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Properties of Cholesterol-reduced Block-type Process Cheese Made by Crosslinked β-Cyclodextrin

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베타사이클로덱스트린 처리에 의한 콜레스테롤 저하 블록형 가공치즈의 특성

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Abstract

The objective of the present study was to compare the chemical, rheological and sensory properties of regular process cheese (control) and cholesterol-reduced block-type process cheese. The cholesterol-reduced process cheese was made by accelerated ripened cholesterol-reduced Cheddar cheese and cholesterol-reduced butter treated by crosslinked β-cyclodextrin (β-CD). The composition of the block-type process cheese was similar to the control cheese. Approximately 91.0% of cholesterol removal was observed when treated by crosslinked β-CD. The production of total free amino acids was significantly higher in cholesterol-reduced process cheese in all storage periods compared with those in the control. In sensory analysis, a significantly higher score of acidic, salty and bitterness, and lower score of elasticity were found. However, no difference was found in free fatty acids, rheological properties, and TBA test between the control and cholesterol-reduced process cheese. Therefore, the present study indicated that even though some of the significant difference was observed in sensory properties in the cholesterol-reduced block-type process cheese, most of chemical and rheological properties were comparable to the control process cheese.

Key words : block-type process cheese, cholesterol removal, crosslinked β-cyclodextrin

Introduction

Process cheese is a dairy product which differs from natural cheese in the fact that process cheese is not made directly from milk. Process cheese is produced by blending natural cheese of different ages and degrees of maturity in the presence of emulsifying salts, and other dairy and nondairy ingredients followed by heating and continuous mixing to form a homogenous product with an extended shelf life (Meyer, 1973; Thomas, 1973; Caric and others, 1985; Guinee *et al.*, 2004).

The popularity of process cheese can be attributed to its numerous end-use applications (Kapoor and Metzger, 2008). According to Sorensen (2001), process cheese is one of the leading cheese varieties in the world that is used as an ingredient in various food preparations (processed foods and food service). In the United States, process cheese is produced as sold in various forms such as loaves, slices, shreds and spreads, and is used as an ingredient in numerous products. The versatility of process cheese can be attributed to its unique functional properties. In addition, texture and meltability of process cheese are widely influenced by the chemical compositions used during manufacture and the proportion of moisture, fat and emulsifying salts added to the blend (Fagan *et al.*, 2007).

Recently, most consumers were not prepared to sacrifice taste or any other quality of foods for any perceived health benefits (Sipahioglu *et al.*, 1999). This implies that the food industry faces a challenge to produce fat-reduced foods, which have similar properties to high-fat products. However, a serious problem in low-fat cheese is that fat reduction has

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profound effects on the final flavor and texture, such as quick disappearance of flavor made lost of the fullness of texture (Bruhn *et al.*, 1992). Thus, much research is focused on the optimization of the sensory and texture qualities of reduced-fat cheeses. Our previous studies have shown the possibility for development of cholesterol-reduced dairy products (Kwak *et al.*, 2002; Shim *et al.*, 2003; Kim *et al.*, 2006; Han *et al.*, 2007), however, little information is available about the effects of the cholesterol reduction on physicochemical and rheological properties of process cheese.

In our previous study (Kwak *et al*, 2002; Seon *et al.*, 2008), it was reported that β-CD treated cream prior to cheese manufacture showed an accelerated ripening in Cheddar cheese. Therefore, the aims of this study were to develop the cholesterol-reduced process cheese made by crosslinked β-CD and to compare the change of physicochemical and sensory characteristics of cholesterol-reduced process cheese throughout the storage.

Materials and Methods

Materials

Raw milk was obtained from Yonam College (Cheonan, Korea) and cream for butter manufacture was obtained from Seoul Dairy Co-op. (Ansan, Korea). Commercial powdered beta-cyclodextrin (β-CD, purity 99.1%) was purchased from Nihon Shokuhin Cako Co., Ltd. (Osaka, Japan). Emulsifying salt was purchased from BK Ladenburg (Bundesrepublik, Germany) and formulated as approx. 60% of sodium citrate, approx. 5% of potassium polyphosphates and approx. 35% of sodium polyphosphates). All chemical and solvents were purchased from Sigma Chemical Co. (St. Louis, MO, USA).

