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Comparison of Cholesterol-reduced Cream Cheese Manufactured Using Crosslinked β-Cyclodextrin to Regular Cream Cheese

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ABSTRACT : The objective of the present study was to compare the chemical and sensory properties of regular cream cheese (control) and cholesterol-reduced cream cheese manufactured using crosslinked β-cyclodextrin (β-CD) or powdered β-CD. Crosslinked β-CD was made using adipic acid. The composition of cream cheese treated by the crosslinked β-CD was similar to the regular cream cheese. Approximately 91% of cholesterol-reduction was observed in the cheeses that were treated using β-CD, which was not significantly different between powdered vs. crosslinked β-CD treatments. Total amount of short-chain free fatty acids was significantly lower in both β-CD-treated cheeses than in the control cheese throughout the storage. The cheeses made by β-CD-treated cream produced much lower amounts of individual free amino acids than the control in all periods. Most rheological characteristics, except cohesiveness, decreased dramatically in the control compared with the cholesterol-reduced cream cheeses. In sensory attributes, both wateryness and spreadability in β-CD-treated cheeses were significantly higher than in the control during 8 wk storage. Sensory scores for sourness increased significantly in the control from 4 to 8 wk storage, however, those in the cream cheese made by crosslinked-β-CD treated cream increased slowly during 8 wk storage, which was shown in the control during a 4 wk period. Therefore, the present study showed the possibility of cholesterol-reduced cream cheese manufacture. (**Key Words** : Cream Cheese, Crosslinked β-CD, Cholesterol Removal)

INTRODUCTION

Cream cheese possesses many forms in North America and Europe, ranging from plain to flavored. In the U.S. it includes an imitation type, made up wholly of milk components, but at a lower fat concentration than prescribed by federal standards of identity. As a reflection of this fat conscious age, Cream cheese production and consumption might be expected to decline, but apparently, this is not the case. Perhaps, the excellent subtle flavors derived from a lactic acid fermentation, or the rich pool of quality nutrients, particularly milk proteins, or the many new and old culinary uses associated with cheese explain why it maintains its popularity. It is often used as a replacement for high fat spreads. The capita consumption in the U.S. of Cream and Neufchatel cheese combined increased from 0.5 kg in 1980 to 1 kg in 1995.

A main problem in many European and American cultures is high consumption of fat (Bruhn et al., 1992). It was shown, in the UK that most consumers were not prepared to sacrifice taste or any other quality of foods for any perceived health benefits (McIlveen and Armstrong, 1995). This implies that the food industry is facing a challenge to produce fat-reduced foods, which have similar properties to high-fat products. A serious problem in low-fat food products, such as cream cheese, is that both partial and total fat reduction has profound effects on the final flavor and texture (de Vor, 1991; Yackel and Cox, 1992).

Consumers have increasingly demanded reduced- and low-fat cheeses during the 1980s and 2000s; however, the removal or reduction of fat adversely affects both flavor and texture. Much research is focused on the optimization of the sensory qualities of reduced-fat cheeses. 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 powdered β-CD (Ahn and Kwak, 1999; Lee et al., 1999; Kwak et al., 2002; Shim et al., 2003; Jung et al., 2005; Lee et al., 2007). Whereas β-CD

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provides advantages when used for cholesterol removal over 90%, powdered 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. Our previous study showed cholesterol-reduced milk and cream using crosslinked β-CD and an effective recycling efficiency (Kim et al., 2004; Han et al., 2005; Han et al., 2007).

A number of studies have indicated that cholesterol-reduced dairy products did not show profound adverse aspects in chemical, rheological and sensory properties. There is a wide variety of cream cheese with different dry matters and fat content. In the U.S., in 1952 the Food and Drug Administration stated that cream cheese must not have less than 33% fat and not more than 55% moisture (Sanchez et al., 1996). The Canadian standards for cream cheese are almost the same but require a minimum of 30% fat (Kalab et al., 1981). In France, cream cheese type cheeses, such as "Triple crème", must have not less than 75% fat in dry matter (Sanchez et al., 1996).

