J. Dairy Sci. 101:1–13
https://doi.org/10.3168/jds.2018-14397

Modeling of coagulation, curd firming, and syneresis of goat milk from 6 breeds

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ABSTRACT

Traditional milk coagulation properties are used to predict the suitability of milk for cheese-making. In bovine and ovine species, the introduction of the concept of curd firming over time, continuously recorded by a lactodynamograph during prolonged tests, provides additional information about milk coagulation, curd-firming, and syneresis processes. The aims of present study were (1) to test the adaptability of a 4-parameter curd-firming model in the assessment of goat milk (also comparing published data of other species); (2) to describe variability of coagulation, curd firming, and syneresis processes among individual goat milk samples; (3) to quantify the effects of farm and animal factors (breed, parity, and stage of lactation); and (4) to compare 6 goat breeds for their model parameters. Milk samples from 1,272 goats reared in 35 farms were collected. Goats were of 6 breeds: Saanen and Camosciata delle Alpi for the Alpine type; and Murciano-Granadina, Maltese, Sarda, and Sarda Primitiva for the Mediterranean type. During a lactodynamographic analysis (60 min), 240 measures of curd firmness (mm) were recorded for each milk sample. The modeling of curd firming allowed us to achieve the rennet coagulation time estimated on the basis of all the data points (min); the curd firming and the curd syneresis instant rate constants; the asymptotical potential value of curd firming; the actual maximum curd firmness; and the time at which the curd firming maximum level is attained. Modeling parameter data were analyzed using a linear mixed model. Comparison with other dairy species showed several differences: goat milk coagulated later than sheep but earlier than bovine, and curd firming and curd syneresis instant rate constants were greater in small ruminants. Modeling parameters of goat milk were mostly affected by the farm effect (37% of the total variance, on average) compared with the results found for bovine and ovine samples, and this was probably attributable to the marked differences among goat farming systems. Small differences were demonstrated between Alpine and Mediterranean breeds, but the time of maximum curd firmness was lower in Murciano-Granadina compared with Maltese, Sarda, and Sarda Primitiva. Sarda and Sarda Primitiva were very similar and exhibited the most favorable coagulation properties of milk. For almost all the model parameters, the direct effect of breed was increased after correction for milk yield and composition. In conclusion, this approach allowed us to fully depict the effects of the different factors on coagulation of goat milk, and clarified the different renneting pattern among goat breeds, and with other species. Results could be used for the valorization of goat dairy products, also when these are linked to particular local breeds, and to stimulate further studies about relationships between coagulation and cheese-making traits.

Key words: milk coagulation, curd firming, lactodynamograph, goat

INTRODUCTION

The contribution of goat milk production to the social and nutritional fields is unquestionable, especially in many developing countries, like those in the Mediterranean, Middle East, Eastern Europe, and South America (Selvaggi et al., 2014). Nowadays, the use of goats in abandoned and degraded areas contributes to the ecosystem, preventing wildfires and providing defense against hydrogeological instability (Marsoner et al., 2017). Moreover, goats fit well to extreme environments and are able to provide high-quality food under diverse climatic conditions (Silanikove, 2000). In developed countries of Europe, Oceania, and North and South America, goat milk production has gradually

Received January 5, 2018.
Accepted March 24, 2018.
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assumed an economic relevance, especially due to the production of different types of labeled cheese (Pirisi et al., 2007), which are often characterized by high market prices because they are properly selected as delicatessen food (Park et al., 2007; Silanikove et al., 2010).

Because the large majority of goat milk is used for the production of cheese, a detailed characterization of its coagulation ability can be very useful for dairy industries. The traditional milk coagulation properties [**MCP**: rennet coagulation time (**RCT**, min), curd firming time ($\mathbf{k_{20}}$, min), and curd firmness ($\mathbf{a_{30}}$, mm)] are single-point parameters introduced to study and evaluate the suitability of bovine milk used to produce cheese. As MCP could affect cheese characteristics (Martin et al., 1997), they are fundamental for cheese labeled with Protected Designation of Origin (**PDO**) in the European Union (Bertoni et al., 2005) and in several dairy chains in which they are used in milk quality payment systems (Bittante et al., 2011).

