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Phenotypic and genetic relationships between indicators of the mammary gland health status and milk composition, coagulation, and curd firming in dairy sheep

Michele Pazzola,*[1] Claudio Cipolat-Gotet,†‡ Giovanni Bittante,† Alessio Cecchinato,† Maria L. Dettori,* and Giuseppe M. Vacca*

*Department of Veterinary Medicine, University of Sassari, via Vienna 2, 07100 Sassari, Italy
†Department of Agronomy, Food, Natural Resources, Animals and Environment (DAFNAE), University of Padova, viale dell'Università 16, 35020 Legnaro (PD), Italy
‡Department of Veterinary Science, University of Parma, Via del Taglio 10, 43126 Parma, Italy

ABSTRACT

The present study investigated the effect of somatic cell count, lactose, and pH on sheep milk composition, coagulation properties (MCP), and curd firming (CF) parameters. Individual milk samples were collected from 1,114 Sarda ewes reared in 23 farms. Milk composition, somatic cell count, single point MCP (rennet coagulation time, RCT; curd firming time, k_{20}; and curd firmness, a_{30}, a_{45}, and a_{60}), and CF model parameters were achieved. Phenotypic traits were statistically analyzed using a mixed model to estimate the effects of the different levels of milk somatic cell score (SCS), lactose, and pH, respectively. Additive genetic, herd, and residual correlations among these 3 traits, and with milk composition, MCP and CF parameters, were inferred using a Bayesian approach. From a phenotypic point of view, higher SCS levels caused a delayed gelification of milk. Lactose concentration and pH were significant for many milk quality traits, with a very intense effect on both coagulation times and curd firming. These traits (RCT, RCT estimated using the curd firming over time equation, and k_{20}) showed an unfavorable increase of about 20% from the highest to the lowest level of lactose. Milk samples with pH values lower than 6.56 versus higher than 6.78 were characterized by an increase of RCT (from 6.00 to 14.3 min) and k_{20} (from 1.65 to 2.65 min) and a decrease of all the 3 curd firmness traits. From a genetic point of view, the marginal posterior distribution of heritability estimates evidenced a large and exploitable variability for all 3 phenotypes. The mean intra-farm heritability estimates were 0.173 for SCS, 0.418 for lactose content, and 0.206 for pH. Lactose (favorably), and SCS and pH (unfavorably), at phenotypic and genetic levels, were correlated mainly with RCT and RCT estimated using the curd firming over time equation and scarcely with the other curd firming traits. The SCS, lactose, and pH were significantly correlated with each other's. In conclusion, results reported in the present study suggest that SCS, pH, and lactose affect, contemporarily and independently, milk quality and MCP. These phenotypes, easily available during milk recording schemes measured by infrared spectra prediction, could be used as potential indicators traits for improving cheese-making ability of ovine milk.

Key words: sheep, milk coagulation, somatic cell count, lactose, pH

INTRODUCTION

Although sheep milk production is limited compared with cow milk production, being 2% of total bovine milk yield (Ramos and Juarez, 2011), in many areas dairy ewes and their related production represent an important sector of agricultural activities. This occurrence is particularly evident for southern European countries, where small ruminants are traditionally linked to the territories and cultures (Boyazoglu and Morand-Fehr, 2001).

Given that sheep milk is almost completely processed into cheese, quality of raw milk is a fundamental feature to predict the final cheese yield. Composition and the measured coagulation properties are suitable at the laboratory and dairy industry level to assess the suitability of milk for cheese production (Bencini, 2002; Pazzola et al., 2014). Other aspects affecting milk quality are represented by hygienic traits. The negative influence of udder inflammatory condition on milk and cheese quality is a well-documented topic in dairy cows

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[1]Corresponding author: pazzola@uniss.it

(Viguier et al., 2009) and sheep (Albenzio et al., 2004; Leitner et al., 2016).

Several markers for mastitis detection have been proposed both at the farm and dairy-plant level. Somatic cell count is the most used method (Hogeveen, 2011; Kelly et al., 2011). Somatic cells in milk are mainly represented by cells of the immune system and epithelial cells, and the difference between 2 or more consecutive counts are used to estimate inflammatory states and distinguish infected udders, as a positive correlation is present between udder inflammatory response and SCC (Schukken et al., 2003).

