

Effect of Crosslinked β -cyclodextrin on Quality of Cholesterol-reduced Cream Cheese

Song-Hee Kim, Eun-Mi Han, Joungjwa Ahn and Hae-Soo Kwak*

Department of Food Science and Technology, Sejong University, 98 Kunja-dong, Kwangjin-ku, Seoul 143-747, Korea

ABSTRACT : This study was carried out to investigate the effects of different types of β -cyclodextrin (β -CD) treatments on chemical and sensory characteristics of cholesterol-reduced cream cheese. The cholesterol removal rates were 92.0% in cream cheese treated by powder β -CD, and 82.6% in cream cheese treated by crosslinked β -CD. Amounts of short-chain fatty acid and free amino acids were significantly lower in cream cheese made by crosslinked β -CD-treated milk, especially after 2 weeks storage, compared with those of no β -CD-treated control and cream cheese made by powder β -CD treated milk. Among rheological properties, cohesiveness was significantly higher, and gumminess in cream cheese made by crosslinked β -CD-treated milk was slightly lower than others. In sensory analysis, no difference was found in texture among treatments, while bitterness was lower in the early stage of storage, and overall quality was higher score, in cream cheese made by crosslinked β -CD-treated cream at 3 and 4 week storage, compared with those in control and powder β -CD-treated group. The present study indicated that crosslinked β -CD treatment resulted in an efficient cholesterol removal rate over 80% and a deceleration of ripening, which may provide a longer shelf life without significant adverse effects in chemical and sensory properties. (*Asian-Aust. J. Anim. Sci.* 2005. Vol 18, No. 4 : 584-589)

Key Words : β -Cyclodextrin, Crosslinking, Cream Cheese

INTRODUCTION

Since a strong positive correlation exists between increased serum cholesterol concentrations and risk of coronary heart disease, most consumers are concerned about excessive intake of cholesterol (Grundy et al., 1982; Gurr 1992). Therefore, physical, chemical, and biological methods to reduce cholesterol have been studied in foods, including dairy products (Szjetli, 1988; Ahn and Kwak, 1999; Lee et al., 1999; Kwak et al., 2001).

Food companies have developed many methods to reduce cholesterol, however, most of these methods are relatively nonselective and remove flavor and nutritional components when cholesterol is removed. Moreover, some methods require high investment and operation costs. A number of studies have indicated that cholesterol removal from dairy products was most effectively achieved by powder β -cyclodextrin (β -CD) (Oakenfull and Sidhu, 1991; Makoto et al., 1992; Ahn and Kwak, 1999; Lee et al., 1999; Kwak et al., 2001). β -CD is a cyclic oligosaccharide composed of α -(1-4) linkages of seven glucose units, and it has a cavity at the center of its molecular arrangements, which forms an inclusion complex with various compounds including cholesterol (Szjetli, 1982). Whereas β -CD provides advantages when used for cholesterol removal over 90% from various foods, powder β -CD is an ineffective way for separation from food system and recovery.

One method to overcome these problems could be a crosslinking of β -CD. Crosslinking is a commonly used derivatization technique for manipulating starch functionality, and epichlorohydrin and adipic anhydride have been extensively used to produce crosslinked starches, which inter- or intramolecular mono- and diethers are formed with hydroxyl groups of starch (Hamerstrand et al., 1959). Our previous study showed a possibility of crosslinked β -CD treatment on cholesterol removal in milk and an effective recycling efficiency (Kim et al., 2004).

A number of our studies have indicated that cholesterol removal from milk, cream and Cheddar and Mozzarella cheeses was effectively achieved by treatment with both powder and crosslinked β -CD (Oakenfull and Sidhu, 1991; Makoto et al., 1992; Ahn and Kwak, 1999; Lee et al., 1999; Kwak et al., 2001). In addition, no profound adverse effect of β -CD treatments was found in chemical and sensory aspects in those products. Cream cheese is one of the most popular soft cheeses in North America, and is used as a spread on bread, in sandwiches and a salad dressing (Tewari and Singh, 1991). Its consumption is also greatly appreciated in Europe, especially in the U.K., Germany and France (Sanchez et al., 1996). However, little information is available the chemical and sensory properties of cream cheese when crosslinked- β -CD treatment. Therefore, objectives of this study were to examine the possibility of the manufacture of cream cheese made by crosslinked β -CD-treated cream, and compare the chemical and sensory characteristics in cream cheeses between powder and crosslinked β -CD-treated.

