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Variations in milk protein fractions affect the efficiency of the cheese-making process

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ABSTRACT

The aim of this study was to assess the influence of the amounts of the α_{S1}-, α_{S2}-, β-, and κ-casein (CN) and the α-lactalbumin and β-lactoglobulin protein fractions on the efficiency of the cheese-making process independently of their genetic polymorphisms. The study was carried out on milk samples from 1,271 Brown Swiss cows from 85 herds classified into 4 categories according to management, feeding, and housing characteristics (traditional and modern systems). To assess the efficiency of the cheese-making process, we processed the milk samples according to a laboratory cheese-making procedure (1,500 mL/sample) and obtained the following measures: (1) 3 percentage cheese yields ($\%CY_{curd}$, $\%CY_{solids}$, $\%CY_{water}$), (2) 2 daily cheese yields obtained by multiplying %CY (curd and total solids) by daily milk yields (dCY_{curd}, dCY_{solids}), (3) 4 measures of nutrient recovery in the curd (REC_{fat}, $REC_{protein}$, REC_{solids}, REC_{energy}), and (4) 2 measures of cheese-making efficiency in terms of the ratio between the observed and theoretical %CY (Ef-$\%CY_{curd}$, Ef-$\%CY_{solids}$). All the aforementioned traits were analyzed by fitting 2 linear mixed models with protein fractions as fixed effects expressed as percentage in the milk (model M-%milk) and as percentage of the total casein content (model M-%cas) together with the effects of total casein content (only in model M-%cas), daily milk yield (only in model M-%milk; not for dCY traits), dairy system, herd (random effect), days in milk, parity, and vat. The efficiency of overall cheese yield (Ef-$\%CY_{curd}$) was mostly positively associated with β-CN content in the milk, whereas Ef-$\%CY_{solids}$ was greater with higher amounts of κ-CN and α_{S1}-CN (M-%milk) due to the strong influence of both fractions on the recovery rate of milk components in the curd (fat and total solids, protein with α_{S1}-CN only) when expressed as percentage of milk and of total casein; only β-CN was more important for $REC_{protein}$. In contrast, we found β-lactoglobulin to be highly negatively related to all the traits related to the cheese-making process and to the daily cheese yield per cow, whereas α-lactalbumin was positively associated with the latter traits. Additional research on this topic is needed, with particular focus on the genetic and genomic aspects of the role of protein fractions in the cheese-making process and on the associations between genetic polymorphisms in milk protein and milk nutrient recovery in the curd.
Key words: milk protein, cheese-making, cheese yield, nutrient recovery

INTRODUCTION

The cheese production industry has a crucial need for an integrated approach to monitor all the relationships between milk quality and cheese-making so that it can guarantee a high level of efficiency (in terms of cheese yield and recovery of milk nutrients in the curd) across the entire process (Banks, 2007). Such an approach would also include gathering information on the milk quality of individual animals for use in current practices related to the genetic improvement of dairy cattle populations and for adjusting the milk-to-cheese economic value (i.e., milk payment systems).

Among the various factors involved, there is universal acknowledgment of the role played by the composition of protein fractions in the cheese-making process from milk gelation to cheese ripening (Emmons et al., 2003; Guinee, 2003; Caroli et al., 2009). As cheese consists of a paracasein reticulum in which fat globules and part of the soluble phase of milk are entrapped (Guinee, 2003; Rybak, 2014), the concentration of casein in milk is positively correlated with the quantity of cheese produced per unit of milk (percentage cheese yield). Moreover,

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physicochemical characteristics and structural properties of milk casein micelles (average size, proportion of caseins, concentration of colloidal calcium phosphate, casein genetic variants) influence the rheological properties of the resulting rennet curd and, consequently, its capacity to retain milk constituents—mainly water, casein, and fat—in cheese (cheese-making efficiency; Bittante et al., 2012). In fact, when empirical predictive formulas for cheese yield using milk composition are to be developed, the coefficients of casein are higher than its own weight (Emmons et al., 1990).

