Korean Journal for Food Science of Animal Resources

pISSN 1225-8563
eISSN 2234-246X

Korean J. Food Sci. An. 37(3): 342~350 (2017)
DOI https://doi.org/10.5851/kosfa.2017.37.3.342

ARTICLE

Physicochemical, Microbial, and Sensory Properties of Queso Blanco Cheese Supplemented with Powdered Microcapsules of Tomato Extracts

Hyeon-Ju Jeong[1], Yun-Kyung Lee, Palanivel Ganesan[2], Hae-Soo Kwak[1], and Yoon Hyuk Chang*

Department of Food and Nutrition, Kyung Hee University, Seoul 02447, Korea
[1]Department of Food Science and Technology, Sejong University, Seoul 05006, Korea
[2]Nanotechnology Research Center and Department of Applied Life Science and Biotechnology, College of Biomedical and Health Science, Konkuk University, Chungju 27478, Korea

Abstract

The present study examined the physical, chemical, microbial, and sensory characteristics of Queso Blanco cheese supplemented with powdered microcapsules containing tomato extracts (0.5-2.0%) during storage at 7°C for 60 d. The lactic acid bacterial count and lycopene concentrations in Queso Blanco cheese supplemented with powdered microcapsules were significantly higher than those of the control. In a texture analysis, the gumminess, chewiness, and hardness values for Queso Blanco cheese were significantly higher with increasing concentrations of the powdered microcapsules containing tomato extracts. Total short-chain fatty acids in Queso Blanco cheese supplemented with powdered microcapsules containing tomato extracts were not significantly altered compared to the control. Sensory evaluation scores for the yellowness, tomato taste, and firmness of Queso Blanco cheese were significantly higher after supplementation with powdered microcapsules containing tomato extracts.

Keywords Queso Blanco cheese, powdered tomato extracts microcapsules, functional cheese, lycopene

Received February 27, 2017
Revised April 12, 2017
Accepted April 20, 2017

*Corresponding author
Yoon Hyuk Chang
Department of Food and Nutrition, Kyung Hee University, Seoul 02447, Korea
Tel: +82-2-961-0552
Fax: +82-2-961-0261
E-mail: yhchang@khu.ac.kr

Introduction

Queso Blanco cheese is a fresh, white, soft cheese that is traditionally made from raw cow or goat's milk. It originated in Latin American. Milk proteins in the cheese are precipitated using heat and acid during cheese production (Tunick *et al*., 2008). This cheese is particularly popular in the United States because of its mild, salty flavor and crumbly texture (Sandra *et al.*, 2004). Apart from the special texture of Queso Blanco cheese, supplementation with organic materials could be of special interest for improving its health benefits for consumers.

Lycopene is a naturally occurring carotenoid in the tomato (Li *et al.*, 2017). Among the carotenoids, lycopene is one of the major functional components. It has been shown that lycopene constitutes over 80% of in tomatoes (Nguyen and Schwarts, 1999). Furthermore, lycopene is an effective antioxidant, and has many valuable health benefits. Some researchers reported that lycopene in tomatoes correlates with a decreased risk of cancer of the prostate, lungs, and stomach, in addition to cardiovascular diseases (Story *et al.*, 2010). Thus, lycopene is an alternative bioactive compound used to enhance food ingredients. However, lycopene is easily deteriorated by oxidation and isomerization during the ripening process because of its highly conjugated double bonds (Matioli and Rodriguez-amaya, 2002).

Microencapsulation techniques offer the protection of functional components against oxygen, heat, humidity, and light in the food industry. This allows a substance to be delivered to a suitable location in the human body after ingestion (Gharsallaoui *et al.*, 2007; Onwulata, 2013). Rocha *et al.* (2012) reported that microencapsulation protected the bioactive compounds in tomatoes from severe environmental conditions during food processing. Bioactive compounds have been successfully used in various dairy products, such as milk, cheese, and yogurt (Chang *et al.*, 2016; Kwak *et al.*, 2016; Lee *et al.*, 2013). These compounds display enhanced functional activities following microencapsulation.

Recently, the most common procedure for microencapsulation in the food industry has been spray-drying. It is the cheapest technique for producing microcapsules of functional materials (Oberoi and Sogi, 2015; Verma and Singh, 2015), which further reduces transport cost and storage times. The strawberry yogurt added with microencapsulated salmon oil was shown to enhance functional properties of this food over the course of 4 wk (Estrada *et al.*, 2011). The addition of powdered microcapsules of peanut sprout extract to yogurt increased antioxidant activities (Lee *et al.*, 2013). Similarly, Bermudez-Aguirre and Barbosa-Canovas (2012) showed that microencapsulated fish oil powder was fortified with omega-3 fatty acids in the preparation of various cheeses, such as Queso fresco, Mozzarella, and Cheddar. However, to the best of our knowledge, the supplementation of lycopene-enriched tomato extract microcapsules to Queso Blanco cheese has not been reported. Therefore, this study aimed to improve Queso Blanco cheese supplemented with microencapsulated tomato extracts, and to determine its physical, chemical, microbial, and sensory properties during a ripening period of 60 d.

Materials and Methods

Materials

Tomato extract containing 6% lycopene (Lyc-O-Mato®, LycoRed Ltd., Israel) was purchased from LycoRed Ltd. (USA). Maltodextrin (MD, DE 18) was supplied by Samyang Genex (Korea). Medium-chain triglycerides (MCT) were supplied by Wellga Co., Ltd. (Korea). Tween-60 (HLB 14.9) was used as an emulsifier, and was provided by Il-Sin Co., Ltd. (Korea). Standard lycopene (>95% purity) was obtained from Sigma-Aldrich Co. (USA). HPLC-grade methyl chloride, *n*-butanol, acetonitrile, and other chemicals were purchased from Samchun Chemicals Co., Ltd. (Korea). Hexanoic acid, decanoic acid, butanoic acid, and octanoic acid were obtained from Sigma-Aldrich Co. (USA).