* Corresponding Author: Hae-Soo Kwak. Tel: +82-2-3408-3226, Fax: +82-2-497-8931, E-mail: kwakhs@sejong.ac.kr

Received September 22, 2004; Accepted December 17, 2004

MATERIALS AND METHODS

Crosslinking of β -cyclodextrin

A sample of 100 g of β -CD was prepared in a 166 ml distilled water and placed in a stirrer at room temperature with constant agitation. Then, 2 g of epichlorohydrin was incorporated and pH was adjusted to 10 with 1 M NaOH. The β -CD solution was stirred at room temperature for 2 h, and then readjusted to pH 5.5 with acetic acid. β -CD was recovered by filtering with Whatman paper No.2, and washed two times with 150 ml of distilled water and once with 15 ml of 95% ethanol. The product was dried at 40°C for 48 h in a Lab-line mechanical convection oven and passed through a 100 mesh sieve.

Milk treatment

Raw milk (milk fat: 3.5%) was obtained from Bingrae Dairy Plant (Kyonggi-do, Korea), and pasteurized at 72°C for 15 sec and cream was separated at 40°C using a cream separator (CE elecrem, Vanves, France). Treatments were divided into three different experimental groups as followed: 1) Control: the separated cream containing 11% milk fat with no treatment, 2) Trt A: the cream containing 35% milk fat was treated with 10% β -CD at 800 rpm with a blender (Tops: Misung Co., Seoul, Korea) in a temperature-controlled water bath at 10°C for 10 min (Kwak et al., 2005), and 3) Trt B: the cream containing 35% milk fat was treated with 10% crosslinked β -CD at 800 rpm for 10 min. Creams for Trt A and B were centrifuged with 166 \times g for β -CD removal. Then, each cream was standardized to 11% milk fat for cream cheese milk, homogenized with 680 psi at 50°C in a single stage homogenizer (HC 5000, Microfluidics Corp., Newton, MA) (Mistry and Anderson, 1993), and cooled to 30°C.

Manufacture of cream cheese

The cholesterol-reduced β -CD-treated milk (15 kg) was inoculated with 0.05% lactic starter culture (CH-N22, Chr. Hansen's Lab., Milwaukee, WI, USA). After 5 min of ripening, rennet (Standard Plus 900, Chr. Hansen's Lab., Milwaukee, WI, USA) was added with 0.005%, followed by 0.03% CaCl₂ (10% Ca). Curd was formed in 1 h and cut when pH was reached at 4.7. After whey was separated from the curd, it was cooked at 45°C for 15-20 min. Whey was drained and curd was molded and turned every 1 h, and the molded cheese was stayed for 4 h at room temperature. It was pressed at 1 atm at 20°C for overnight, and vacuum packaged (Turbovac, Howben Food Equipment, Hertogenbosch, The Netherlands) in a barrier bag and stored at 4°C (Cheese and fermented milk foods). The cheese making was triplicate on different days using different batches of treatments. Each batch of cheese making was triplicate.

Extraction and determination of cholesterol

Cholesterol was extracted (Adams et al., 1986) and stored at -20°C until analysis. Total cholesterol was determined on a silica fused capillary column (HP-5, 30 m \times 0.32 mm I.D. \times 0.25 μ m thickness) using Hewlett-Packard 5890A gas chromatography (Palo Alto, CA, USA) equipped with a flame ionization detector. The temperatures of injector and detector were 270 and 300°C, respectively. The oven temperatures were programmed from 200 to 300°C at 10°C/min and held for 20 min. Nitrogen was used as a carrier gas at a flow rate of 2 ml with a split ratio of 1/50. Quantitation of cholesterol was done by comparing the peak areas with a response of an internal standard.

The percentage of cholesterol reduction was calculated as followed: cholesterol reduction (%) = 100 - (amount of cholesterol in β -CD-treated cheese \times 100 / amount of cholesterol in control). Cholesterol determination for control was averaged with each batch of treatment.

Analysis of chemical composition and yield of cheese

Raw milk and cheese were analyzed for moisture, fat, and protein using the methods of Association of Official Analytical Chemists (1990). Cheese yield was determined as wt. cheese \times 100 / wt. milk.

