Low Cholesterol Mozzarella Cheese Obtained from Homogenized and β-Cyclodextrin-Treated Milk

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ABSTRACT : The effects of homogenization conditions and β-cyclodextrin (β-CD) on cholesterol removal of Mozzarella cheese were examined. The homogenization pressure influenced markedly on the cholesterol removal in milk and, 75.64% of cholesterol, the highest rate, was removed at 70.0 kg/cm^2. In addition, an increase in temperature resulted in an increase of cholesterol removal in the range of 71.75 to 78.22%. Among different concentrations of β-CD addition, 1.0% showed 78.21% of cholesterol removal. Therefore, cholesterol-reduced Mozzarella cheese was made by cheese milk treated with 70 kg/cm^2 homogenization at 70℃ and 1% β-CD addition for a subsequent study. The cholesterol reduction of cholesterol-reduced Mozzarella cheese was 63.92%. Meltability, stretchability and oiling-off in cholesterol-reduced cheese were significantly lower than those in control. Hardness, gumminess and chewiness were significantly reduced, while cohesiveness and elasticity increased. Appearance and flavor of the cheese were superior, but texture inferior to the control. *(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 2 : 268-275)*

Key Words : Cholesterol Removal, β-Cyclodextrin, Mozzarella Cheese, Homogenization

INTRODUCTION

A traditional Italian product, Mozzarella cheese is now well known in the U.S., Asian and European countries. Especially, in Asia, the expanding popularity of pizza has caused an increase of Mozzarella cheese consumption dramatically over the past 10 years (Kosikowski and Mistry, 1997). However, most consumers are concerned about the excessive intake of cholesterol (Grundy et al., 1982; Gurr, 1992). Therefore, physical, chemical, and biological methods to reduce cholesterol have been studied in food containing dairy products (Ahn and Kwak, 1999; Lee et al., 1999).

A number of studies have been indicated that the removal of cholesterol in milk and cream was effectively conducted by β-cyclodextrin (β-CD) (Ahn and Kwak, 1999; Lee et al., 1999; Makoto et al., 1992; Oakenfull and Sihdu, 1991). Beta-CD is a cyclic oligosaccaride composed of seven glucose units linked by α-(1-4) bonds. It has a cavity at the center of the molecule which allows complex formation with cholesterol (Szejtli, 1982; Vollbrecht, 1991). β-CD is nontoxic, edible, non-hygroscopic, chemically stable and easy to separate (Nagamoto, 1985). Thus, it has positive attributes when used for the removal of cholesterol from foods. To apply this method to Mozzarella cheese, milk must be homogenized prior to the cheese making process because of a low rate of cholesterol removal (30%) of unhomogenized milk by β-CD (unpublished).

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Homogenization of milk adversely affects protein structure and causes casein micelles and their subunits to be incorporated into the fat globule membranes. These interactions between fat and casein lead to a weaker rennet curd, curd shattering, and improper curd matting (Metzger and Mistry, 1993). Therefore, milk used for full fat Mozzarella cheese is not usually homogenized.

A study indicated that homogenization in the manufacture of Mozzarella cheese from cow milk resulted in reduction of milk solids losses in whey and fat leakage when used on pizza (Jana and Upadhyay, 1993a). Jana and Upadhyay (1993a) reported that homogenization of buffalo milk led to reduced fat leakage and meltability during baking on pizza, while significant reduction in the hardness, cohesiveness, springiness, gumminess and chewiness (Jana and Upadhyay, 1993b). In addition, homogenization of milk for Mozzarella cheese making has been used to improve the yield and texture of the cheese, and impart a white color to the product (Anderson et al., 1993; Tunick et al., 1995).

Our objectives were to determine optimum homogenization conditions of cheese milk on cholesterol reduction, fat leakage, textural properties and behaviors of Mozzarella cheese.

MATERIALS AND METHODS

Materials

Raw milk was obtained from Kon-Kuk Dairy Plant (Seoul, Korea) and adjusted to 3.5% milk fat by skim milk. Commercial β-CD (purity 99.1%) was purchased from Nihon Shokuhin Kaku Co. LTD. (Osaka, Japan). Cholesterol and 5α-cholestane were purchased from Sigma Chemical Co. (St. Louis, MO, USA) and all solvents were gas chromatographic grade.

Cholesterol removal of milk

To study the effects of 3 different factors, milk was homogenized in a single stage homogenizer (HC 5000, Microfluidics Corp., Newton, MA, USA) with different homogenization pressures (17.5, 35, 52.5 and 70 kg/cm^2) and temperatures (40, 50, 60 and 70℃). Fifty grams of the milk was placed in a 1000-ml beaker, and then different concentrations of β-CD (0.5, 1.0, 1.5 and 2.0%) were added. The mixture was stirred at 800 rpm with a blender (Misung Co., Seoul, Korea) in a temperature-controlled waterbath at 10℃ for 10 min. The mixture was then centrifuged with 72 $\times$g for 10 min (HMR-220IV, Hanil Industrial Co., Seoul, Korea).