However, littler information is available in the chemical and sensory properties of cream cheese when crosslinked β-CD was applied. The objective of this study was to compare the chemical and sensory properties of regular cream cheese and cholesterol-reduced cream cheese manufactured using crosslinked β-CD or powdered β-CD.

MATERIALS AND METHODS

Materials

Raw milk was obtained from Biggare Dairy Plants (Kyunggi-do, Korea). Commercial beta-cyclodextrin (β-CD, purity 99.1%) was purchased from Nihon Shokuhin Cako Co. Ltd. (Osaka, Japan). Cholesterol and 5α-cholestane were purchased from Sigma Chemical Co. (St. Louis, MO), and all solvents were gas-chromatographic grade.

Preparation of crosslinked β-CD

A sample of 100 g of β-CD was added in 80 ml distilled water and placed in a stirrer at room temperature with constant agitation for 2 h. Then 2 g of adipic acid was incorporated with 100 g β-CD and pH was adjusted to pH 10 with 1 N NaOH. The β-CD solution was stirred at room temperature for 90 min, and then readjusted to pH 5 with acetic acid. β-CD was recovered by filtering with Whatman paper No. 2, and washed three times with 150 ml of distilled water. The product was dried at 60°C in a Lab-line mechanical convection oven for 20 h and passed through a 100 mesh sieve (Han et al., 2005).

Treatment of cream

The raw milk obtained was pasteurized at 72°C for 15 sec and cream was separated at 40°C using a cream separator (CE Elecrem, Vanves, France). Bulk pasteurized cream (15 kg) was stirred with 10% crosslinked β-CD at 800 rpm with a blender (Tops, Misung Co., Seoul, Korea) in a temperature-controlled water bath at 20°C for 30 min. The cream was then centrifuged at 166×g for β-CD removal. All treatments were run in triplicate (Han et al., 2005).

Manufacture of cream cheese

Cholesterol-reduced cream was standardized with skim milk to a fat content of 11%, pasteurized, homogenized and cooled to the incubation temperature of approximately 30°C. The cheese-making process was described by Kosikowski and Mistry (1997). The mixture was then inoculated with a 0.05% lactic culture (CHN-22, Mesophilic aromatic culture containing *Lactococcus lactis* subsp. *cremoris*, *Lactococcus lactis* subsp. *lactis*, *Leuconostoc mesemteorides* subsp. *cremoris* and *Lactococcus lactis* subsp. *lactis biovar diacetylactis*, Chr. Hansen, Denmark) and incubated under gentle mixing. The curd was cut and ripened for 7 h to pH of 4.7. Then it was heated in coil vats to about 45°C until a proper "break" is obtained between the curd and the whey. Whey was drained and the curd was cooled to 28°C for 4 h with continuous turning. One percent of salt was added and it was drained in bags, pressed over night and stored at 4°C for 8 wk. The cheese-making experiment was carried out in triplicate on different days using different batches of treatments. Each batch of cheese making was done in triplicate.

Extraction and determination of cholesterol

For the extraction of cholesterol, 1 g of cream sample was placed in a screw-capped glass tube (15 mm×180 mm), and 500 μl of 5α-cholestane (1 mg/ml) was added as an internal standard. The sample was saponified at 60°C for 30 min with 5 ml of 2 M ethanolic potassium hydroxide solution (Adams et al., 1986). After cooling to room temperature, cholesterol was extracted with 5 ml of hexane (Adams et al., 1986). The process was repeated four times. The hexane layers were transferred to a round-bottomed flask and dried under vacuum. The extract was redissolved in 1 ml of hexane and was stored at -20°C until analysis.

Total cholesterol was determined on a silica fused capillary column (HP-5, 30 m×0.32 mm I.D.×0.25 μm thickness) using Hewlett-Packard 5890A gas chromatography (Palo Alto, CA) 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 hold for 20 min at 300°C. 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

Table 1. Mean chemical composition of cholesterol-reduced cream cheese treated by crosslinked β-CD[1]

Component	Control[2]	Powdered[3]	Crosslinked[4]
Moisture (%)	55.9[a]	56.0[a]	57.1[a]
Fat (%)	33.1[a]	32.7[a]	32.3[a]
Protein (%)	8.5[a]	8.3[a]	7.9[a]
Yield (%)	33.5[a]	34.2[a]	35.9[a]
Cholesterol removal (%)	-	91.8[a]	91.4[a]
Cholesterol (mg/100 g cheese)	95.0	7.8	8.2

[1] Means within a row with different letters differ significantly ($p<0.05$).
[2] Cream was not treated with β-CD.
After cream separation, cream was treated with either powdered β-CD[3] or crosslinked β-CD[4] and blended with skim milk at 680 psi.