Analysis of short-chain free fatty acid

Cheese samples (1 g) were removed periodically from control cheese ripened for 0, 8, 16, 24 and 32 weeks and 0, 2, 4, 6 and 8 weeks for experimental cheeses and extracted with diethylether and hexane for 2 h, and eluted through a 10 mm i.d. glass column containing neutral alumina as described by Kwak et al. (1990). A Hewlett-Packard Model 5880A GC equipped with a flame ionization detector was used. The preparation of FFA was achieved using a 15 m \times 0.53 mm i.d. Nukol fused-silica capillary column (Supleco Inc., Bellefonte, PA, USA). The GC was operated with helium carrier gas at 2 ml/min, hydrogen gas 37 ml/min, and air at 300 ml/min. The column oven was programmed as an initial holding for 1 min at 110°C and first level holding to 180°C at 5°C/min for 10 min and holding for 20 min. Both temperatures for injector and detector were 250°C. All quantitative analyses were done by relating each peak area of individual FFA to the peak area of tridecanoic acid as an internal standard. Each FFA was identified by the retention time of standard.

Analysis of free amino acids (FAA)

RP-HPLC analysis of the FAAs was performed according to the method of Izco et al. (2000). Samples were analyzed on a Waters HPLC system consisting of 600 pump, 486 tunable absorbance detector 254 nm, operated using Millennium software. The column used was a Waters

Table 1. Mean chemical composition of cholesterol-reduced cream cheese¹

Component	Control ²	Trt A ³	Trt B ⁴
Moisture (%)	54.7 ^a	56.0 ^a	57.2 ^a
Fat (%)	33.5 ^a	32.8 ^a	33.1 ^a
Protein (%)	7.0 ^a	7.5 ^a	7.6 ^a
Yield (%)	33.0 ^a	34.8 ^a	35.2 ^a
Cholesterol removal (%)	-	92.0 ^a	82.6 ^b
Cholesterol (mg/g cheese)	95.0	-	-

¹Means within a row with different letters differ significantly ($p < 0.05$).

² Cream was not treated with β -CD.

³ Cream was treated with powder β -CD after cream separation.

⁴ After cream separation, cream was crosslinked β -CD and blended with skim milk at 680 psi.

PicoTag C₁₈ reversed-phase column maintained at 46°C. An internal standard was added for identification of amino acids (Sigma, St. Louis, MO, USA). A gradient with two solvents was used to run the sample: solution A comprised 70 mM sodium acetate adjusted to pH 6.55 with acetic acid and added containing 2.5% acetonitrile, and solution B was 45% acetonitrile, 40% water and 15% methanol. Before each injection, the column was equilibrated with solvent A for 2 min.

Rheological analysis

Cylindrical samples (2 cm diameter \times 2 cm height) were cut, and force distance curves were obtained using SUN Rheometer (CR-200D, Sun Scientific Co., Ltd., Tokyo, Japan) with a crosshead of 50 mm/min and chart speed of 200 mm/min. From these curves, the basic characteristics of the texture profile were determined, including hardness, elasticity, cohesiveness, gumminess and chewiness. The point at which the highest force during the first compression was hardness. The extent to which the sample returned to its original between the first and second compression was elasticity. The ratio of the area under the second compression was cohesiveness. Gumminess and chewiness were calculated by hardness \times cohesiveness, and gumminess \times elasticity, respectively.

Sensory analysis

Seven trained sensory panelists evaluated randomly coded cheeses. Texture and overall flavor were evaluated on a 9-point scale (1=poor and 9=excellent). Typical cream cheese flavor intensity, bitterness, and texture were scored on an 9-point scale (1=low intensity to 9=high intensity).

Statistical analysis

Data from the determination of optimum conditions of cheeses were analyzed by analysis of variance (ANOVA) using a SAS program (1985) was used. The significance of the results was analyzed by the least significant difference (LSD) test. Difference of $p < 0.05$ were considered to be significant.