Preparation of crosslinked β-CD and cholesterol removal

A crosslinked β-CD preparation and cholesterol removal were followed the procedure described in our previous study (Han *et al.*, 2007).

Manufacture of block-type process cheese

For Cheddar cheese as natural cheese manufacture, cholesterol-reduced cream and skim milk were reconstituted and homogenized with 500 psi at 50°C and cooled to the incubation temperature of approximately 32°C (Kwak *et al.*, 2002). The cheese-making process was followed as described by Kosikowski and Mistry (1997). The Cheddar cheese was vacuum-packaged and ripened at 4°C for 9 wk for later use. Cholesterol-reduced butter was manufactured as described by Kim *et al.* (2006). For cholesterol-reduced process cheese manufacture, ripened Cheddar cheese and butter were formulated as followed: 72% of cholesterol-reduced Cheddar cheese which blended with 50% 3 wk ripened, 20% 6 wk ripened and 30% 9 wk ripened Cheddar cheese, 10% of butter, 3% emulsifying salt, 5% of skim milk powder and 10% of water. The cholesterol-reduced process cheese was made by both cholesterol-reduced Cheddar cheese (3, 6, and 9 wk ripened) and cholesterol-reduced butter. Control cheese were manufactured with mixing of commercial Kraft cheese labeled as mild, medium and sharp and commercial butter (Seoul Dairy Co-op., Ansan, Korea). The cheese-making experiment was carried out in triplicate on different days using different batches of treatments.

Analysis of chemical composition and thiobarbituric acid (TBA) test

Cheese was analyzed for moisture, fat and protein using the methods of the Association of Official Analytical Chemists (1984). Cholesterol removal was determined as described by Kwak *et al.* (2002). Oxidation products were analyzed spectrophotometrically using the TBA test described by Hegenauer *et al.* (1979).

Analysis of short-chain free fatty acids (FFAs) and free amino acids (FAAs)

For short-chain FFAs, cheese samples (1 g) were removed periodically, extracted with diethyl ether and hexane for 2 hr, and eluted through a 10 mm i.d. glass column containing neutral alumina, as described by Kwak *et al.* (2002). A Hewlett-Packard model 5880A GC equipped with a flame ionization detector was used and 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.

RP-HPLC analysis of the FAAs was performed according to our previous study (Kwak *et al.*, 2002). Samples were analyzed on a waters HPLC system consisting of a 600 pump and 486 tunable absorbance detector at 254 nm, operated using Millenium software.

Rheological analysis

Cylindrical samples (1.5 cm diameter x 1.5 cm height) were cut, and force-distance curves were obtained from using a Sun Rheometer (CR-200D, Sun Scientific Co., Ltd., Tokyo, Japan) with a crosshead of 50 nm/min and a chart speed of 200 mm/min.

Sensory analysis

The cholesterol-reduced process cheese was stored at 4°C throughout 6 mon, and ten-trained panels evaluated randomly coded cheese. The appearance, flavor, taste and texture were evaluated on a 7-point scale (1=none, 4=moderate, and 7= strong). Also, the overall acceptance was on a 7-point scale (1=dislike very much, 4=neither like nor dislike and, 7=like very much).

Statistical analysis

One-way ANOVA (SAS, 1985) was used and 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 cheese composition

The composition of Cheddar cheese as a natural cheese and butter which was used as a major ingredient for cholesterol-reduced block-type process cheese were shown in Table 1. The cholesterol content of control process cheese was 122.0 mg/100 g, and 91.0% of the cholesterol was reduced by 10% crosslinked β-CD treatment. Cholesterol-reduced process cheese showed a similar composition to the control in terms of moisture, total fat and protein (Table 2). This study indicated that the crosslinked β-CD treatment did not significantly affect the chemical composition of the process cheese.

In our previous studies (Kwak *et al.*, 2002; Kim *et al.*, 2005; Han *et al.*, 2007; Bae *et al.*, 2008, Kim *et al.*, 2008), stirring with β-CD resulted in high water retention and slow whey drainage in cholesterol-reduced cheese products. In addition, a lower fat content of the cholesterol-reduced cheese than the control was expected since more fat would be released due to the smaller size of fat globules, resulting from stirring. It may be that the fat globule was too small to incorporate with casein or the protein compound via a fat-protein network. However, in the process cheese, we did not find the lower moisture content. This could be explained by that the mixing of ripened Cheddar cheese and butter may compromise the moisture content during ripening.