Preparation of powdered microcapsules containing tomato extracts

Tomato extracts were dissolved in MCT at 1:9 ratio (w/w) to prepare the core material. After stirring at 500 rpm for 2 h, the mixture was filtered using a Whatman No. 4 filter paper. To prepare the coating material, maltodextrin (MD) was dissolved in distilled water at a concentration of 30% (w/v). The ratio of tomato extract of the core material to 30% MD of the coating material was 1:9, and 1% Tween-60 (HLB 14.9) was used for emulsification. The mixture was homogenized at 10,000 rpm for 3 min using a high-speed homogenizer (SSC1811EA, Matsushida Electronic Industrial Co., Japan).

To produce powdered microcapsules containing tomato extracts, the emulsion was spray-dried (Eyela spray dryer SD-1000; drying capacity 1,500 mL/h; Tokyo Rikakikai Co., Ltd., Japan) using a 100 kPa atomization pressure. Outlet and inlet air temperatures for this dryer were 90°C and 190°C, respectively. Stirring was used to separate the powdered microcapsules containing tomato extracts prepared with the emulsion from the chamber using a peristaltic pump. Powdered microcapsules containing tomato extracts were prepared in duplicate.

Manufacturing of Queso Blanco cheese

Queso Blanco cheese was manufactured according to the improved method of Farkye (2004). Raw milk for production of Queso Blanco cheese was supplied by an animal farm affiliated with Suncheon National University (Korea). Raw milk (150 kg) was standardized at a protein/fat ratio of 1.2 by adding powdered skim milk. It was then pasteurized at 83°C for 10 min, and 0.5% (w/w) of 1.5% citric acid was added. After stirring for 15 min, whey was removed and 1.0% $NaCl_2$ was added to the curd. Powdered microcapsules containing tomato extracts were supplemented to curd at different concentrations (0, 0.3, 0.6, 0.9, and 1.2%) with an initial pH of 5.6. The curds were pressed for 5 h. After pressing, each sample was divided into five packs of 200 g each, and vacuum-packaged for storage at 7°C for 60 d. Samples were periodically taken at 0, 15, 30, 45, and 60 d for analysis. The experiment was repeated three times with freshly produced Queso Blanco cheese.

Chemical composition

The chemical composition was examined according to the AOAC methods (AOAC, 2005). Moisture and dry matter were measured using oven-drying with 2 g of each sample at 105°C for 4 h. The protein content was measured by the Kjeldahl method. The fat content was determined by the Gerber method. All samples were quantified in triplicate.

pH

The pH values for Queso Blanco cheese made with different concentrations of powdered microcapsules containing tomato extracts were determined using a pH meter (Orion 900A, USA). Samples of cheeses (1.0 g) were aliquoted into 9 mL of 2% sodium citrate. Samples were then prepared by homogenizing (Matsushita Electric Industrial Co., Japan) at 1,500 rpm for 1 min.

Lycopene analysis

The lycopene content in the Queso Blanco cheese supplemented with powdered microcapsules containing tomato extracts was determined by high performance liquid chromatography (HPLC). Cheese samples weighing 2 g were added to 40 mL of distilled water, and then a 40-mL mixture of ethanol-hexane (4:3, v/v) was added. After that, this solution was sonicated for 30 min, and the supernatant was collected. Residue was extracted using the same procedure described above, and the supernatants were pooled. The pooled supernatant solution was then resuspended with 10 mL of 10% sodium chloride solution and 15 mL of distilled water. The mixture was sonicated for 5 min. The top layer was then collected, and the residue was repeatedly extracted. The top layers of all the extracts were pooled, evaporated under a vacuum, dissolved in 1 mL of hexane, and filtered using a 0.2-μm membrane filter for analysis on an HPLC (Agilent Technologies 1200 series, USA) equipped with a UV detector and C18 column (5 μm, 4.6 mm × 250 mm) (Sunfire^{TM} C18, Water Ltd., Ireland). The mobile phase consisting of acetonitrile (solvent A), *n*-butanol (solvent B), and methyl chloride (solvent C) was examined with the following gradient profile: 0 min: 69.3% A, 29.7% B, and 1% C; 10 min: 67.2% A, 28.8% B, and 4% C; 20 min: 61.6% A, 26.4% B, and 12% C; 40 min: 49% A, 21% B, and 30% C; 50 min: 69.3% A, 29.7% B, and 1% C. This was followed by detection at 472 nm. The identification of lycopene was achieved by comparing the peak area and retention time with a reference lycopene standard. The calibration was linear in the concentration range of 10-100 μg/mL (R^2=0.9991).

Lactic acid bacteria (LAB) count

Powdered agar was added to MRS broth (Difco Laboratories, USA) and 0.004% bromophenol blue to perform LAB counts. Each sample (1 g) was aliquoted into 9 mL of 2% sodium citrate. Samples were prepared by homogenizing for 1 min at 1,500 rpm. Next, 1 mL of the prepared sample was diluted with 9 mL of 0.8% NaCl. Subsequent dilutions of each sample were plated in triplicates and incubated at 37°C for 48 h.

Short-chain fatty acids

At 0, 15, 30, 45, and 60 d, 1 g of each sample was obtained from the cheeses and extracted with 5 mL of diethyl ether, 2.5 g of sodium sulfate, and 0.1 mL of 4 N H_2SO_4 for 2 h. This was eluted through a 10-mm i.d. glass column containing 1 g of deactivated alumina (alumina oxide neutral), which was deactivated with 0.24% distilled water. Short-chain fatty acids (SCFA) were analyzed using Donam instruments INC DS 6200 (Korea). A HP-INNOWax column (30 m × 250 μm × 0.25 μm) from Agilent Technologies (USA) was used for all analyses. GC was prepared using a flame ionization detector. Oven temperatures were increased at 5°C/min from 60°C to 170°C. The temperature of the detector was 220°C. The experiments for each sample were performed in triplicate.