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 cream cheese×100/amount of cholesterol in control). Cholesterol determination for control was averaged with each batch of treatments.

Analysis of chemical composition and yield of cheese

Cheese was analyzed for moisture, fat, salt and protein using the methods of the Association of Official Analytical Chemists (AOAC, 1984). Cheese yield was determined as wt cheese×100/wt milk.

Analysis of short-chain fatty acids

Cheese samples (1 g) were removed periodically from the cheeses for 0, 2, 4, 6 and 8 wk, extracted with diethyl ether 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 free fatty acids (FFAs) was achieved using a 15 m×0.53 mm i.d. Nukol fused-silica capillary column (Supelco Inc., Bellefonte, PA). The GC was operated with helium carrier gas at 2 ml/min, hydrogen gas at 37 ml/min, and air at 300 ml/min. The column oven was programmed for an initial holding for 1 min at 110°C, heating to 180°C at 5°C/min for 10 min, and holding for 20 min. The temperature for both the injector and detector was 250°C. All qualitative analyses were done by relating each peak area of individual FFAs to the peak area of tridecanoic acid as an internal standard. Each FFA was identified by the retention time of a standard.

Analysis of free amino acids

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 a 600 pump and a 486 tunable absorbance deector at 254 nm, oprerated using Millennium software. The column used was a Waters PicoTag C_{18} reversed-phase column maintained at 46°C. For identification of amino acids, methionine sulfone was added as an internal standard. A gradient with two solvents was used to run the sample: solution A, comprised of 70 mM sodium acetate adjusted to pH 6.55 with acetic acid and containing 2.5% acetonitrile; and solution B, containing 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×4.5 cm height) were cut, and force-distance curves were obtained using a Sun Rheometer (CR-200D, Sun Scientific Co., LTD., Tokyo, Japan) with a crosshead of 50 nm/min and a chart speed of 100 mm/min. From these curves, the basic characteristics of the texture profile were determined, including hardness, elasticity, cohesiveness, gumminess, and chewiness. The point of highest force during the first compression was the hardness. The extent to which the sample returned to its shape between the first and second compressions was the elasticity. The ratio of the area under the second compression curve was the cohesiveness. Gumminess and chewiness were calculated as hardness×cohesiveness and gumminess×elasticity, respectively.

Sensory analysis

For the sensory test, cholesterol-reduced cream cheese was stored at 4°C for 0, 2, 4, 6 and 8 wk. A ten-trained panel evaluated randomly coded cream cheese. The texture, color, flavor and taste were evaluated on a 9-point scale (1 = extremely weak, 3 = very weak, 5 = moderate, 7 = very strong, 9 = extremely strong). A randomized, balanced, complete block design was used (Cochran and Cox, 1957) that resulted in two replications for all samples.

Statistical analysis

One-way ANOVA (SAS, 1985) was used. The significance of the results was analyzed by the least significant difference (LSD) test. Difference of $p<0.05$ was considered to be significant.

RESULTS AND DISCUSSION

Cholesterol removal and composition

To find out whether a difference existed in cholesterol removal between treatments, cholesterol content was measured as shown in Table 1. The cholesterol content of the control cheese was 95 mg/100 g. The cholesterol reduction reached 91.4-91.8% when treated with 10% powdered or crosslinked β-CD. Our previous studies showed similar reduction in milk (Han et al., 2005) and egg

Table 2. Concentration of short-chain free fatty acids in cholesterol-reduced cream cheese by crosslinked β-CD during storage at 4°C for 8 wk[1]