The MCP have been frequently determined by mechanical lactodynamographic instruments that measure curd formation and firmness during a 30-min test (McMahon and Brown, 1982). Recently, the synergic possibility to extend the MCP analysis beyond 30 min (Cipolat-Gotet et al., 2012) and to model the entire output of lactodynamograph analyses by introducing the concept of curd firming over time ($\mathbf{CF_t}$) pattern provides additional information about milk coagulation, curd firming, and syneresis processes. That approach has been already applied in dairy cows (Malchiodi et al., 2014; Stocco et al., 2017) and used to mimic Grana Padano PDO coagulation process (Stocco et al., 2015). It includes the asymptotic potential value of curd firmness at an infinite time ($\mathbf{CF_P}$, mm) and the curd-firming instant rate constant ($\mathbf{k_{CF}}$, %/min). The RCT is not predicted as a single point measurement but from the result of modeling all data available ($\mathbf{RCT_{eq}}$, min). Moreover, as proposed by Bittante et al. (2013), the modeling of data obtained using prolonged lactodynamographic tests permits also to gain information of the syneresis instant rate constant ($\mathbf{k_{SR}}$, %/min) that tends to reduce curd firming beyond a maximum value ($\mathbf{CF_{max}}$, mm) after a given time interval ($\mathbf{t_{max}}$, min). Modeling of CF_t has been studied also in sheep milk from different Alpine breeds (Bittante et al., 2014) and from the Sarda (Vacca et al., 2015).

Those studies on cow and sheep milk indicate the limitations of the traditional MCP and the need for modeling of the curd firming information. Indeed, the sole investigation of the traditional MCP, with the standard 30-min lactodynamographic analysis, causes an inaccurate interpretation of the processes of milk coagulation, curd firming, and syneresis.

In both developed and developing countries, to achieve the increase of goats' productive performances, animals of foreign specialized breeds have been imported with the aim to replace or to be crossed with autochthonous genetic types (Dubeuf and Boyazoglu, 2009; Vacca et al., 2016). However, those strategies do not take into account the effect of the environment on imported animals, the differences in milk coagulation, curd firming, and syneresis of different breeds of goat in the local conditions. The differences among goat breeds in relation to traditional MCP have been already investigated (Vacca et al., 2018), but the existing literature does not include any information regarding the CF_t modeling parameters in goat species. For these reasons, we extended the objective of our survey on 6 different goat breeds to achieve the following aims: (1) to test the adaptability of a 4-parameter curd-firming model in the assessment of goat milk, also comparing published data from other species; (2) to describe variability of coagulation, curd firming, and syneresis processes among individual goat milk samples; (3) to quantify the effects of farm and animal factors (breed, parity, and stage of lactation) on coagulation pattern; and (4) to compare 6 goat breeds for their CF_t modeling parameters.

MATERIALS AND METHODS

Farm Characteristics and Milk Sampling

The study involved 1,272 goats reared in 35 farms (24 single breeds and 11 multi-breeds), distributed over the whole island of Sardinia (Italy). Farms were selected among those officially registered in the flock books and recording system of provincial associations of goat breeders. Six different breeds were sampled: Saanen (**Sa**) and Camosciata delle Alpi (**CA**) for the Alpine type; and Murciano-Granadina (**MG**), Maltese (**Ma**), Sarda (**Sr**), and Sarda Primitiva (**SP**) for the Mediterranean type.

Individual milk samples (200 mL/goat) were collected during the afternoon milking (1 sampling day for each farm), stored at 4°C and analyzed within 24 h after collection. Daily milk yield (**dMY**) was recorded as the total yield of morning plus evening milking of the same day of sampling. Details about farms, number of sampled animals at each farm, parity, and stage of lactation of goats and sampling procedures are described in Vacca et al. (2018).

Analysis of Milk Samples

Analysis of milk composition and MCP are described in Vacca et al. (2018). In brief, MilkoScan FT6000