Color measurement

Color values were obtained using a colorimeter (Minolta CT-310, Japan) after standardizing its original value with a standard plate. L*, a*, and b* values were determined as indicators of lightness, redness, and yellowness, respectively. All samples in the experiment were tested 10 times.

Texture analysis

Cube-shaped samples (1.5 cm^3) for each cheese at each stage of storage were cut from the central part of the cheese. Textural properties of the samples were assessed using a TMS-Pro Texture Analyzer (Food Technology Co., USA). We installed 100 N load cells in the TMS Pro. Cross-head and chart recorder speeds were 5 and 10 cm/min, respectively. Samples were stored at room temperature for 30 min before examination and measurement.

Sensory evaluation

For the sensory test, samples of Queso Blanco cheese supplemented with powdered microcapsules containing tomato extract were periodically obtained at 0, 15, 30, 45, and 60 d. The sensory properties were examined by 10 trained panel subjects, who were graduate students at the Sejong University, and they were familiar with cheese consumption. Panels were established using the Spectrum method (Sensory Spectrum, USA). The panel assessed the cheeses in terms of their appearance, taste, and texture during ripening. Before each evaluation session, the panels were trained for 1 h. Sensory tests for texture and taste were introduced to panelists. Samples were served with an unsalted cracker and a glass of water was given to the panelists after eating the samples. Samples were left at room temperature for 10 min. The panels evaluated randomly coded Queso Blanco cheeses. The taste, texture, and appearance were evaluated on a 7-point scale (1 = very weak, 4 = moderate, 7 = very strong). A randomized and composed block design was used.

Statistical analysis

Duncan's multiple tests and Analysis of Variance (ANOVA) were performed to analyze the differences between groups. Data were expressed as the means ± SD and the statistical significance was set at $p<0.05$. All statistical analyses were performed using SAS 9.4 (SAS Institute Inc., USA), and graphical representations were created using Sigmaplot 11.0 (Systat Software Inc., USA).

Results and Discussion

Proximate composition and pH

The proximate composition and pH of Queso Blanco cheese supplemented with different concentrations (0.5, 1.0, 1.5, and 2.0%) of powdered microcapsules containing tomato extracts are shown in Table 1. The control had a 47.45% moisture content, 20.58% fat content, 26.39% protein content, 2.56% ash content, and had a pH of 5.64. Moisture, fat, proteins, and ash in the control were not significantly different from those of the Queso Blanco cheese supplemented with powdered microcapsules containing tomato extracts ($p>0.05$), indicating that the supplementation itself did not substantially affect the proximate compositions of the cheese. The pH of the control and the cheese supplemented with 0.5%, and 1.0% powdered microcapsules containing tomato were not significantly changed ($p>0.05$). However, increasing the concentration of the supplements (1.5% and 2.0%) significantly decreased the pH ($p<0.05$). This was most likely due to acidic compounds in the powdered microcapsules containing tomato extracts.

Lycopene content

The lycopene content of Queso Blanco cheese supplemented with different concentrations (0.5, 1.0, 1.5, and 2.0%) of powdered microcapsules containing tomato extracts are shown in Fig. 1. Increasing the supplement concentration in the cheese significantly increased the lycopene content ($p<0.05$). The higher lycopene concentrations were probably due to the higher amount of lycopene in the powdered microcapsules and the protection of the cheese from the environment. According to Rocha *et al.* (2012), the stability of bioactive compounds was greatly enhanced as a result of microencapsulation. Similarly, microencapsulation of green tea catechins led to higher retention of those compounds in low fat hard cheeses (Rashidinejad *et al.*, 2014).

LAB count

LAB counts were performed for the Queso Blanco cheese supplemented with different concentrations (0.5, 1.0, 1.5,

Table 1. Proximate composition and pH of Queso Blanco cheese[1)] supplemented with different concentrations of powdered microcapsules of tomato extracts

Concentration (%, w/w)	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	pH
Control	47.45±0.12$^{A2)}$	20.58±0.09^{A}	26.39±0.06^{A}	2.56±0.02^{A}	5.64^{A}
0.5	47.30±0.29^{A}	20.73±0.10^{A}	26.38±0.07^{A}	2.56±0.02^{A}	5.64^{A}
1.0	46.87±0.66^{A}	20.60±0.17^{A}	26.73±0.07^{A}	2.59±0.01^{A}	5.62^{A}
1.5	46.03±0.05^{A}	20.68±0.01^{A}	26.61±0.04^{A}	2.60±0.04^{A}	5.42^{AB}
2.0	46.23±0.01^{A}	20.54±0.11^{A}	26.44±0.38^{A}	2.57±0.03^{A}	5.24^{B}

[1)] Initial cheese was used for analyses.

[2)] Data values were expressed as means±SD (n=3). Means with different superscripts in a column (A-B) are significant at $p<0.05$ by Ducan's multiple range test.

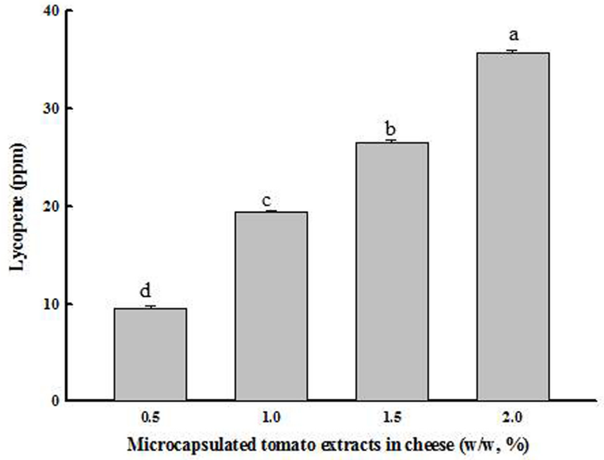

Fig. 1. Quantitative analysis of lycopene[1)] based on Queso Blanco cheese supplemented with different concentrations of powdered microcapsules of tomato extracts. [1)]The analysis of lycopene was measured at 0 d of the cheese making.