RESULTS AND DISCUSSION

Cholesterol removal rate and composition

To find out whether a difference existed in cholesterol removal between treatments, the cholesterol content was measured as shown in Table 1. The cholesterol content of the control cream cheese was 95.0 mg/100 g. The cholesterol reduction of the cream cheese reached 92.0% when separated cream was treated with 10% powder β -CD (Trt A), whereas that was 82.6% when separated cream was treated with 10% crosslinked β -CD (Trt B). Our previous study (Immobilization) showed 40.2% cholesterol reduction of milk when immobilized β -CD beads as a solid support.

In the raw milk, the moisture content was 88.0%, and fat and protein contents were 3.2 and 3.3%, respectively. Lactose and ash were 5.0 and 0.7%, respectively. In cream cheese composition, no significant difference was found in all chemical compositions except for moisture. Moisture content was in the range of 54.7 to 57.2% and fat was 32.8 to 33.5%. No change of fat content was an unexpected result. Based on our previous study (Kwak et al., 2002), Cheddar cheese made by β -CD-treated cream showed a lower fat content than the control, since more fat would be released in the manufacture of experimental cheese due to the smaller size of fat globule, resulting from stirring. It may be that the fat globule was too small to incorporate with casein or other protein compounds via a fat-protein network.

Production of short-chain free fatty acids (FFA)

It is well known that short-chain free fatty acids (FFA, C₄ through C₁₀) constitute the backbone of Cheddar flavor (Lin and Jeon, 1987). Therefore, the production of short-chain FFA profiles was considered to be an important aspect. Our previous study (Kwak et al., 2002) indicated that cheese by the mixture of β -CD-treated cream and skim milk was ripened rapidly with the high production of short-chain FFA, compared with control in Cheddar cheese.

The production of short-chain FFA in control and experimental cream cheeses stored for 4 weeks at 5°C is shown in Table 2. The total amount of short-chain FFA was lower in cheeses made by crosslinked β -CD-treated cream (Trt B) than other groups ($p < 0.05$). No difference was found at 0 week in all groups, however, FFA production in crosslinked β -CD-treated group (Trt B) was not increased throughout 4 week storage ($p < 0.05$). During 4 week, the total production of short-chain FFA in cheese made by powder β -CD-treated cream (Trt A) was slightly, but not significantly higher than that of no-treated cream (Control).

In Control, the amount of total short-chain FFA increased from 76.7 to 104.8 ppm during 4 weeks. In Trt A, cream cheese made by powder β -CD-treated cream, 79.4 ppm of total short-chain FFA were found at 0 week, and

Table 2. Concentrations of short-chain fatty acids in cholesterol-reduced cream cheese stored at 4°C for 4 weeks¹

Treatment	Storage period (wk)	SCFA production (ppm)				
		C ₄	C ₆	C ₈	C ₁₀	Total
Control ²	0	19.5 ^a	18.5 ^a	20.5 ^a	18.2 ^a	76.7 ^a
	1	22.7 ^b	20.9 ^a	23.1 ^b	22.9 ^b	89.6 ^b
	2	24.4 ^b	22.2 ^b	26.1 ^c	23.2 ^b	95.9 ^b
	3	25.7 ^{bc}	24.6 ^{bc}	28.2 ^c	23.5 ^b	102.0 ^{bc}
	4	27.1 ^c	26.5 ^c	28.1 ^c	23.1 ^b	104.8 ^c
Trt A ³	0	19.1 ^a	20.4 ^a	20.1 ^a	19.8 ^a	79.4 ^a
	1	21.8 ^a	24.9 ^{bc}	24.9 ^b	20.9 ^a	92.5 ^b
	2	24.6 ^b	26.7 ^c	25.4 ^{bc}	21.5 ^a	98.2 ^b
	3	25.1 ^b	27.3 ^c	26.1 ^c	25.1 ^b	103.6 ^{bc}
	4	27.8 ^c	29.3 ^c	28.1 ^c	27.2 ^c	112.4 ^c
Trt B ⁴	0	20.4 ^a	18.4 ^a	19.4 ^a	19.3 ^a	77.5 ^a
	1	21.8 ^a	19.6 ^a	20.9 ^a	20.1 ^a	82.4 ^a
	2	22.5 ^{ab}	19.9 ^a	21.6 ^a	20.6 ^a	84.6 ^a
	3	23.5 ^b	20.1 ^a	22.7 ^a	21.5 ^a	87.8 ^a
	4	23.8 ^b	20.2 ^a	23.3 ^b	22.2 ^a	89.5 ^a

¹ Means within a column with different letters differ significantly ($p < 0.05$).