For each treatment after centrifugation, the supernatant containing cholesterol-reduced milk was decanted and used for cholesterol determination. All treatments were run in triplicate.

Manufacture of Mozzarella cheese

The cheese milk was standarized for 3.5% milk fat, pasteurized at 72℃ for 17 s, and homogenized with different pressures (52.5, 70 and 91 kg/cm^2). The milk was then cooled to 10℃, mixed with β-CD, stirred and centrifuged as mentioned above. The cholesterol-reduced milk (15 kg) was warmed up to 36℃. A frozen concentrated direct vat set mesophilic lactic starter culture designed for Mozzarella cheese (TCC-3, Chr. Hansen's Lab., Denmark) was added to the cheese milk with the percentage of 0.004, followed by $CaCl_2$ (10% Ca) with 0.03%. After 30 min of ripening, rennet (Standard Plus 900, Chr. Hansen's Lab., Denmark) was added with 0.019%. Curd was formed in 20 to 30 min and cut with 1.2 cm wire knife and allowed to heal for 15 min. It was cooked at 45℃ for 40 min and developed whey acidity with 0.18 to 0.19%. Whey was then drained at 0.22-0.24% whey acidity. Curds were washed with tap water at 45℃ with same volume of the drained whey. Curds were piled in the center of the vat. Curd slabs were turned every 15 min until the curd reached the desired whey acidity (0.5-0.6%). Curds slabs were heated in tap water at 70-80℃, stretched manually for 7 min and molded. The molded cheese was cooled in cold water at 4℃ for 2 h and brined in 23% brine solution for 2 h. The cheese was vacuum packaged (Turbovac, Howben Food Equipment, Hertogenbosch, The Netherlands) in a barrier bag and stored at 4℃. The cheese making experiment was replicated on different days using different batches of homogenized pressure. Each batch of cheese making was triplicated.

Extraction and determination of cholesterol

For the extraction of cholesterol in milk, 1 and 0.25 g of the β-CD-treated milk and cheese were placed in screw-capped glass tube (15 mm$\times$180 mm), and 1 mL and 0.25 mL of 5α-cholestane (1 mg/mL) was added as an internal standard, respectively. The samples were saponified with 5 mL of 2 M ethanolic potassium hydroxide solution at 60℃ for 30 min for milk and saponified with 10 mL of KOH solution at 80℃ for 2 h (Adams et al., 1986) for Mozzarella cheese. After cooling to room temperature, cholesterol was extracted with 5 mL of hexane (Adams et al., 1986). The process was replicated 4 times. The hexane layers were transferred to a round-bottomed flask and dried under vacuum. The extract was re-dissolved in 1 mL hexane and stored at -20℃ 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 μm thickness) using Hewlett-Packard 5890A gas chromatograph (Palo Alto, CA, USA) equipped with a flame ionization detector. The temperatures of injector and detector were 270 and 300℃, respectively. The oven temperature was programmed from 200 to 300℃ at 10 ℃/min and held for 20 min. Nitrogen was used as a carrier gas at a flow rate of 2 mL/min. The sample injection volume was 2 μL 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 milk$\times$ 100/ amount of cholesterol in untreated milk). Cholesterol determination for control was done with each batch of treatment.

Compositional analysis and cheese yield

Total protein, fat, moisture, ash, and salt were measured by the AOAC (1990). Cheese yield was determined by Jana and Upadhyay (1993b) as follows: wt. cheese$\times$100/ wt. Milk.

Meltability and stretchability

Meltability was determined by the Schreiber test, in which the expansion of a disk of cheese (18 mm diameter and 5 mm thickness) was measured on a target graph of numbered concentric circles after 5 min in a 232℃ oven (Tunick et al., 1995).

For stretchability, the grated cheese (10 g) was placed on a slice of white bread (1$\times$10$\times$10 cm) and heated for 1 min in microwave oven and cooled for 1 min. The melted cheese was assessed subjectively for stretching by placing a fork into the cheese layer, lifting and measuring the distance the cheese stretched without breaking (Lemay et al., 1994) and ranking as followed: over 30 cm=5, 2030 cm=4, 10-20 cm=3, under 10 cm=2, and under 5 cm=1.

Oiling-off

Grated cheese sample (6 g : particle size 5 mm or less) was prepared at ambient temperature as quickly as possible, after which samples were placed in tightly sealed plastic bags and tempered at 4℃ for 2 h or longer to allow temperature equilibration.