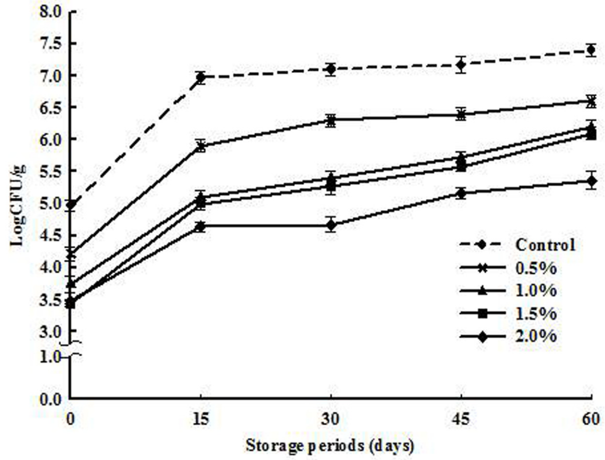

Fig. 2. Growth of lactic acid bacteria in Queso Blanco cheese supplemented with different concentrations of powdered microcapsules of tomato extracts during ripening at 7°C for 60 d.

and 2.0%) of microcapsules containing tomato extracts after storage at 7°C for 60 d (Fig. 2). LAB counts of the microcapsule-treated cheeses were significantly higher compared to controls as the ripening period proceeded from 0 to 60 d ($p<0.05$). Similarly, in Queso Blanco, Caciocavallo, and Mozzarella cheeses, the LAB counts increased during ripening (Bermudez-Aguirre and Barbosa-Canovas, 2012; Ko *et al.*, 2017; Van Hekken *et al.*, 2012). Increasing the concentrations of powdered microcapsules containing tomato extracts proportionally decreased the LAB counts in Queso Blanco cheeses because of the antibacterial activity of lycopene (Bartkiene *et al.*, 2015; Mukhopadhyay *et al.*, 2014). Based on these results, adding the powdered microcapsules containing tomato extracts can prevent the growth of LAB in Queso Blanco cheeses during ripening.

Short-chain fatty acids

It has been reported that short-chain fatty acids (C_4 [butyric acid], C_6 [caproic acid], C_8 [caprylic acid], and C_{10} [acpric acid]) are the major volatile compounds present during cheese ripening (Lin *et al*., 1987). Short-chain fatty acids provide a desirable piquant aroma and flavor in most cheeses (Kwak *et al.*, 1990). Alterations in short-chain fatty acids found in Queso Blanco cheese supplemented with different concentrations (0.5, 1.0, 1.5, and 2.0%) of powdered microcapsules containing tomato extracts stored at 7°C for 60 d are shown in Table 2. The total amount of short-chain fatty acids increased significantly with longer ripening times ($p<0.05$). On the other hand, it was found that the total amount of short-chain fatty acids was not significantly different between the control and microcapsules-supplemented cheeses ($p>0.05$). These results indicate that Queso Blanco cheese supplemented with powdered microcapsules containing tomato extracts did not influence the production of short-chain fatty acids during the 60-d ripening period.

Color

Changes in the color of Queso Blanco cheese supplemented with different concentrations (0.5, 1.0, 1.5, and 2.0%) of powdered microcapsules containing tomato extracts stored at 7°C for 60 d are shown in Table 3. The L* values significantly decreased with increasing concentrations of microcapsules during ripening over the course of 60 d ($p<0.05$). The b* and a* values of Queso Blanco cheese supplemented with powdered microcapsules containing tomato extracts (0.5-2.0%, w/w) on the last day of storage were significantly higher than those of the control ($p<0.05$). This is because powdered microcapsules containing tomato extracts are generally light yellow in color. It was observed that b* and a* values can increase when the microcapsules are added to the cheese.

Texture analysis

The texture profiles of Queso Blanco cheese supplemented with different concentrations (0.5, 1.0, 1.5, and 2.0%) of powdered microcapsules containing tomato ext-

Table 2. Short-chain fatty acid of Queso Blanco cheese supplemented with different concentrations of powdered microcapsules of tomato extracts during ripening at 7°C for 60 d