Table 1. Mean chemical composition of cholesterol-reduced Cheddar cheese and butter treated by crosslinked β-cyclodextrin

Component	Cholesterol-reduced Cheddar cheesel[1]	Cholesterol-reduced butter[2]
Moisture (%)	39.9±0.60	18.6±0.31
Fat (%)	29.4±0.70	78.6±0.30
Protein (%)	23.4±0.11	1.8±0.06
Cholesterol (mg/100g cheese)	10.2±0.22	20.4±0.17
Cholesterol removal (%)	91.5±0.13	90.5±0.21

[1] After cream separation, cream was treated with crosslinked β-CD and blended with skim milk at 500 psi.
[2] Cream was treated with crosslinked β-CD.

Table 2. Mean chemical composition of cholesterol-reduced block-type process cheese treated by crosslinked β-cyclodextrin

Component	Control[2]	Cholesterol-reduced[3]
Moisture (%)	39.1±0.82[a1)]	39.8±0.06[a]
Fat (%)	29.3±0.40[a]	29.3±0.40[a]
Protein, (%)	24.8±0.15[a]	25.4±0.30[a]
Cholesterol (mg/100g cheese)	122.0±0.21	11.0±0.24
Cholesterol removal (%)	-	91.0±0.21

[1] Means within a row with different letters differ significantly ($p<0.05$).
[2] Commercial process cheese was purchased.
[3] Cholesterol-reduced Cheddar cheese and butter were blended.

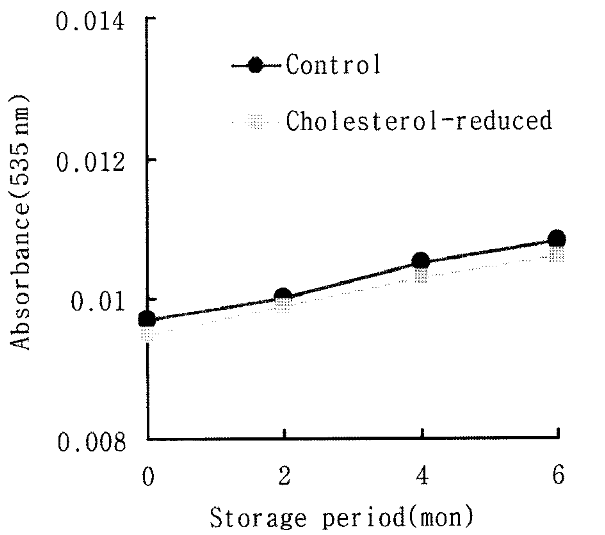

Fig. 1. Changes in thiobarbituric acid values (TBA) in cholesterol-reduced block-type process cheese stored at 4°C for 6 mon. Control, commercial process cheese; Cholesterol-reduced, cholesterol-reduced process cheese made by 10% crosslinked β-cyclodextrin-treated cream.

Thiobarbituric acid (TBA) test throughout the ripening

TBA absorbance was significantly different between the control and the cholesterol-reduced cheese made by crosslinked β-CD treatment throughout 0 to 6 mon storage (Fig. 1). From 0 to 6 mon storage, the TBA value increased steadily up to 6 mon in both groups. This result was in accordance to our previous studies (Lee *et al.*, 2007; Bae *et al.*, 2008), which indicated that no significant difference in

TBA value between β-CD-untreated and treated yogurt (Lee *et al.*, 2007) and cholesterol-reduced Camembert cheese (Bae *et al.*, 2008) throughout 4 wk storage.

Short-chain free fatty acids (FFAs)

The amount of short-chain FFAs in the control and cholesterol-reduced process cheese stored at 4°C for 6 mon is shown in Table 3. There was no difference between the control and the cholesterol-reduced cheese in total amount of short-chain FFAs in every storage period. A slight but significant increase was observed in both total and individual FFAs at 6 mon storage (p<0.05) in both cheeses. In the control, the amount of total short-chain FFAs increased from 63.4 to 67.2 ppm, and it increased from 63.2 to 65.9 ppm for the cholesterol-reduced process cheese during 6 mon storage. Above results indicated that there was no difference in amounts of short-chain FFAs between the control and the cholesterol-reduced process cheese made by crosslinked β-CD-treated Cheddar cheese and not much difference was found throughout the storage.