² Cream was not treated with β -CD.

After cream separation, cream was treated with powder β -CD³ or crosslinked β -CD⁴ and blended with skim milk at 680 psi.

112.4 ppm were produced at 4 weeks. However, in Trt B, cream cheese made by crosslinked β -CD-treated cream, 77.5 ppm was produced in 0 week and 89.5 ppm in 4 weeks. This study showed that crosslinked β -CD-treated cream cheese produced the steady amount of short-chain FFA during 4 week storage, while other two groups produced a dramatic amount of short-chain FFA during storage. This result indicated that crosslinked β -CD-treated cream cheese may be extended shelf-life longer than no-treated cream

cheese.

With regard to free fatty acid production, we may assume that small particles of fat due to stirring process can be easily released from cheese curds in the process of cream cheese manufacture. In cream cheese made from powder or crosslinked β -CD-treated cream in the present study, in which cream was first separated from milk and then treated with 10% β -CD, and then skim milk and the treated cream were mixed, fat globule separation was observed to occur easily. The FFA production was higher in the powder β -CD-treated cream cheese than in the crosslinked β -CD-treated cheese, which may attribute to a decrease of lipolysis in crosslinked β -CD-treated cheese. The above results indicated that the cream cheese made from crosslinked β -CD-treated cream (Trt B) ripened slower than those on other groups (Control and Trt A).

Production of free amino acids (FAA)

The production of total free amino acids during storage is shown in Table 3. The cream cheese made by crosslinked β -CD-treated cream (Trt B) produced much lower individual FAA than the cream cheeses made by no-treated (Control) and by powder β -CD-treated cream (Trt A) in all periods. Total FAA amounts were 12.74 μ mol/g cheese at 4 weeks in Control and 16.23 μ mol/g cheese in cream cheese made by powder β -CD-treated cream (Trt A) and 5.01 μ mol/g cream cheese in experimental cream cheese made by crosslinked β -CD-treated cream (Trt B) at 4 week storage period. The concentration of lysine increased dramatically in control group during storage, while the amounts of aspartic acid and serine were produced

Table 3. Production of free amino acids in cream cheese in storage at 4°C for 4 weeks (μ mol/ml)

Treatment	Storage period (wk)	Amino acids													Total amino acid	Bitter amino acid ¹
		Asp	Glu	Ser	Asn	Thr	Ala	Tyr	Val	Met	Ile	Leu	Phe	Lys		
Control ¹	0	0.09	0.38	0.85	0.31	0.59	0.71	0.84	0.27	0.05	0.15	0.50	0.12	0.65	5.51 ^a	1.70 ^a
	1	0.12	0.41	1.21	0.38	0.69	0.83	1.11	0.33	0.06	0.25	0.62	0.14	0.88	7.03 ^a	2.24 ^a
	2	0.11	0.59	1.13	0.38	0.79	0.94	1.01	0.35	0.05	0.23	0.67	0.17	0.99	7.41 ^a	2.19 ^a
	3	0.10	0.50	1.06	0.38	0.73	0.93	0.98	0.33	0.06	0.24	0.76	0.13	0.72	6.92 ^a	2.21 ^a
	4	0.64	0.80	1.65	0.50	1.22	1.30	1.44	0.52	0.07	0.28	1.13	0.23	2.96	12.74 ^b	3.72 ^b
Trt A ²	0	0.13	0.50	1.05	0.40	0.50	0.80	0.89	0.01	0.08	0.17	0.67	0.14	1.11	6.45 ^a	2.00 ^a
	1	0.06	0.40	1.02	0.38	0.17	0.91	0.95	0.29	0.05	0.19	0.59	0.13	0.93	6.07 ^a	1.92 ^a
	2	0.05	0.40	1.20	0.40	0.71	0.95	1.00	0.88	0.06	0.20	0.61	0.14	1.00	7.60 ^a	2.00 ^a
	3	0.09	0.53	1.28	0.45	0.85	1.12	1.20	0.35	0.07	0.20	0.75	0.03	1.50	8.42 ^a	2.27 ^a
	4	0.39	1.34	1.47	0.92	2.61	2.11	1.12	1.02	0.13	0.76	2.11	0.40	1.85	16.23 ^b	4.78 ^{ab}
Trt B ³	0	0.10	0.11	0.66	0.30	0.30	0.60	0.61	0.07	0.02	0.10	0.35	0.14	0.30	3.66 ^a	1.30 ^a
	1	0.10	0.12	0.67	0.34	0.33	0.59	0.64	0.05	0.02	0.12	0.35	0.14	0.31	3.78 ^a	1.35 ^a
	2	0.10	0.12	0.55	0.38	0.44	0.62	0.70	0.08	0.02	0.13	0.35	0.14	0.31	3.94 ^a	1.42 ^a
	3	0.30	0.13	0.71	0.34	0.62	0.87	0.66	0.1	0.03	0.15	0.36	0.10	0.35	4.72 ^a	1.57 ^a
	4	0.50	0.11	1.32	0.34	0.50	0.47	0.57	0.08	0.04	0.08	0.30	0.28	0.42	5.01 ^a	1.73 ^a