Most studies at the cow level limit their analyses to the effect of protein fractions on the coagulation process (Macheboeuf et al., 1993; Hallén et al., 2007) or sample only a small number of animals (Wedholm et al., 2006; Hallén et al., 2010) due to the time-consuming and labor-intensive nature of cheese-making trials. Furthermore, there is a lack of knowledge about the role of proteins in milk nutrient recovery in the curd. Recently, we proposed a laboratory model cheese-manufacturing procedure that allows several cheese-making traits to be measured. This method was used to process more than 1,000 individual Brown Swiss milk samples, which revealed high variability in cheese-making traits related to dairy system (Bittante et al., 2015) and animal characteristics (Stocco et al., 2018). The aim of the present study was to examine the influence of the amounts of protein fractions (caseins and whey proteins), expressed as percentage in milk, and their proportions to total casein content on the efficiency of the cheese-making process and on the daily cheese production of individual cows.

MATERIALS AND METHODS

Animals, Dairy Systems, and Milk Sample Collection

This study falls within the scope of the Cowability–Cowplus project. Herd selection, dairy farming systems, and sampling procedure are described in detail in Bittante et al. (2015). Briefly, milk samples were taken from a total of 1,264 Brown Swiss cows (3 subsamples per cow) during the evening milking. Cows were selected from the clinically healthy cows of 85 herds (a maximum of 15 cows per herd) located in Trento Province (Italy) to represent different parities and lactation stages. The herds were chosen from 610 farms and classified into 4 dairy farming systems (3 modern and 1 traditional).

One subsample of milk (50 mL) was transported to the Milk Quality Laboratory of the Trento Breeders Association (Trento, Italy) for milk composition analysis. The other subsamples were taken to the Milk Laboratory of the Department of Agronomy, Food, Natural Resources, Animals and Environment of the University of Padua (Legnaro, Padua, Italy) for cheese-making and protein fraction analyses. All phases, from sampling to storage of milk samples, were standardized to maximize reproducibility among herds and collection dates. The Superbrown Consortium of Trento (Trento, Italy) provided information on the cows and herds.

Milk Analyses and Processing

Gross Composition Traits. Individual raw full-fat milk samples (50 mL) of all cows sampled were analyzed within 20 h of milking for gross composition (protein, casein, fat, lactose, and TS) using a MilkoScan FT6000 (Foss, Hillerød, Denmark) calibrated according to the following reference methods: fat (ISO, 2010b; ISO1211/IDF 1; gravimetric method, Röse-Gottlieb), protein (ISO, 2014; ISO 8968-1/IDF 20-1; titrimetric method, Kjeldahl), casein (ISO, 2004; ISO 17997-1/IDF 29; titrimetric method, Kjeldahl), lactose (ISO, 2002; ISO 5765-1/IDF 79-1; enzymatic method), and TS (ISO, 2010a; ISO 6731/IDF 21; determination of TS content). Somatic cell count was measured with a Fossomatic FC counter (Foss) and log-transformed to SCS (Ali and Shook, 1980). Milk pH, adjusted for sample temperature, was obtained with a Crison Basic 25 electrode (Crison, Barcelona, Spain).

Milk Protein Fractions. Individual milk samples of all cows sampled (2 aliquots of 1 mL each per cow) were mixed with preservative (bronopol, 2-bromo-2-nitropropan-1,3-diol, 0.6:100 vol/vol) to prevent microbial development and frozen at −20°C in portable chilling devices immediately after collection and then stored at −80°C until analysis. Frozen individual milk aliquots were prepared following the method proposed by Bobe et al. (1998). The contents of the casein (α_{S1}-, α_{S2}-, β-, and κ-CN) and the whey protein (β-LG and α-LA) fractions were assessed separately for each of their major genetic variants by the reversed-phase HPLC method (Bonfatti et al., 2008). The phosphorylated form of the α_{S1}-CN (with 9 phosphorylated serine residues instead of 8) was also obtained (Bonfatti et al., 2011b). The genetic variants of each protein fraction (A and B for κ-CN; A1, A2, and B for β-CN; A and B for β-LG) were recorded for each milk sample, and their concentrations were summed to obtain the total concentration of the protein fraction.

Cheese-Making Efficiency. Individual raw full-fat milk samples (2,000 mL) were processed within 20 h of milking using the model cheese-making procedure (1,500 mL of individual milk sample/vat) described by Stocco et al. (2018). Using this method, we were

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