Free amino acids (FAAs)

The production of total free amino acids (FAAs) during 6 mon storage is shown in Table 4. The principal amino acids present in both cheeses were glutamic acid, serine, threonine and leucine. Significant increase in total free amino acid production was found in the cholesterol-reduced cheese at every storage period compared with those in the control. Total amount of FAAs was 64.9 μmol/g cheese in the control and 76.0 μmol/g cheese in the cholesterol-reduced cheese at 0 mon, and those were reached to 69.6 and 78.1 μmol/g cheese at 6 mon storage, respectively. These results indicated that the cholesterol-reduced process cheese made by crosslinked β-CD-treated Cheddar cheese produced more total FAAs amounts than that in the control throughout 6 mon storage.

Table 3. Concentration of short-chain free fatty acids in cholesterol-reduced block-type process cheese by crosslinked β-cyclodextrin during storage at 4°C for 6 mon

Treatment	Storage (month)	Short-chain free fatty acid (ppm)				
		C_4	C_6	C_8	C_{10}	Total
Control[2)]	0	17.4±0.0$^{a1)}$	15.5±0.0^{a}	11.9±0.1^{a}	18.6±0.1^{a}	63.4±0.1^{a}
Cholesterol-reduced[3)]		17.3±0.1^{a}	15.5±0.0^{a}	11.9±0.1^{a}	18.5±0.2^{a}	63.2±0.2^{a}
Control	2	17.5±0.0^{a}	15.7±0.0^{a}	12.0±0.1^{a}	18.7±0.2^{a}	63.8±0.1^{a}
Cholesterol-reduced		17.5±0.0^{a}	15.6±0.0^{a}	12.0±0.0^{a}	18.6±0.1^{a}	63.7±0.2^{b}
Control	4	17.8±0.2^{a}	15.8±0.14^{a}	12.3±0.3^{a}	18.7±0.1^{a}	64.6±0.4^{a}
Cholesterol-reduced		17.4±0.1^{a}	15.6±0.1^{b}	12.3±0.3^{b}	18.7±0.1^{a}	64.0±0.3^{a}
Control	6	18.2±0.0^{a}	16.4±0.1^{a}	13.3±0.3^{a}	19.4±0.2^{a}	67.2±0.2^{a}
Cholesterol-reduced		18.0±0.1^{a}	16.0±0.2^{a}	12.9±0.2^{a}	19.0±0.1^{a}	65.9±0.1^{a}

[1]Means within a column with different letters differ significantly (p<0.05).
[2]Commercial process cheese was purchased.
[3]Cholesterol-reduced Cheddar cheese and butter were blended.

Table 4. Production of free amino acids in cholesterol-reduced block-type process cheese by crosslinked β-cyclodextrin during storage at 4°C for 6 mon (unit: μmol/g)

Treatment	Storage (month)	Asp	Glu	Ser	Thr	Arg	Ala	Tyr	Met	Val	Phe	Ile	Leu	Lys	Total
Control[2]	0	1.69	12.35	6.67	6.66	1.61	3.44	1.99	0.78	1.52	6.21	1.01	10.79	4.45	64.9±12.0$^{b1)}$
Cholesterol-reduced		2.88	15.84	8.72	6.04	3.37	4.25	3.37	1.48	3.83	6.59	1.48	11.71	7.48	76.0±5.5^{a}
Control	2	1.77	13.74	7.37	6.77	1.75	4.57	2.23	0.82	1.73	6.91	0.82	11.03	4.65	64.5±11.9^{b}
Cholesterol-reduced		2.91	15.84	8.72	6.04	2.31	4.26	3.38	1.49	3.80	6.70	1.49	11.72	7.47	76.2±5.4^{a}
Control	4	1.78	13.98	7.71	7.11	1.78	4.73	2.21	0.85	1.77	6.99	0.85	11.12	5.52	67.1±6.0^{b}
Cholesterol-reduced		2.92	15.85	8.63	6.05	2.31	4.27	3.39	1.51	3.85	6.72	1.51	11.73	7.53	76.3±5.3^{a}
Control	6	1.85	14.52	7.74	7.94	1.72	4.70	2.24	0.99	1.82	7.29	0.99	11.23	6.00	69.6±10.6^{b}
Cholesterol-reduced		2.97	15.86	9.07	6.28	2.68	4.39	3.40	1.51	4.09	6.77	1.51	11.96	7.56	78.5±5.3^{a}

[1]Means within a column with different letters differ significantly (p<0.05).
[2]Commercial process cheese was purchased.
[3]Cholesterol-reduced Cheddar cheese and butter were blended.