Short-chain fatty acid (ppm)	Concentration (%, w/w)	Storage period (d)				
		0	15	30	45	60
C_4	Control	12.13±0.06$^{Ae1)}$	14.14±0.13^{Ad}	16.65±0.21^{Ac}	22.34±0.30^{Ab}	25.91±0.60^{Aa}
	0.5	12.23±0.10^{Ae}	14.39±0.10^{Ad}	16.60±0.16^{Ac}	22.24±0.19^{Ab}	25.94±0.23^{Aa}
	1.0	12.25±0.10^{Ae}	14.54±0.12^{Ad}	16.52±0.09^{Ac}	22.53±0.29^{Ab}	25.80±0.15^{Aa}
	1.5	12.27±0.10^{Ae}	14.22±0.14^{Ad}	16.40±0.25^{Ac}	22.84±0.35^{Ab}	25.87±0.24^{Aa}
	2.0	12.45±0.15^{Ae}	14.42±0.09^{Ad}	16.39±0.16^{Ac}	22.86±0.38^{Ab}	26.06±0.25^{Aa}
C_6	Control	7.73±0.22^{Ae}	8.57±0.20^{Ad}	10.16±0.24^{Ac}	11.45±0.17^{Ab}	12.66±0.31^{Aa}
	0.5	7.84±0.14^{Ae}	8.42±0.24^{Ad}	10.24±0.15^{Ac}	11.46±0.45^{Ab}	12.64±0.18^{Aa}
	1.0	7.62±0.20^{Ae}	8.36±0.30^{Ad}	10.26±0.11^{Ac}	11.26±0.21^{Ab}	12.56±0.18^{Aa}
	1.5	7.69±0.23^{Ae}	8.44±0.20^{Ad}	10.37±0.11^{Ac}	11.32±0.33^{Ab}	12.54±0.23^{Aa}
	2.0	7.77±0.18^{Ae}	8.56±0.09^{Ad}	10.35±0.08^{Ac}	11.31±0.19^{Ab}	12.90±0.23^{Aa}
C_8	Control	6.28±0.22^{Ae}	7.51±0.19^{Ad}	8.50±0.29^{Ac}	10.61±0.24^{Ab}	11.41±0.33^{Aa}
	0.5	6.17±0.15^{Ae}	7.44±0.26^{Ad}	8.48±0.31^{Ac}	10.61±0.19^{Ab}	11.55±0.34^{Aa}
	1.0	6.30±0.23^{Ae}	7.62±0.18^{Ad}	8.25±0.14^{Ac}	10.58±0.25^{Ab}	11.50±0.34^{Aa}
	1.5	6.29±0.19^{Ae}	7.60±0.17^{Ad}	8.04±0.33^{Ac}	10.57±0.21^{Ab}	11.52±0.27^{Aa}
	2.0	6.26±0.20^{Ae}	7.35±0.33^{Ad}	8.43±0.23^{Ac}	10.60±0.37^{Ab}	12.02±0.18^{Aa}
C_{10}	Control	11.30±0.21^{Ae}	12.34±0.12^{Ad}	14.13±0.09^{Ac}	16.77±0.18^{Ab}	17.98±0.20^{Aa}
	0.5	11.13±0.13^{Ae}	12.40±0.12^{Ad}	14.12±0.12^{Ac}	16.74±0.14^{Ab}	17.88±0.09^{Aa}
	1.0	11.00±0.13^{Ae}	12.55±0.17^{Ad}	13.97±0.17^{Ac}	16.64±0.23^{Ab}	17.86±0.10^{Aa}
	1.5	11.30±0.16^{Ae}	12.29±0.14^{Ad}	14.16±0.09^{Ac}	16.76±0.30^{Ab}	17.85±0.10^{Aa}
	2.0	11.43±0.16^{Ae}	12.60±0.25^{Ad}	14.23±0.11^{Ac}	16.64±0.21^{Ab}	17.93±0.12^{Aa}
Total	Control	37.44±0.57^{Ae}	42.56±0.30^{Ad}	49.15±0.23^{Ac}	61.73±0.34^{Ab}	67.96±0.61^{Aa}
	0.5	37.37±0.22^{Ae}	42.65±0.34^{Ad}	49.43±0.20^{Ac}	61.05±0.37^{Ab}	68.02±0.66^{Aa}
	1.0	37.17±0.13^{Ae}	43.08±0.25^{Ad}	49.00±0.21^{Ac}	61.01±0.08^{Ab}	67.33±0.72^{Aa}
	1.5	37.55±0.63^{Ae}	42.56±0.42^{Ad}	48.97±0.32^{Ac}	61.49±0.46^{Ab}	67.78±0.75^{Aa}
	2.0	37.90±0.10^{Ae}	42.93±0.05^{Ad}	49.40±0.18^{Ac}	61.41±0.68^{Ab}	68.92±0.67^{Aa}

1)Data values were expressed as means±SD (n=3). Means with different superscripts in a column (A-E) and row (a-e) is significant at $p<0.05$ by Ducan's multiple range test.

Table 3. Changes of color in Queso Blanco cheese supplemented with different concentrations of powdered microcapsules of tomato extracts during ripening at 7°C for 60 d

Color value	Concentration (%, w/w)	Storage period (d)				
		0	15	30	45	60
L	Control	81.10±0.27$^{Aa1)}$	79.33±0.49^{Aa}	79.01±0.29^{Aa}	78.32±0.16^{Aab}	77.66±0.33^{Ab}
	0.5	77.70±0.61^{ABa}	76.60±0.38^{Ba}	75.65±0.51^{BCa}	74.41±0.41^{ABab}	73.87±0.29^{Bb}
	1.0	76.93±0.61^{Ba}	76.00±0.55^{Ba}	75.41±0.54^{BCab}	73.89±0.60^{Bb}	73.11±0.33^{Bb}
	1.5	75.49±0.71^{BCa}	73.95±0.94^{Cab}	72.45±0.73^{CDab}	72.05±0.72^{BCab}	71.77±0.43^{BCb}
	2.0	74.51±0.71^{Ca}	72.63±0.54^{Cab}	71.25±0.53^{Db}	70.79±0.27^{Cbc}	69.91±0.32^{Cc}
a	Control	-4.21±0.13^{Cb}	-3.95±0.07^{Dab}	-3.74±0.05^{Ea}	-3.73±0.06^{Ea}	-3.61±0.03^{Ea}
	0.5	1.15±0.41^{Ba}	1.19±0.41^{Ca}	1.21±0.45^{Da}	1.31±0.19^{Da}	1.42±0.29^{Ca}
	1.0	1.47±0.55^{Bb}	2.10±0.31^{Ba}	2.38±0.30^{Ca}	2.42±0.74^{Ca}	2.50±0.23^{Ca}
	1.5	3.03±0.88^{Ab}	3.69±0.81^{ABb}	3.84±0.84^{Bab}	4.21±0.53^{Bab}	4.46±0.24^{Ba}
	2.0	3.50±0.87^{Ad}	4.25±0.33^{Ac}	5.12±1.17^{Ab}	5.59±0.59^{Aab}	6.02±0.41^{Aa}
b	Control	16.70±0.18^{Db}	16.77±0.09^{Cb}	16.82±0.17^{Dab}	16.87±0.13^{Da}	17.05±0.14^{Ca}
	0.5	23.75±0.69^{Cb}	25.91±0.71^{Bb}	25.77±1.29^{Cab}	26.36±0.78^{Ca}	26.60±1.42^{BCa}
	1.0	25.74±1.32^{Cb}	26.98±1.38^{ABab}	27.44±1.61^{BCa}	28.35±0.85^{Ba}	28.62±1.09^{Ba}
	1.5	28.50±1.52^{Bc}	29.49±1.52^{Abc}	30.82±1.46^{ABb}	30.94±1.55^{Bb}	32.62±1.53^{ABa}
	2.0	29.84±2.28^{Ac}	31.38±1.51^{Ac}	33.11±1.60^{Abc}	34.78±1.03^{Ab}	36.89±1.33^{Aa}