Storage period (wk)	Treatment	Short-chain FFA concentration (ppm)				
		C_4	C_6	C_8	C_{10}	Total
0	Control[2]	4.19^{cd}	5.21^{c}	12.54^{b}	24.10^{b}	46.04^{c}
	Powdered[3]	4.18^{cd}	3.44^{e}	5.58^{c}	6.60^{de}	19.80^{de}
	Crosslinked[4]	3.41^{d}	2.39^{f}	3.86^{d}	5.04^{e}	14.70^{e}
2	Control	4.38^{cd}	5.46^{c}	13.20^{b}	26.44^{b}	49.48^{bc}
	Powdered	4.37^{cd}	3.79^{de}	5.82^{c}	7.04^{de}	21.02^{d}
	Crosslinked	3.55^{d}	2.75^{ef}	4.10^{d}	5.95^{e}	16.35^{e}
4	Control	4.81^{c}	5.70^{c}	13.98^{b}	28.75^{a}	53.24^{b}
	Powdered	4.84^{c}	4.17^{d}	5.95^{c}	7.54^{d}	22.50^{d}
	Crosslinked	3.68^{d}	3.12^{e}	4.22^{cd}	6.88^{de}	17.90^{e}
6	Control	5.66^{bc}	6.57^{b}	15.01^{ab}	30.59^{a}	57.83^{b}
	Powdered	5.11^{c}	4.70^{cd}	6.17^{c}	8.77^{d}	24.75^{d}
	Crosslinked	3.94^{cd}	3.49^{e}	4.36^{cd}	7.96^{d}	19.75^{de}
8	Control	7.73^{a}	8.09^{a}	17.27^{a}	32.65^{a}	65.74^{a}
	Powdered	6.44^{b}	5.53^{c}	6.71^{c}	10.53^{c}	29.21^{d}
	Crosslinked	4.80^{c}	4.07^{d}	4.63^{cd}	9.21^{c}	22.71^{d}

[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 either powdered β-CD[3] or crosslinked β-CD[4] and blended with skim milk at 680 psi.

(Jung et al., 2005) when they were treated with crosslinked β-CD.

In the cream cheese, the moisture content was 55.9%, and the fat content was 33.1%. Cholesterol-reduced cream cheeses showed similar composition in terms of moisture, total fat, and protein. In our previous study, stirring with β-CD resulted in slow whey drainage in reduced-cholesterol Cheddar cheese (Kwak et al., 2002). A lower fat content of the cholesterol-reduced cheese than the control may be resulted by the less incorporation with casein via a fat-protein network probably due to modification of casein matrix by β-CD.

Short-chain free fatty acids

It is well known that short-chain fatty acids (C_4 through C_{10}) are primarily responsible for cheese flavor (Lin and Jeon, 1987). Therefore, the concentration of short-chain FFA was considered to be an important aspect of this study. The amount of short-chain FFAs in the control and cholesterol-reduced cheeses stored for 8 wk at 4°C is shown in Table 2. The total amount of short-chain FFAs was significantly lower in cheeses treated by the powdered or the crosslinked β-CD than in the control group at every storage period ($p<0.05$).

The caprylic acid (C8) and capric acid (C10) mostly contributed to the increase of total amount of FFAs in all groups. In the control, the amount of total short-chain FFAs increased from 46.4 to 65.7 ppm, while it increased from 14.7 to 22.7 ppm for the cholesterol-reduced cream cheese during 8 wk storage. These results indicated that the cream cheeses made from both powdered or crosslinked β-CD-treated cream had lower concentration of short-chain FFAs throughout the storage. The reason of the lower concentration of short-chain FFAs in the treated cheese may be explained by the weak network between fat and casein because of β-CD.

The interesting thing we found was that the amount of short-chain FFA in crosslinked β-CD-treated group was 22.7 ppm at 8 wk storage, which was even lower than that of short-chain FFA level of control at 0 wk. In control group, total short-chain FFA amounts were significantly higher at 0 wk storage and increased up to 65.7 ppm at 8 wk ($p<0.05$). Comparatively, in both powdered or crosslinked β-CD treated groups, less than 30 ppm of short-chain FFA amounts were determined at 8 wk.