Our previous studies (Bae *et al.*, 2008; Kim *et al.*, 2008) showed a different result indicating that the cholesterol-reduced Blue (Kim *et al.*, 2008), Camembert (Bae *et al.*, 2008) and Feta cheese (Bae *et al.*, 2008) had a slightly lower amount of FAAs compared with the control cheese, however, it was not significantly different (p>0.05). In the Cheddar cheese study (Seon *et al.*, 2008), total amount of FAA in the cholesterol-reduced cheese reached similar amounts of FAA to that of control cheese ripened for longer period. This suggests that the cheese made from β-CD-treated showed an accelerated ripening in terms of FAA production. In present, it may not be clearly explained, however, β-CD treatment may partly explain the accelerated proteolysis.

Proteolysis in cheese is caused by the action of rennet retained in the curd, plasmin of the milk and proteases and peptidases off the starter cultures used. Protease activity leads to a large amount of peptides, the so-called soluble fraction in a cheese. These peptides are further degraded to small peptides and free amino acids, the amino-nitrogen fraction in cheese protease and peptidase activities are dependent on the starter culture used. For this reason, a lot of attention has been paid to the used starter cultures and lactic acid bacteria, which enhance ripening and flavor formation in cheese (Smit *et al.*, 2000; Yvon, 2006).

Rheological characteristics

The effect of crosslinked β-CD treatment on textural properties of cholesterol-reduced process cheese is shown in Table 5. No significant difference was found between the control and cholesterol-reduced cheeses in all rheological characteristics and all characteristics were not changed throughout storage. Therefore, we may suggest that the rheological characteristics of cholesterol-reduced process cheese may not be affected by the β-CD treatment.

Sensory characteristics

The sensory attributes of cholesterol-reduced process cheese are shown in Table 6. In appearance, yellowish color was significant in cholesterol-reduced cheese at 0 and 1 mon storage in the cholesterol-reduced cheese compared with that

Table 5. Rheological properties of cholesterol-reduced block-type process cheese by crosslinked β-cyclodextrin during storage at 4°C for 6 mon

Treatment	Storage (month)	Hardness	Cohesiveness	Elasticity	Gumminess	Brittleness
Control[2)]	0	146.2±0.6[a1)]	9.0±0.1[a]	9.4±0.1[a]	1314.5±6.1[a]	12341.6±12.3[a]
Cholesterol-reduced[3)]		146.3±0.1[a]	9.0±0.1[a]	9.1±0.3[a]	1322.8±5.2[a]	12038.9±14.2[a]
Control	2	146.2±0.6[a]	9.1±0.1[a]	9.4±0.1[a]	1323.8±5.4[a]	12366.3±13.3[a]
Cholesterol-reduced		146.3±0.1[a]	9.1±0.1[a]	9.1±0.3[a]	1324.9±0.4[a]	12065.5±14.2[a]
Control	4	146.2±0.6[a]	9.2±0.1[a]	9.5±0.1[a]	1338.4±4.9[a]	12692.8±13.2[a]
Cholesterol-reduced		146.3±0.1[a]	9.2±0.1[a]	9.1±0.2[a]	1340.6±1.7[a]	12231.1±12.3[a]
Control	6	146.3±0.6[a]	9.2±0.1[a]	9.5±0.1[a]	1340.6±5.4[a]	12726.4±13.3[a]
Cholesterol-reduced		146.3±0.1[a]	9.2±0.1[a]	9.1±0.1[a]	1341.9±0.6[a]	12251.8±14.1[a]

[1]Means within a column with different letters differ significantly (p<0.05).
[2]Commercial process cheese was purchased.
[3]Cholesterol-reduced Cheddar cheese and butter were blended.