1)Data values were expressed as means±SD (n=10). Means with different superscripts in a column (A-E) and row (a-e) is significant at $p<0.05$ by Ducan's multiple range test.

racts were assessed for chewiness, cohesiveness, hardness, springiness, and gumminess over the ripening period of 60 d. This is presented in Table 4. The hardness, gumminess, and chewiness values were significantly higher than those of the control during the 60 d ($p<0.05$). This was probably due to the reduction in pH after the supplementation with the microcapsules, as shown in Table 1. According to Lawrence *et al.* (1987), the pH of cheddar cheese influenced the texture, and as the pH decreases to pH 5.4, ionic species that covalently bind to casein strands become protonated during curd formation. This subsequently increases hydrophobic interactions between protein molecules, making the curd harder and more elastic. Cumulatively, it was shown in this study that the supplementation of powdered microcapsules containing tomato extracts improved the texture of Queso Blanco cheese.

Sensory evaluation

The sensory properties associated with Queso Blanco cheese supplemented with different concentrations (0.5, 1.0, 1.5, and 2.0%) of powdered microcapsules containing tomato extracts stored at 7°C for 60 d are shown in Table 5. The yellowness scores significantly increased with higher concentrations of microcapsules ($p<0.05$), likely owing to their yellow color. For taste scores, the sourness and astringency scores increased significantly with higher concentrations of microcapsules ($p<0.05$). The tomato taste was a unique characteristic of the microcapsules, and in the present study, it influenced the taste of the cheese. The tomato taste of Queso Blanco cheese increased significantly at higher concentrations of the powdered microcapsules ($p<0.05$). This was likely due to a decrease in moisture content. For the texture of these cheese samples, the firmness increased significantly after supplementation with the microcapsules ($p<0.05$), likely due to decreases in the pH values of Queso Blanco cheese. This was confirmed by the textural data (Table 4). Similarly, texture scores for Appenzeller cheese were improved after supplementation with powdered microcapsules containing tomato extracts (Kwak *et al.*, 2016).

Table 4. Texture properties of Queso Blanco cheese supplemented with different concentrations of powdered microcapsules of tomato extracts during ripening at 7°C for 60 d

