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Effect of whey concentration on protein recovery in fresh ovine ricotta cheese

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ABSTRACT

Ricotta cheese, particularly the ovine type, is a typical Italian dairy product obtained by heat-coagulation of the proteins in whey. The aim of this work was to investigate the influence of whey protein concentration, obtained by ultrafiltration, on yield of fresh ovine ricotta cheese. Ricotta cheeses were obtained by thermocoagulation of mixtures with protein content of 1.56, 3.10, 4.16, and 7.09 g/100 g from the mixing of skim whey and ultrafiltered skim whey. A fat-to-protein ratio of 1.1 (wt/wt) was obtained for all mixtures by adding fresh cream. The initial mixtures, as well as the final ricotta cheeses, were analyzed for their composition and by SDS-PAGE. Protein bands were quantified by QuantityOne software (Bio-Rad, Hercules, CA) and identified by liquid chromatography-tandem mass spectrometry. Significant differences in the composition of the ricotta cheese were observed depending on protein concentration. Particularly, ricotta cheese resulting from the mixture containing 7.09 g/100 g of protein presented higher moisture (72.88 ± 1.50 g/100 g) and protein (10.18 ± 0.45 g/100 g) contents than that prepared from the mixture with 1.56 g/100 g of protein (69.52 ± 1.75 and 6.70 ± 0.85 g/100 g, respectively), and fat content was lower in this sample (12.20 ± 1.60 g/100 g) compared with the other treatments, with mean values between 15.72 and 20.50 g/100 g. Each protein fraction presented a different behavior during thermocoagulation. In particular, the recovery of β-lactoglobulin and α-lactalbumin in the cheese increased as their content increased in the mixtures. It was concluded that concentrating ovine rennet whey improved the extent of heat-induced protein aggregation during the thermal coagulation process. This resulted in a better recovery of each protein fraction in the product, and in a consequent increase of ricotta cheese yield.

Key words: sheep whey, ultrafiltration, protein recovery, ricotta cheese

INTRODUCTION

Ovine whey cheeses are mainly produced in the Mediterranean countries, such as Italy, Greece, Portugal, and Spain (Kandarakis, 1986). Usually, they are manufactured according to traditional protocols by thermal denaturation of whey proteins. Among them, ricotta cheese is probably the oldest and the best known dairy product obtained from cheese whey (Pizzillo et al., 2005), and in recent decades it has become rather popular in the United States and Canada. In ricotta cheese production, whey represents the raw material, although milk or cream can be added (Farkye, 2004).

Cheese whey is a by-product of the dairy industry, containing mainly lactose, soluble proteins, minerals, and milk fat, which may reach about 50% of the milk TS (Casper et al., 1998). The production of ricotta cheese is considered to be one of the most convenient ways to use whey originating from the cheese-making process (Shukla and Kaur Brar, 1986).

The ovine and caprine types of ricotta cheese are usually manufactured following the traditional protocol described herein. The cheese whey (normally at a pH of about 6.50) without exogenous acidification is heated to a final temperature of 78 to 80°C under constant stirring. The applied heat results in the coagulation of the whey proteins, which is characterized by the appearance of small flakes on the surface as consequence of a multiple-reaction process related to the unfolding and aggregation of the proteins (Morr and Josephson, 1968; Parris et al., 1993). After a resting period of 10 min at 78 to 80°C, the formed coagulum is carefully scooped off and placed in plastic perforated conical molds, where it drains for 8 to 24 h in a cool room (4°C). After the completion of draining, the product can be packed and commercialized.

The typical yield of ricotta cheese is only about 5 to 6%, and this highlights the very low efficiency of the process. In particular, significant losses of proteins with high nutritional and biological value exist. After ricotta cheese production, the residual whey still contains about 1% of proteins (Nudda et al., 2004). It has been demonstrated that parameters, such as heating temperature, protein concentration, pH, and the type and concentration of salts, represent important factors

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affecting the heat-induced aggregation of whey proteins (Mangino, 1984; Taylor et al., 1994; Hollar et al., 1995). Among whey proteins, it has been shown that α-LA has a greater resistance to thermal denaturation compared with the other whey protein fractions (Singh and Havea, 2003). Specifically, the resistance to denaturation decreases from α-LA to β-LG to BSA to Ig (in order). However, when present in a solution containing other proteins, the aggregation behavior is altered. It has been shown, for example, that the interactions between α-LA and β-LG enhance the denaturation of α-LA (Dalgleish et al., 1997). The ionic strength of the whey is an important parameter in determining the protein aggregation and consequently the gel-structuring process. In particular, the presence of divalent cations, such as calcium and magnesium, are fundamental to promote the aggregation by partially shielding the negative charges of whey proteins and bridging between protein molecules, reducing the electrostatic repulsion, and favoring the formation of large aggregates.