Free amino acids

The determination of total free amino acids (FAA) during 8 wk of storage is shown in Table 3. The cheeses made by β-CD–treated cream produced much lower amounts of individual FAAs than the control in all periods. Total amount of FAA was 31.7 μmol/g cheese in the control and 16.8 μmol/g cheese in the cream treatment group after 8 wk storage. All individual amino acids were increased highly in control than in cholesterol-reduced cream cheeses. Especially, from 0 to 4 wk, FAA was increased sharply in control, however, that was increased steadily in cream cheese made by crosslinked-β-CD. In terms of amount of individual amino acids produced, serine, tyrosine, threonine, arginine, leucine and lysine dominated in all samples. The amount of serine was the highest in all storage periods. In addition, the cream cheese treated by crosslinked β-CD kept the bitter amino acid concentration lower than the control and powered β-CD-treated cheese throughout storage

Table 3. Concentration of free amino acids in cholesterol-reduced cream cheese by crosslinked β-CD during storage at 4°C for 8 wk[1]

Storage period (wk)	Treatment	Asp	Glu	Ser	Asn	Thr	Arg	Tyr (μmol/g)	Val	Met	Ile	Leu	Phe	Lys	Total FAA
0	Control[2]	0.05	0.21	0.99	0.24	0.50	0.57	0.69	0.22	0.04	0.10	0.42	0.09	0.53	4.50
	Powdered[3]	0.06	0.29	0.57	0.26	0.58	0.70	0.81	0.20	0.11	0.09	0.46	0.17	0.72	5.02
	Crosslinked[4]	0.06	0.28	0.6	0.21	0.49	0.52	0.77	0.20	0.13	0.07	0.43	0.15	0.70	4.61
2	Control	0.12	0.29	0.87	0.35	0.74	0.62	0.76	0.28	0.09	0.25	0.61	0.15	0.68	5.81
	Powdered	0.08	0.38	0.69	0.35	0.68	0.82	1.07	0.41	0.22	0.16	0.85	0.21	0.90	6.82
	Crosslinked	0.07	0.33	0.72	0.35	0.59	0.69	0.89	0.27	0.22	0.12	0.64	0.16	0.82	5.87
4	Control	0.24	0.40	1.13	0.51	1.03	0.82	1.21	0.40	0.18	0.48	0.75	0.22	1.05	8.42
	Powdered	0.15	0.51	1.03	0.51	0.80	1.27	1.32	0.69	0.39	0.28	1.27	0.25	1.15	9.62
	Crosslinked	0.19	0.51	0.86	0.49	0.71	0.93	1.08	0.35	0.33	0.20	0.89	0.19	0.99	7.72
6	Control	0.51	0.99	2.95	0.83	2.21	1.75	2.73	0.70	0.62	0.75	1.77	0.48	2.34	18.63
	Powdered	0.28	0.94	2.24	0.74	1.28	2.08	1.91	0.92	0.86	0.59	1.91	0.31	1.94	16.00
	Crosslinked	0.31	0.73	1.15	0.61	1.00	1.29	1.31	0.50	0.57	0.25	1.12	0.22	1.26	10.32
8	Control	0.94	2.15	4.53	1.20	3.44	3.59	4.11	1.17	1.30	1.09	3.17	0.74	4.27	31.70
	Powdered	0.61	1.88	4.47	1.15	2.69	2.46	3.18	1.33	2.14	1.08	2.74	0.44	3.16	27.33
	Crosslinked	0.44	1.25	2.78	0.76	1.81	2.01	1.86	0.73	0.82	0.41	1.64	0.28	2.08	16.87

[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 either powdered β-CD[3] or crosslinked β-CD[4] and blended with skim milk at 680 psi.