Texture value	Concentration (%, w/w)	Storage period (d)				
		0	15	30	45	60
Hardness (N)	Control	$14.36\pm0.60^{Cc1)}$	16.46 ± 1.08^{Cbc}	17.66 ± 0.80^{Bb}	19.30 ± 0.73^{Ba}	19.91 ± 0.59^{Da}
	0.5	15.83 ± 1.93^{Bc}	17.19 ± 0.74^{Cbc}	18.04 ± 1.67^{Bb}	19.58 ± 1.82^{Bab}	21.14 ± 0.36^{Da}
	1.0	16.18 ± 0.89^{Bc}	21.03 ± 0.64^{Bb}	21.55 ± 0.84^{Aab}	21.98 ± 1.50^{Aab}	23.16 ± 1.69^{Ca}
	1.5	19.14 ± 0.92^{Ac}	21.09 ± 0.34^{Bb}	22.34 ± 2.21^{Aab}	23.45 ± 1.02^{Aab}	25.16 ± 0.64^{Ba}
	2.0	19.18 ± 0.32^{Ac}	22.20 ± 0.81^{Ab}	22.97 ± 1.06^{Ab}	23.58 ± 0.46^{Ab}	26.78 ± 1.83^{Aa}
Cohesiveness	Control	0.71 ± 0.01^{Ba}	0.72 ± 0.01^{Ba}	0.72 ± 0.01^{Ca}	0.73 ± 0.01^{Ba}	0.74 ± 0.01^{Ba}
	0.5	0.71 ± 0.01^{Ba}	0.72 ± 0.01^{Ba}	0.72 ± 0.00^{Ca}	0.73 ± 0.00^{Ba}	0.74 ± 0.00^{Ba}
	1.0	0.72 ± 0.01^{ABa}	0.72 ± 0.01^{Ba}	0.73 ± 0.01^{Ba}	0.74 ± 0.01^{Ba}	0.75 ± 0.00^{Ba}
	1.5	0.73 ± 0.00^{Ab}	0.74 ± 0.01^{Ab}	0.75 ± 0.01^{Aab}	0.77 ± 0.02^{Aa}	0.78 ± 0.03^{Aa}
	2.0	0.73 ± 0.01^{Ac}	0.75 ± 0.02^{Abc}	0.76 ± 0.01^{Ab}	0.79 ± 0.03^{Aa}	0.79 ± 0.02^{Aa}
Springiness (mm)	Control	0.71 ± 0.01^{Cc}	0.73 ± 0.01^{Cbc}	0.73 ± 0.02^{Bbc}	0.81 ± 0.10^{Bab}	0.87 ± 0.11^{Ba}
	0.5	0.72 ± 0.01^{Cc}	0.75 ± 0.02^{Cbc}	0.80 ± 0.11^{Bab}	0.88 ± 0.15^{Bab}	0.92 ± 0.10^{ABa}
	1.0	0.73 ± 0.01^{Cb}	0.81 ± 0.10^{BCab}	0.91 ± 0.11^{Aa}	0.99 ± 0.00^{Aa}	0.99 ± 0.01^{Aa}
	1.5	0.83 ± 0.08^{Bb}	0.90 ± 0.13^{Bab}	1.00 ± 0.00^{Aa}	1.00 ± 0.00^{Aa}	$1.00\pm.01^{Aa}$
	2.0	1.00 ± 0.00^{Aa}	1.00 ± 0.00^{Aa}	1.00 ± 0.00^{Aa}	1.00 ± 0.00^{Aa}	1.01 ± 0.01^{Aa}
Gumminess (N)	Control	10.25 ± 1.12^{Dc}	12.01 ± 0.75^{Cb}	12.98 ± 0.54^{Cb}	14.44 ± 0.56^{Ca}	14.69 ± 1.15^{Da}
	0.5	10.98 ± 0.55^{Dd}	12.79 ± 0.42^{Cc}	13.48 ± 1.11^{Cc}	15.09 ± 0.44^{Cb}	16.45 ± 0.28^{Ca}
	1.0	11.92 ± 0.41^{Cd}	14.37 ± 0.47^{Bc}	15.70 ± 0.63^{Bb}	16.17 ± 0.38^{Bb}	17.26 ± 0.81^{Ca}
	1.5	13.93 ± 0.35^{Bc}	15.94 ± 1.65^{Abc}	16.58 ± 0.98^{ABb}	17.37 ± 0.52^{Aab}	18.37 ± 0.51^{Ba}
	2.0	15.91 ± 0.65^{Ac}	16.23 ± 0.62^{Ab}	17.36 ± 0.69^{Ab}	17.62 ± 0.71^{Ab}	19.27 ± 0.43^{Aa}
Chewiness (J)	Control	8.52 ± 1.07^{Cc}	10.56 ± 1.20^{Dbc}	11.37 ± 2.19^{Cb}	12.58 ± 0.52^{Cab}	13.48 ± 1.08^{Ca}
	0.5	10.11 ± 1.09^{BCc}	12.02 ± 1.01^{Cbc}	12.56 ± 0.99^{Cbc}	13.48 ± 1.20^{Cb}	14.99 ± 1.18^{Ba}
	1.0	10.20 ± 0.52^{BCc}	13.38 ± 1.09^{Bb}	13.91 ± 0.41^{Bb}	15.83 ± 0.49^{Ba}	16.15 ± 0.53^{Ba}
	1.5	11.78 ± 1.28^{ABd}	14.09 ± 0.49^{Ac}	15.05 ± 1.23^{ABbc}	16.17 ± 0.49^{Bb}	18.20 ± 0.65^{Aa}
	2.0	13.36 ± 1.75^{Ab}	15.80 ± 0.97^{Ab}	15.88 ± 1.60^{Ab}	17.41 ± 0.60^{Aab}	18.59 ± 1.29^{Aa}

[1)] Data values were expressed as means±D (n=5). Means with different superscripts in a row (a-d) and column (A-D) are significant at $p<0.05$ by Ducan's multiple range test.

Table 5. Sensory characteristics of Queso Blanco cheese supplemented with different concentrations of powdered microcapsules of tomato extracts during ripening at 7°C for 60 d

Concentration (%, w/w)	Appearance	Taste			Texture
	Yellowness	Sourness	Astringency	Tomato	Firmness
Control	1.25±0.10$^{D1)}$	1.38±0.05^{C}	1.51±0.31^{D}	1.34±0.18^{D}	4.25±0.11^{C}
0.5	3.39±1.07^{C}	2.25±0.58^{B}	1.82±0.53^{C}	2.78±0.79^{C}	4.39±0.38^{BC}
1.0	4.54±0.49^{BC}	2.25±0.00^{B}	2.25±0.82^{AB}	2.78±0.53^{C}	4.96±0.76^{B}
1.5	5.82±0.53^{B}	2.68±0.53^{B}	2.96±0.95^{A}	4.92±1.13^{B}	4.96±0.95^{B}
2.0	6.11±0.38^{A}	3.25±1.41^{A}	3.39±1.07^{A}	5.92±1.12^{A}	5.54±0.95^{A}

1)Data values were expressed as means±SD (n=7). Means with different superscripts in a column (A-D) is significant at $p<0.05$ by Ducan's multiple range test.

Conclusion

This study investigated the physical, sensory, microbial, and chemical characteristics of Queso Blanco cheese supplemented with different concentrations (0.5, 1.0, 1.5, and 2.0%) of powdered microcapsules containing tomato extracts over 60 d of ripening. Supplementation with the microcapsules significantly increased the lycopene content of the cheese. The amount of short-chain fatty acids steadily increased during the 60-d ripening period, regardless of the type of treatment. LAB counts decreased with increasing concentrations of the microcapsules, but these slightly increased during ripening. The textural properties of Queso Blanco cheese also improved after supplementation with the microcapsules. In a sensory analysis, the tomato taste and firmness scores of the cheese increased after supplementation during 60 d of ripening. Cumulatively, the results of this study show that powdered microcapsules containing tomato extracts can be successfully used in the production of Queso Blanco cheese, and these supplements will benefit the dairy industry and customers.