¹ Cream was not treated with β -CD.

² Cream was treated with powder β -CD after cream separation.

³ After cream separation, cream was crosslinked β -CD and blended with skim milk at 680 psi.

⁴ Bitter amino acid: Asp, Tyr, Ile, Leu and Phe.

Table 4. Textural properties of cholesterol-reduced cream cheese stored at 4°C for 4 weeks¹

Treatment	Storage period (wk)	Hardness	Cohesiveness	Elasticity	Gumminess
Control ²	0	415.6 ^b	60.5 ^a	80.2 ^{ab}	28.4 ^a
	1	397.3 ^a	62.8 ^a	80.7 ^{ab}	31.3 ^a
	2	380.7 ^a	63.1 ^a	78.9 ^a	31.0 ^a
	3	387.6 ^a	70.6 ^b	78.1 ^a	30.2 ^a
	4	380.1 ^a	68.2 ^b	76.9 ^a	30.4 ^a
Trt A ³	0	560.8 ^c	76.3 ^{bc}	85.7 ^b	49.0 ^b
	1	559.2 ^c	62.0 ^a	80.2 ^{ab}	48.9 ^b
	2	555.1 ^c	68.1 ^b	82.1 ^{ab}	42.4 ^b
	3	556.7 ^c	65.4 ^b	82.6 ^{ab}	48.0 ^b
	4	535.3 ^c	64.6 ^b	81.7 ^{ab}	46.3 ^b
Trt B ⁴	0	379.0 ^a	77.8 ^{bc}	86.6 ^b	22.5 ^a
	1	356.6 ^a	78.5 ^{bc}	85.9 ^b	26.6 ^a
	2	356.9 ^a	82.4 ^c	82.5 ^{ab}	23.6 ^a
	3	346.8 ^a	89.8 ^c	81.4 ^{ab}	25.5 ^a
	4	333.9 ^a	81.7 ^c	81.5 ^{ab}	23.3 ^a

¹ Means within a column with different letters differ significantly ($p < 0.05$).

² Cream was not treated with β -CD.

³ Cream was treated with powder β -CD after cream separation.

⁴ After cream separation, cream was crosslinked β -CD and blended with skim milk at 680 psi.

Table 5. Sensory characteristics of cholesterol-reduced cream cheese at stored at 4°C for 4 weeks¹

Treatment	Storage period (wk)	Texture	Flavor	Bitterness	Overall
Control ²	0	4.32 ^b	1.30 ^a	4.11 ^b	4.87 ^b
	1	4.11 ^{ab}	1.85 ^a	4.21 ^b	4.58 ^b
	2	4.10 ^{ab}	2.14 ^a	4.17 ^b	4.21 ^{ab}
	3	3.43 ^a	2.95 ^{ab}	4.50 ^a	4.07 ^{ab}
	4	3.18 ^a	3.41 ^b	4.30 ^a	3.54 ^a
Trt A ³	0	4.90 ^b	1.14 ^a	2.83 ^a	4.78 ^b
	1	4.17 ^{ab}	1.42 ^a	3.33 ^{ab}	4.63 ^b
	2	3.49 ^a	1.85 ^a	4.50 ^c	4.42 ^{ab}
	3	3.28 ^a	2.51 ^{ab}	4.83 ^c	3.93 ^{ab}
	4	3.18 ^a	2.84 ^{ab}	4.83 ^a	3.41 ^a
Trt B ⁴	0	4.52 ^b	1.27 ^a	2.83 ^a	4.26 ^a
	1	4.14 ^{ab}	2.47 ^{ab}	3.15 ^{ab}	4.07 ^{ab}
	2	3.63 ^a	2.86 ^{ab}	4.50 ^c	4.58 ^b
	3	3.52 ^a	3.27 ^{ab}	4.17 ^b	4.72 ^b
	4	3.41 ^a	3.81 ^b	4.17 ^b	4.61 ^b