Table 4. Rheological properties of cholesterol-reduced cream cheese by crosslinked β-CD during the storage at 4°C for 8 wk[1]

Storage (wk)	Treatment	Cohesiveness (%)	Hardness (dyne/cm^2)	Elasticity (g)	Gumminess (g)
0	Control[2]	60.5^b	2,669.1^a	82.0^a	28.6^{ab}
	Powdered[3]	77.4^a	2,137.5^c	84.2^a	34.1^a
	Crosslinked[4]	78.9^a	1,947.1^d	87.3^a	35.9^a
2	Control	62.3^b	2,500.7^a	71.9^{ab}	27.5^{ab}
	Powdered	78.6^a	2,050.7^{cd}	75.2^a	31.0^a
	Crosslinked	81.0^a	1,827.2^e	76.4^a	33.6^a
4	Control	63.5^b	2,311.4^b	60.1^b	26.3^{ab}
	Powdered	80.1^a	1,900.1^d	67.5^b	26.6^{ab}
	Crosslinked	83.0^a	1,701.1^f	68.9^b	31.4^a
6	Control	57.2^{bc}	1,992.3^d	41.6^{cd}	22.5^b
	Powdered	70.4^{ab}	1,784.4^f	58.8^{bc}	23.9^b
	Crosslinked	83.8^a	1,571.6^g	58.7^{bc}	27.6^{ab}
8	Control	47.2^c	1,259.5^h	22.9^d	18.0^c
	Powdered	60.9^b	1,711.1^f	53.6^c	22.4^b
	Crosslinked	84.5^a	1,509.0^g	52.9^c	24.9^b

[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 either powdered β-CD[3] or crosslinked β-CD[4] and blended with skim milk at 680 psi.

period (data not shown). These results indicated that less amount of FAA in the β-CD–treated were found and it is probably due to the modification of casein matrix by β-CD treatment.

Rheological characteristics

The effect of β-CD treatment on textural properties of cholesterol-reduced cream cheese is shown in Table 4. In the control, most properties except cohesiveness were decreased more dramatically compared with those in the cholesterol-reduced groups throughout 8 wk storage. Comparatively, cohesiveness was increased in cream cheese made by crosslinked β-CD whereas those were decreased in other groups. Elasticity score in control group was 60.1 at 4 wk and dramatically decreased to 22.9 at 8 wk. However, elasticity in crosslinked β-CD-treated cream cheese was 52.9 at 8 wk storage, which was quiet close to that in control at 4 wk storage. Similar trend was found in gumminess score.

Sensory characteristics

The sensory attributes of reduced-cholesterol cream cheese are shown in Table 5. The most significant difference was found in watery and spreadability characteristics between control and crosslinked β-CD-treated cream cheese. Both watery and spreadability in cream cheese made by the corsslinked β-CD were significantly higher in the control than even at 0 wk storage. This could be attributed that homogenization of cream in β-CD-treated cheeses may result in more content of water in experimental cheese, thus spreadability was increased.

The most interesting finding was sourness and butter in

Table 5. Sensory characteristics in cholesterol-reduced cream cheese by crosslinked β-CD during storage at 4°C for 8 wk[1]

