after 30 min compared with dairy cows. Furthermore, correlations between MCP in sheep are much lower than in bovines and some of the assumptions and interpretations related to cows cannot be applied to sheep.

Key words: sheep milk, coagulation property, Sarda sheep breed, flock characteristic

INTRODUCTION

Milk-coagulation properties (**MCP**) are generally used in the dairy industry to assess the suitability of milk for cheese making and predict yield and technological characteristics of cheese. Since the 1970s, many techniques have been investigated and both mechanical and infrared-based instruments have been assembled to obtain MCP (Cipolat-Gotet et al., 2012). One of the most commonly used mechanical instruments is the Formagraph (Foss Electric A/S, Hillerød, Denmark). It is able to provide a diagram that graphically illustrates the sequences of formation and development of curd after the addition of rennet (usually for 30 min) and it allows the measurement of 3 MCP: rennet-coagulation time (**RCT**; measured in min), curd-firming time [time to reach a curd firmness of 20 mm ($\mathbf{k_{20}}$); min], and curd-firmness ($\mathbf{a_{30}}$; mm) traits (McMahon and Brown, 1982). Milk-coagulation properties have been extensively studied in dairy cows and the effects of the breed, milk genetic variants, and measurement methods as well as repeatability, heritability, and genetic correlations with milk quality traits have recently been reviewed by Bittante et al. (2012).

Milk-coagulation properties of milk from small ruminants, and particularly from sheep, are much less known. Milk production from dairy sheep farming is of great economic importance, especially in the countries of Southern Europe and the Mediterranean basin in

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general (Vacca et al., 2010; Ramos and Juarez, 2011). The European Union produced about 2.8 million tonnes of ewe milk in 2011, representing 29% of the whole world ovine milk production (FAOSTAT, 2013). This milk is mainly produced by local breeds, such as in Sardinia, a region of Italy in the center of the Mediterranean Sea, where it has been estimated that 5% of the whole world ewe's milk is produced by its indigenous breed, the Sarda sheep (Vacca et al., 2008).

The Sarda is a dairy specialized breed, well adapted to the difficult environment of the island of Sardinia (Macciotta et al., 1999) where farming is characterized by a large variation in the application of semi-extensive and semi-intensive methods (Carta et al., 2009). Nowadays, the Sarda is the top-ranked sheep breed in Italy, with an estimated total population size of about 3 million head (Carta et al., 2009), among which 220,000 animals in 1,000 farms are officially recorded (ICAR, 2013). Milk from Sarda ewes is almost completely used to produce 3 protected designation of origin cheeses, according to the rules of the European Union: Pecorino Romano (EU, 2009), Pecorino Sardo, and Fiore Sardo (EU, 1996). In contrast to cattle, MCP are scarcely used as a tool to characterize milk for protected designation of origin dairy products and for milk payment scales (Bittante et al., 2011a,b).

To our knowledge, no study has yet investigated ovine MCP under field conditions and on the basis of a large sampled population. Hence, the objectives of this paper were to (1) characterize traditional MCP of the Sarda sheep breed obtained using the Formagraph instrument (RCT, k_{20}, and a_{30}); (2) analyze curd firmness after the standard interval of 30 min [i.e., at 45 (**a_{45}**) and 60 min (**a_{60}**)] by extending the duration of the analysis to 60 min; (3) investigate the effect of management, feeding, and farming system on MCP, using the flock size as a statistical indicator; and (4) investigate individual effects, such as parity, stage of lactation, and daily milk yield, on a large population on MCP.

MATERIALS AND METHODS

Animals and Milk Sampling

The study involved 1,121 ewes reared in 23 different farms, evenly distributed over the whole island of Sardinia, Italy. Farms were chosen among those officially registered in the flock book of the Sarda breed and were generally managed following the common semi-extensive and semi-intensive methods as described by Carta et al. (2009) and Carcangiu et al. (2011). In brief, lactating ewes were pasture fed, with a commercial concentrate supplementation given during the milkings, which were performed by manually operated milking machines twice per day (often at 0600 and at 1600 h); reproduction was based on natural mating or, rarely, on AI, and lambs were milk fed by their dams and weaned when they were about 1 mo old.

A report regarding general characteristics of sampled flocks, such as geographical location, flock size, and working environment description, management, and feeding conditions is summarized in Table 1. On the basis of management and feeding characteristics, farms were classified in 3 categories: (1) traditional semi-extensive farming with free-ranging pasture, (2) presence of cultivated grasslands and rotational pasture and control of the lambing season, or (3) modern semi-intensive farming with investments made in new buildings and facilities, use of TMR, and advice provided by consultants and experts in animal feeding. Scores were assigned by one skilled technician to minimize error of subjective criteria.

Groups of ewes ranging in size from 32 to 82 were sampled per flock (1 sampling day for each flock). Ewes presenting clinical symptoms of disease, those within 60 d after parturition (often feeding their lambs), and those after 7 mo of lactation were excluded. The sampled ewes were selected to represent the different levels of parities, DIM, and daily milk yield. The selected ewes were daughters of 120 different sires (with a minimum of 4 and a maximum of 40 daughters per sire).

During the afternoon milking, individual milk samples were collected from each ewe in 200-mL disposable sterile plastic containers and, on the same day, daily milk yield (morning plus evening milking) was recorded. Milk samples were kept at 4°C and analyzed within 24 h after collection.

Analysis of Milk Traits and Coagulation Properties

The chemical composition (fat, protein, casein, lactose, urea, and pH) of individual milk samples was analyzed using a MilkoScan FT6000 milk analyzer (Foss Electric A/S), casein number (%) was calculated as the ratio between casein and protein contents, and SCC was determined with a Fossomatic 5000 somatic cell counter (Foss Electric A/S) and total bacterial count (**TBC**) with a BactoScan FC150 analyzer (Foss Electric A/S) according to International Dairy Federation methods [IDF (2006) and IDF (2000), respectively]. Both SCC and TBC were logarithmically transformed to normalize the distribution: SCC to SCS, as proposed by Ali and Shook (1980), and TBC to logarithmic bacterial count [TBC = $\log_{10}$ (total bacterial count/1,000)].

Measures of MCP were obtained using a Formagraph (Foss Italia S.P.A., Padova, Italy). For each individual sample, 10 mL was heated to 35°C before the addition of 200 µL of rennet solution [Hansen Naturen Plus 215