In the European Union, the criteria for hygienic production of sheep milk are reported in Regulation 853/2004 (EU, 2004), but no limit has been fixed for SCC. In the United States, sheep milk must meet standards set by the Ordinance of Pasteurized Milk of the Food and Drug Administration (US PMO, 2007), and content of somatic cells must be lower than 750,000/mL. Even with the differences between legal documents dealing with sheep milk SCC, the individual measurement of SCC is a useful tool to reveal subclinical mastitis also in dairy sheep farming (Berthelot et al., 2006; Boyazoglu and Morand-Fehr, 2001; Riggio and Portolano, 2015).

Many parameters other than SCC are proposed as diagnostic tools for mastitis (Hogeveen, 2011; Kelly et al., 2011; Jensen et al., 2016). In the past, lactose and pH changes have been used to estimate udder inflammatory processes (Vanlandingham et al., 1941). Mastitis causes damage to the barrier between blood and milk, the consequent change of fluid flow, and the interrelated variation of both lactose and pH (Poulsen et al., 2015). Recently, the decrease of lactose percentage has been regularly recognized for the detection of mastitis in cattle (Auldist et al., 1995; Gonçalves et al., 2016). Several studies have also estimated the genetic correlations between these milk traits and coagulation properties in both dairy cattle (Bittante et al., 2012) and sheep (Othmane et al., 2002; Puledda et al., 2017).

Up to date, no study has been conducted to simultaneously investigate, at the field level, the effect of milk quality markers on a complete range of ovine milk quality and technological traits. Therefore, the aims of the present study were (1) to investigate the effect of SCC, lactose, and pH on sheep milk composition, coagulation properties (**MCP**), and curd firming (**CF**) parameters; (2) to assess the relevance of the aforementioned indicator traits of mammary gland status in explaining the variation of technological traits by estimating the additive genetic correlations between SCC, lactose, and pH, and milk composition, MCP, and CF parameters.

MATERIALS AND METHODS

Animals and Milk Sampling

The present study is based on data recorded from 1,114 Sarda ewes reared in 23 different commercial farms located in Sardinia, Italy. Animals and farms are described in Pazzola et al. (2014). To obtain a representative sample of health animals, ewes were submitted to clinical examinations by veterinarians with experience in the field of small ruminant practice. Ewes showing clinical mastitis, and any other evident disease, were discarded, whereas healthy ewes were retained and sampled. This sampling strategy allowed to focus our study on associations between milk parameters and deviating levels of SCS, lactose, and pH.

Sampled ewes ranged in number from 22 to 89 per each farm; they were between 2 and 7 mo after parturition, and the first to seventh parity.

Ewes from each farm were individually sampled on a single day. Milk samples were collected in 200-mL disposable sterile plastic containers during the afternoon milking and refrigerated at 4°C. Daily milk yield (morning plus evening milking) was recorded on the same day of collection.

Analysis of Milk Traits and Coagulation Properties

Milk samples were analyzed within 24 h after collection for milk composition [fat, protein, casein, lactose, and pH; casein number (%) calculated as the ratio between casein and protein contents], SCC, and single point MCP (rennet coagulation time, **RCT**, as the interval between rennet addition and gel formation; curd firming time, $\mathbf{k_{20}}$, as the interval between gel formation and a curd firmness of 20 mm; and curd firmness $\mathbf{a_{30}}$, $\mathbf{a_{45}}$, and $\mathbf{a_{60}}$, 30, 45, and 60 min after rennet addition, respectively). Lactose and pH were measured using a MilkoScan FT6000 milk analyzer (Foss Electric A/S); SCC with a Fossomatic 5000 somatic cell counter (Foss Electric A/S); the others traits were measured using the methods reported in Pazzola et al. (2014). The model parameters of curd-firming [curd firmness at an infinite time ($\mathbf{C_{FP}}$, measured in mm), curd-firming instant rate constant ($\mathbf{k_{CF}}$, % × min^{-1}), rennet coagulation time from the result of modeling ($\mathbf{RCT_{eq}}$, min), syneresis instant rate constant ($\mathbf{k_{SR}}$, % × min^{-1}) that tends to reduce curd firming over time ($\mathbf{CF_t}$) beyond a maximum curd firmness ($\mathbf{CF_{max}}$, mm) after a given time interval ($\mathbf{t_{max}}$, min)] were measured as reported in Vacca et al. (2015). The analysis of both the traditional MCP and parameters of CF_t modeling was performed