¹ Means within a column with different letters differ significantly ($p < 0.05$).

The scale of texture, flavor and bitterness: 1=none, 3=moderate, 5=very strong.

The scale of overall: 1=dislike very much, 3=neither like nor dislike, 5=like very much.

² Cream was not treated with β -CD.

³ Cream was treated with powder β -CD after cream separation.

⁴ After cream separation, cream was crosslinked β -CD and blended with skim milk at 680 psi.

relatively sharply in cream cheese made by crosslinked β -CD-treated cream.

The total amount of bitter amino acids was significantly lower in cream cheese made from crosslinked β -CD-treated cream than in the control and powder β -CD-treated group. The highest concentration was found in cream cheese made

from powder β -C-treated cream (Trt A), 4.78 $\mu\text{mol/g}$ cream cheese, while the lowest concentration was in crosslinked β -CD-treated group (Trt B) as 1.73 $\mu\text{mol/g}$ cream cheese. These results suggested that the cream cheese made from crosslinked β -CD-treated cream ripened more slowly than other samples in terms of FAA production as observed as in the production of short-chain FFA (Table 2).

Rheological characteristics

The effect of β -CD treatment for textural properties on cholesterol-reduced cream cheese was shown in Table 4. Hardness was significantly higher in powder β -CD-treated group (Trt A), compared with two other groups (Control and Trt B), however, no difference was found between Control and crosslinked β -CD-treated group (Trt B). Cohesiveness was significantly higher in crosslinked β -CD-treated groups (Trt B), and gumminess was significantly higher in powder β -CD-treated cream cheese (Trt A). These results indicated that rheological characteristics in crosslinked β -CD-treated group were not different from that in the control cream cheese.

Sensory evaluation

The sensory attributes of experimental cream cheese made by β -CD-treated cream cheese stored at 5°C for 4 weeks were shown in Table 5. From 0 to 4 week, texture score decreased steadily in all groups, which may present more soft and spreadable. Also, no difference was found among three different groups.

For cream cheese flavor, cream cheese made by crosslinked β -CD-treated cream showed a similar increasing trend during storage, while the flavor

development in cream cheese made by powder β -CD-treated cream did not reach the scores of no-treated (Control) and crosslinked β -CD-treated group (Trt B). For bitterness, lower scores were presented in both β -CD-treated groups (Trt A and B) in 0 and 1 week, compared with that of control, however, the bitterness scores were developed up to the similar level after 2 week and thereafter.

Interestingly, the overall score of the cream cheese made from crosslinked β -CD-treated cream was significantly higher, compared with those of control cream cheese (Control) and cream cheese made from powder β -CD-treated cream (Trt A), especially at 3 and 4 week storage. No difference was found between Control and powder β -CD-treated group throughout storage periods. These data indicated that cream cheese made by crosslinked β -CD-treated cream may maintain longer the early stage of overall quality of cream cheese than other groups.

In conclusion, the present study showed that crosslinked β -CD-treatment of cream was an effective process for cholesterol removal in cream cheese making. In addition, the ripening during storage may be decelerated in cream cheese made from crosslinked β -CD-treated cream, which may provide a longer shelf-life like a newly-made cream cheese in chemical and sensory aspects.

ACKNOWLEDGEMENTS

This study was supported by a grant of the Korea Health 21 R and D Project, Ministry of Health & Welfare, Republic of Korea (02-PJ1-PG10-220055-0002).