Although ricotta is a very widespread whey cheese, the literature on this product is scarce and outdated, in particular as it relates to the factors affecting ricotta cheese processing and yield. Protein concentration seems to be an important parameter. Streiff et al. (1979) used condensed whey to produce ricotta cheese and obtained high yields, but minerals were also concentrated in their study. Conversely, very little has been reported on UF of ovine whey for ricotta cheese manufacture. During this process, the protein concentration is increased, whereas the ionic strength is lower than in the case of evaporated whey.

In the present study, we hypothesized that an increased concentration of whey before ricotta cheesemaking would change the interactions between the main whey protein fractions. Hence, the aim of the current work was to study the influence of the concentration of the whey by UF on the recovery rate of the different whey proteins and on the resulting ricotta cheese yield.

MATERIALS AND METHODS

Preparation of UF Whey

Ovine whey from protected designation of origin Pecorino Sardo cheese-making was obtained from experimental cheese plant of Agris Sardegna. All thermal treatments described herein occurred in a batch-wise (discontinuous) process. The whey was heated at 63°C (from 40 to 63°C in 8 min) in a stainless steel cheese vat, quickly cooled to 40°C (from 63 to 40°C in 5 min), and skimmed. Cream was kept at 4°C, whereas skim whey was concentrated by UF at 40°C to produce retentate at 6× (based on volume reduction), using a pilot plant (Mete srl, Membrane Technology, Varese, Italy) equipped with a polyethersulfone membrane (20 kDa; Celgard, Charlotte, NC), with a nominal area of 5 m^2. Cross-membrane pressure and flow rate were 0.15 MPa and 2.5 m^3/h, respectively. Retentate was immediately stored at 4°C until further use.

Preparation of Whey Mixtures and Their Composition

Skim whey, retentate, and cream were used to get 4 different mixtures with different concentrations of fat and protein, but the same fat-to-protein ratio of 1.1. The mixtures had final protein concentrations of 1.56, 3.10, 4.16, and 7.09% (**M1**, **M2**, **M3**, and **M4**, respectively). The amount of each component (skim whey, retentate, and cream), which had to be added to obtain the predetermined mixtures, was calculated by solving the following mathematical system:

$$\begin{cases} d = ax + by + cz \,/\, \mathrm{AM} \\ d1 = a1x + b1y + c1z \,/\, \mathrm{AM}, \\ x + y + z = \mathrm{AM} \end{cases}$$

where x, y, and z are the amount (kg) of cream, retentate, and skim whey, respectively; AM (kg) is the amount of the whey mixture processed; d and $d1$ are the amount (g/kg) of fat and protein in the mixture, respectively; a, b, and c are the amount of fat (g/kg) in cream, retentate, and skim whey, respectively; $a1$, $b1$, and $c1$ are the amount of protein (g/kg) in cream, retentate, and skim whey, respectively.

Skim whey, retentate, cream, and the whey mixtures were analyzed for pH (Orion model 420A pH meter, Orion Research Inc., Boston, MA), TS (IDF,1987), fat (Gerber method), total nitrogen (**TN**), and NPN (Rowland, 1938). The protein content was estimated (nitrogen × 6.38) by the difference between TN and NPN. Ionic calcium (Ca^{2+}) and magnesium (Mg^{2+}) contents of whey mixtures were determined by atomic absorption spectrophotometry with a SpectrAA 250 plus (Varian, Palo Alto, CA) using a standard curve and following the procedures recommended by AOAC (1990), with slight modifications.

Ricotta Cheese Production and Analysis

Ricotta cheeses were manufactured starting from each corresponding whey mixture (**R1**, **R2**, **R3**, and **R4** from M1, M2, M3, M4, respectively) according to a traditional protocol. Each whey mixture was heated (in a pilot-scale cheese coagulation vat) to 78 to 80°C under stirring without further acidification (see Table