Storage (wk)	Treatment	Yellowish	Watery	Sourness	Butter flavor	Sourness taste	Butter taste	Bitterness taste	Granularity	Spreadability	Overall
0	Control[2]	5.0^{c}	5.0^{b}	5.0^{cd}	5.0^{a}	5.0^{bc}	5.0^{a}	5.0^{bc}	5.0^{bc}	5.0^{c}	5.0^{cd}
	Powdered[3]	4.8^{c}	5.1^{b}	4.0^{d}	4.9^{a}	4.0^{d}	4.7^{a}	4.3^{c}	4.8^{b}	5.5^{bc}	6.4^{b}
	Crosslinked[4]	5.0^{c}	5.9^{a}	5.0^{cd}	4.8^{a}	4.8^{c}	4.9^{a}	3.0^{d}	4.2^{c}	6.1^{b}	7.5^{a}
2	Control	5.2^{bc}	4.4^{c}	5.5^{c}	4.9^{a}	5.6^{b}	4.8^{a}	5.3^{b}	5.3^{b}	4.9^{c}	7.1^{a}
	Powdered	5.1^{bc}	5.0^{b}	4.4^{d}	4.8^{a}	4.1^{d}	4.1^{b}	4.4^{c}	5.1^{b}	5.2^{c}	5.8^{c}
	Crosslinked	5.3^{b}	5.7^{a}	5.2^{c}	5.0^{a}	5.0^{bc}	5.1^{a}	3.4^{d}	4.3^{c}	6.3^{b}	7.5^{a}
4	Control	5.3^{b}	4.2^{c}	5.6^{c}	4.8^{a}	5.9^{b}	4.7^{a}	5.8^{b}	5.5^{b}	4.5^{c}	6.5^{b}
	Powdered	5.3^{b}	4.7^{bc}	4.9^{cd}	4.7^{a}	4.6^{c}	4.0^{b}	5.0^{bc}	5.5^{b}	5.0^{c}	5.4^{c}
	Crosslinked	5.4^{b}	5.9^{a}	5.4^{c}	5.3^{a}	5.2^{bc}	4.9^{a}	3.7^{cd}	4.5^{bc}	6.5^{ab}	7.2^{a}
6	Control	5.6^{ab}	3.9^{d}	6.9^{ab}	4.0^{b}	6.7^{ab}	3.8^{b}	6.9^{a}	6.2^{a}	3.7^{d}	4.6^{d}
	Powdered	5.8^{a}	4.5^{c}	5.8^{bc}	3.4^{c}	5.3^{bc}	3.7^{b}	6.2^{ab}	5.9^{a}	4.6^{c}	5.0^{cd}
	Crosslinked	5.7^{a}	6.0^{a}	5.5^{c}	5.2^{a}	5.7^{b}	4.8^{a}	4.4^{c}	4.7^{b}	6.8^{a}	6.9^{b}
8	Control	5.8^{a}	3.3^{d}	7.4^{a}	3.2^{c}	7.3^{a}	3.4^{c}	7.3^{a}	6.4^{a}	3.1^{d}	3.7^{e}
	Powdered	5.9^{a}	4.4^{c}	6.1^{b}	2.5^{d}	5.7^{b}	3.4^{c}	6.9^{a}	6.0^{a}	4.6^{c}	4.3^{d}
	Crosslinked	5.8^{a}	6.2^{a}	5.6^{c}	4.8^{a}	5.4^{bc}	4.8^{a}	5.3^{b}	4.9^{b}	7.2^{a}	6.9^{b}

[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 either powdered β-CD[3] or crosslinked β-CD[4] and blended with skim milk at 680 psi.

both flavor and taste. In both sourness flavor and taste, the score in control were 5.6 and 5.9 at 4 wk and kept increasing up to 7.4 and 7.3 at 8 wk storage, respectively, which were strong. Comparatively, those in crosslinked β-CD-treated cholesterol-reduced cream cheese were slowly increased to 5.6 and 5.4 at 8 wk storage, which were not different from that at 4 wk in the control group ($p>0.05$). Butter flavor and taste showed the decreasing trend in control, however, those were maintained in β-CD-treated cheeses throughout 8 wk storage. Since the dramatic increase in the control cream cheese for last 4 wk could be a reason of the 4 wk shelf-life of cream cheese, no change in sourness in crosslinked β-CD-treated cream cheese may provide the possibility of prolonged shelf-life. Other sensory properties, such as bitterness and granularity were maintained in cream cheese made by crosslinked-β-CD as the level of control at 4 wk.

Based on the above results, the sensory scores of 4 wk storage in the control were compared with those of β-CD-treated cholesterol-reduced cream cheeses.

CONCLUSION

The present study designed to develop a cholesterol-reduced cream cheese by crosslinked β-CD, and to compare the chemical, textural, and sensory properties of regular cream cheese and β-CD-treated cream cheeses using either powdered or crosslinked β-CD. Approximately 91% cholesterol-reduction was observed in the cheeses that were treated using β-CD. The amounts of free fatty acids and free amino acids were lower in the cholesterol-reduced cream cheese than in the control throughout storage. Interestingly, the amount of free fatty acids in crosslinked β-CD-treated cream cheese at 8 wk was similar to that in the control at 4 wk. Additionally, we found that in sensory analysis, both taste and flavor of sour and buttery properties of the crosslinked β-CD-treated cream cheese reached to the score of the control at 4 wk and were maintained up to 8 wk storage. Therefore, the present study may provide the possibility of cholesterol-reduced cream cheese manufacture.

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