REFERENCES

- Adams, M. L., D. M. Sullivan, R. L. Smith and E. F. Richer. 1986. Evaluation of direct saponification method in determination of cholesterol in meats. *J. Assoc. Anal. Chem.* 69: 844-846.
- Ahn, J. and H. S. Kwak. 1999. Optimizing cholesterol removal in cream using β -cyclodextrin and response surface methodology. *J. Food Sci.* 64:629-632.
- AOAC. 1990. Official methods of Analysis 15th ed. Association of Official Analytical Chemists, Method 948.12. Arlington, Virginia, USA.
- Grundy, S. M., D. Brheimer, H. Blackburn, W. V. Brown, P. O. Kwiterovich, F. Mattson, G. Schonfeld and W. H. Weidman. 1982. Rational of the diet-heart statement of the American Heart Association Report of the Nutrition Committee. *Circulation.* 65:839A-854A.
- Gurr, M. I. 1992. Dietary lipids and coronary disease: old evidence, new perspectives and progress. *Lipid Res.* 31:195-243.
- Hamerstrand, G. E., B. T. Hofreiter and C. L. Mehlretter. 1959. Determination of the extent of reaction between epichlorohydrin and starch. 37:519-524.
- Izco, J. M., A. Irigoyen, P. Torre and Y. Barcina. 2000. Effect of the activity levels of the added proteolytic enzyme mixture on free amino acids in ripening Ossau-Iraty cheese. *J. Chromatogr.* 881:69-79.
- Kim, S. H., E. M. Han, J. Ahn and H. S. Kwak. 2004. Crosslinking of β -cyclodextrin for cholesterol removal in milk. *Arch. Pharm. Res.* 27:1183-1187.
- Kwak, H. S., H. J. Ahn and J. Ahn. 2005. Development of phytosterol ester-added Cheddar cheese for lowering blood cholesterol. *Asian-Aust J. Anim. Sci.* 18:267-276.
- Kwak, H. S., I. J. Jeon and J. Park. 1990. Effects of food grade porcine pancreatic lipase on the production of short-chain fatty acids and its contribution. *Kor. J. Food Sci. Technol.* 22:248-254.
- Kwak, H. S., C. S. Jung, S. Y. Shim and J. Ahn. 2002. Removal of cholesterol from Cheddar cheese by β -cyclodextrin. *J. Agric. Food Chem.* 50:7293-7398.
- Kwak, H. S., C. G. Nam and J. Ahn. 2001. Low cholesterol Mozzarella cheese obtained from homogenized and β -cyclodextrin-treated milk. *Asian-Aust. J. Anim. Sci.* 14:268-275.
- Lee, D. K., J. Ahn and H. S. Kwak. 1999. Cholesterol removal from homogenized milk with β -cyclodextrin. *J. Dairy Sci.* 82:2327-2330.
- Lin, J. C. C. and I. J. Jeon. 1987. Effects of commercial food grade enzymes on fatty acid profiles in granular cheese. *J. Food Sci.* 52:78-82.
- Makoto, K., O. Akio and S. Rejiro. 1992. Cholesterol removal from animal with cyclodextrin by inclusion. Honnen LTD., assignee. Japan Pat. No. 4:168, 198.
- Mistry, V. V. and D. L. Anderson. 1993. Composition and microstructure of commercial full-fat and low-fat cheeses. *Food Struct.* 12:259-262.
- Oakenfull, D. G. and G. S. Sidhu. 1991. Cholesterol reduction. Commonwealth scientific and industrial research organization. Int. Pat. No. 91/11114.
- Sanchez, C., J. L. Beauregard, M. H. Chassagne, J. J. Bimbenet and J. Hardy. 1996. Effects of processing on rheology and structure of double cream cheese. *Food Res. Int.* 28:547-552.
- SAS[®]. 1985. Users Guide: Statistics, Version 5 Edition. SAS Inst., Inc., Cary, NC, USA.
- Szjetli, J. 1982. Chemistry and separation of cyclodextrins. In: (Ed. J. Szjetli) *Cyclodextrins and Their Inclusion Complexes*. Akademiai Kiado, Budapest, Hungary, pp. 17-43.
- Szjetli, J. 1988. Cyclodextrin inclusion complexes. In: (Ed. J. Szjetli) *Cyclodextrin Technology*. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 79-170.
- Tewari, B. D. and S. Singh. 1991. Cream cheese production. A review. *Indian J. Dairy Sci.* 44:348-351.