Table 6. Sensory characteristics in cholesterol-reduced block-type process cheese by crosslinked β-cyclodextrin during storage at 4°C for 6 mon

Treatment	Storage (month)	Appearance		Flavor		Taste			Texture			Overall
		Yellowness	Shiny	Processed	Balanced	Acidic	Salty	Bitterness	Elasticity	Crumbly	Slimy	
Control[2]	0	3.8±0.2[a1)]	4.0±0.6[a]	4.4±0.2[a]	4.5±0.1[a]	3.8±0.0[a]	3.8±0.0[a]	3.1±0.1[a]	4.4±0.4[b]	4.4±0.2[a]	3.3±0.2[a]	4.3±0.1[a]
Cholesterol-reduced[3]		4.2±0.2[b]	4.0±0.6[a]	4.8±0.2[a]	4.8±0.1[a]	4.4±0.2[b]	4.4±0.0[b]	4.1±0.0[b]	3.3±0.3[a]	4.6±0.2[a]	4.1±0.3[b]	5.3±0.1[b]
Control	2	3.9±0.3[a]	4.0±0.5[a]	4.2±0.2[a]	4.4±0.1[a]	3.8±0.1[a]	4.0±0.1[a]	3.3±0.0[a]	4.5±0.2[b]	4.5±0.3[a]	3.4±0.2[a]	4.5±0.1[a]
Cholesterol-reduced		4.1±0.4[b]	4.0±0.5[a]	4.5±0.2[a]	4.6±0.2[a]	4.3±0.2[b]	4.0±0.1[a]	4.2±0.1[b]	3.4±0.2[a]	4.6±0.3[a]	4.1±0.2[b]	5.4±0.1[b]
Control	4	4.1±0.1[a]	4.0±0.5[a]	4.2±0.2[a]	4.4±0.0[a]	3.7±0.1[a]	4.0±0.0[a]	3.5±0.1[a]	4.5±0.2[b]	4.5±0.2[a]	3.6±0.2[a]	4.5±0.0[a]
Cholesterol-reduced		4.2±0.2[a]	4.0±0.5[a]	4.4±0.2[a]	4.6±0.0[a]	4.3±0.1[b]	4.0±0.0[a]	4.3±0.1[b]	3.5±0.1[a]	4.5±0.2[a]	4.2±0.1[b]	5.4±0.1[b]
Control	6	4.0±0.4[a]	4.0±0.1[a]	4.3±0.3[a]	4.4±0.1[a]	3.7±0.0[a]	4.0±0.0[a]	3.5±0.0[a]	4.5±0.2[b]	4.0±0.2[a]	3.5±0.2[a]	4.5±0.0[a]
Cholesterol-reduced		4.0±0.4[a]	4.0±0.1[a]	4.3±0.2[a]	4.5±0.1[a]	4.2±0.1[b]	4.0±0.0[a]	4.3±0.1[b]	3.3±0.2[a]	4.0±0.3[a]	4.3±0.1[b]	5.4±0.1[b]

[1]Means within a column with different letters differ significantly (p<0.05).
[2]Commercial process cheese was purchased.
[3]Cholesterol-reduced Cheddar cheese and butter were blended.

in the control, however, it became similar between both groups at 4 and 6 mon storages. In shiny characteristics, no significant difference was observed between two cheeses throughout the storage. In addition, flavor characteristics including processed and balanced scores were not significantly different between the groups.

In taste, acidic, salty and bitterness scores were significantly higher in the cholesterol-reduced cheese than those in the control ($p<0.05$), and there was no difference in taste scores during the storage period. Crumbly scored in texture properties showed the similar trend, which was a sharp decrease at 6 mon storage. However, other characteristics such as elasticity and slimy showed the significant difference between the control and the cholesterol-reduced cheese. The elasticity score was significantly lower and slimy score was significantly lower in the cholesterol-reduced cheese throughout the storage. The overall preference was maintained with the storage period and a significantly higher score was observed in the cholesterol-reduced process cheese than the control at every storage period. The present study indicated that while the cholesterol-reduced process cheese showed the higher acidic, salty and bitterness scores, and lower elasticity, overall acceptability was higher than the control cheese. Therefore, we may suggest the possibility of cholesterol-reduced block-type process cheese manufactured by crosslinked β-CD treatment.

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