References

1. Association of Official Analytical Chemists (AOAC). (2005) Official Method of Analysis of AOAC Intl, Gaithersburg (Method 996.11.), MD, USA; 18th ed.
2. Bartkiene, E., Juodeikiene, G., Zadeike, D., Viskelis, P., and Urbonaviciene, D. (2015) The use of tomato powder fermented with *Pediococcus pentosaceus* and *Lactobacillus sakei* for the ready-to-cook minced meat quality improvement. *Food Technol. Biotechnol.* **53,** 163-170.
3. Bermudez-Aguirre, D. and Barbosa-Cánovas, G. V. (2012) Fortification of queso fresco, cheddar and mozzarella cheese using selected sources of omega-3 and some nonthermal approaches. *Food Chem.* **133,** 787-797.
4. Chang, Y. H., Lee, S. Y., and Kwak, H. S. (2016) Physicochemical and sensory properties of milk fortified with iron microcapsules prepared with water-in-oil-in-water emulsion during storage. *Int. J. Dairy. Technol.* **69,** 452-459.
5. Estrada, J. D., Boeneke, C., Bechtel, P., and Sathivel, S. (2011) Developing a strawberry yogurt fortified with marine fish oil. *J. Dairy Sci.* **94,** 5760-5769.
6. Farkye, N. Y. (2004) Cheese technology. *Int. J. Dairy Technol.* **57,** 91-98.
7. Gharsallaoui, A., Roudaut, G., Chambin, O., Voilley, A., and Saurel, R. (2007) Applications of spray-drying in microencapsulation of food ingredients: An overview. *Food Res. Int.* **40,** 1107-1121.
8. Ko, E. J., Chang, Y, H., and Kwak, H. S. (2017) Physicochemical and microbial properties of nanopowdered peanut sprout-supplemented Caciocavallo-like cheese during ripening. *Int. J. Dairy Technol.* **70**, 84-91.
9. Kwak, H. S., Chimed, C., Yoo, S. H., and Chang, Y. H. (2016) Physicochemical and sensory properties of appenzeller cheese supplemented with powdered microcapsule of tomato extract during ripening. *Korean J. Food Sci. An.* **36,** 244-253.
10. Kwak, H. S., Jeon, I. J., and Park, J. N. (1990) Effects of food grade porcine pancreatic lipase on the production of short-chain fatty acids and its contribution. *Korean J. Food Sci. Technol.* **22,** 248-254.
11. Lawrence, R. C., Creamer, L. K., and Gilles, J. (1987) Texture development during cheese ripening. *J. Dairy Sci.* **70,** 1748-1760.
12. Lee, Y. K., Al, Mijan. M., Ganesan, P., Yoo, S., and Kwak, H. S. (2013) The physicochemical properties of yoghurt supplemented with microencapsulated peanut sprout extract, a possible functional ingredient. *Int J. Dairy Technol.* **66,** 417-423.
13. Li, W., Jiang, B., Cao, X., Xie, Y., and Huang, T. (2017) Protective effect of lycopene on fluoride-induced ameloblasts apoptosis and dental fluorosis through oxidative stress-mediated Caspase pathways. *Chem-Biol. Interact.* **261,** 27-34.
14. Lin, J. C. C., Jeon, I. J., Roberts, H. A., and Milliken, G. A. (1987) Effects of commercial food grade enzymes on proteolysis and textural changes in granular Cheddar cheese. *J. Food Sci*. **52,** 620-625.
15. Matioli, G. and Rodriguez-Amaya, D. B. (2002) Lycopene encapsulated with gum Arabic and maltodextrin: Stability study. *Braz. J. Food Technol.* **5,** 197-203.
16. Mukhopadhyay, S., Ukuku, D. O., Juneja, V., and Fan, X. (2014) Effects of UV-C treatment on inactivation of *Salmo-*

nella enterica and *Escherichia coli* O157: H7 on grape tomato surface and stem scars, microbial loads, and quality. *Food Control* **44,** 110-117.
17. Nguyen, M. L. and Schwartz, S. J. (1999) Lycopene: Chemical and biological properties. *Food Technol-Chicago* **53,** 38-45.
18. Oberoi, D. P. S. and Sogi, D. S. (2015) Effect of drying methods and maltodextrin concentration on pigment content of watermelon juice powder. *J. Food Eng.* **165,** 172-178.
19. Onwulata, C. I. (2013) Microencapsulation and functional bioactive foods. *J. Food Process. Pres.* **37,** 510-532.
20. Rashidinejad, A., Birch, E. J., Sun-Waterhouse, D., and Everett, D. W. (2014) Delivery of green tea catechin and epigallocatechin gallate in liposomes incorporated into low-fat hard cheese. *Food Chem.* **156,** 176-183.
21. Rocha, G. A., Fávaro-Trindade, C. S., and Grosso, C. R. F. (2012) Microencapsulation of lycopene by spray drying: Characterization, stability and application of microcapsules. *Food Bioprod. Process* **90,** 37-42.
22. Sandra, S., Stanford, M. A., and Goddik, L. M. (2004) The use of high-pressure processing in the production of Queso Fresco cheese. *J. Food Sci.* **69,** 153-158.
23. Story, E. N., Kopec, R. E., Schwartz, S. J., and Harris, G. K. (2010) An update on the health effects of tomato lycopene. *Ann. Rev. Food Sci. Technol.* **1,** 189-210.
24. Tunick, M. H., Van Hekken, D. L., and Cooke, P. H. (2008) Rheology and microstructure of Queso Blanco as affected by pressing procedure and storage conditions. *Milchwissenschaft* **63,** 157-160.
25. Van Hekken, D. L., Tunick, M. H., Leggett, L. N., and Tomasula, P. M. (2012) Impact of curd milling on the chemical, functional, and rheological properties of starter-free Queso Fresco. *J. Dairy Sci.* **95,** 5527-5535.
26. Verma, A. and Singh, S. V. (2015) Spray drying of fruit and vegetable juices - A review. *Crit. Rev. Food Sci.* **55,** 701-719.