All cheeses were analyzed on the same day and they were grated. Each grated sample was accurately weighed into a 200 mm screw pyrex tube. The tube with sample was immersed in boiling water for 4 min and then removed. Immediately, 10 mL of acidified water (pH 2.2 with HCl) at 60℃ were dispersed onto the melted sample. The sample tube was then centrifuged in a Gerber centrifuge for 5 min. After centrifugation, 10 mL of 1:1 distilled water: methanol (v/v) at ambient temperature were added. The sample tube was then placed in the 60℃ water bath for 1 min, centrifuged 2 min, and again tempered at 60℃ for 1 min.

This treatment resulted in a distinct yellow butteroil layer at the surface of the aqueous methanol. The butteroil layer was quantitatively transferred to a Gerber bottle using a Pasteur pipet. The aqueous methanol was also transferred to the bottle, rinsing the pipet free of butteroil residue. When necessary, a small amount of additional 1:1 distilled water: methanol was added to force the fat column completely into the calibrated neck of the bottle.

The Gerber bottle was stoppered tempered at 60℃ for 1 min, centrifuged for 2 min, tempered at 60℃ and additional 2 min, and then measured. If only curd particle was present in the calibrated neck, the bottle was recentrifuged for 5 min to achieve complete separation of curd from the column of butteroil. The measured value was divided by two to give free oil value expressed as percentage in cheese.

Table 1. Effect of various homogenization pressures on cholesterol removal in milk[1,2]

Homogenization pressure	Cholesterol removal
(kg/cm^2)	(%)
0	30.29^e
17.5	35.64^d
35.0	49.17^c
52.5	64.88^b
70.0	75.64^a
SEM	1.07

a,b Means within a column with different superscript letter differ ($p<0.05$).

1 Means of triplicate.

2 Other experimental factors included homogenization temp., 60℃; β-cyclodextrin added, 1%; mixing speed, 800 rpm; mixing temp, 10℃; mixing time, 10 min; centrifugal force, 72×g, and centrifugation time, 10 min.

Texture

Cylindrical samples (2 cm diameter×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, cohesiveness, and springiness. 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×cohesiveness, and gumminess ×elasticity, respectively.

Sensory evaluation

A trained sensory panel (eight panelists) evaluated randomly coded cheese. Flavor, texture and appearance were evaluated on a 7-point scale (1=poor to 7=excellent).

Statistical analysis

Data from the determination of optimum conditions of cholesterol-reduced Mozzarella cheese, one-way ANOVA (SAS Institute Inc., Cary, NC, USA, 1985) was used. For the effect of homogenization pressure on textural and sensory properties, 3×4 randomized block design 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

Effect of homogenization pressure

The effect of homogenization pressure on cholesterol removal in milk is shown in table 1. The homogenization pressure influenced markedly on the cholesterol removal when homogenized at 60℃ and treated with 1% β-CD. Without homogenization (control), the cholesterol removal revealed only 30.29%, while 75.64% of cholesterol, the highest rate, was removed with 70 kg/cm^2 pressure.

This result could be confirmed by our two previous studies, which indicated that at most 30% of cholesterol was removed in unhomogenized milk (unpublished) and 95.9% cholesterol removal under 154 kg/cm^2 of homogenization (Lee et al., 1999). The reason for the necessity of homogenization of cholesterol removal in the process is that about 80% of milk cholesterol exists in fat globule, thus the surface area of the fat globule should be increased for an effective adsorption of β-CD to cholesterol molecule.

The pressure for milk homogenization is generally used in the range of 70 to 200 kg/cm^2. In Mozzarella cheese manufacturing, high pressure of milk homogenization resulted in poor hardness, elasticity and gumminess (Jana and Upadhyay, 1993a). Based on our data, we selected 70 kg/cm^2 as an optimum homogenization pressure for an effective cholesterol removal in the cheese milk (table 1).

Effect of homogenization temperature

Cholesterol removal was also significantly affected by homogenization temperature (table 2), when homogenized at 70 kg/cm^2 and treated with 1% β-CD. An increase in temperature resulted in an increase in cholesterol removal (71.75 to 78.22%). The difference among four different temperatures was significant, but not pronounced. These data suggested that the cholesterol removal was enhanced with an increase of homogenization temperature up to 70℃. Another study also reported that the effective temperature of homogenization in milk was between 60 and 70℃ (Jana and Upadhyay, 1993a). Therefore, the optimum temperature of homogenization was selected at 70℃.

Effect of β-CD concentration

The effect of β-CD concentration on cholesterol removal in milk when homogenized with 70 kg/cm^2 at 70℃ is shown in table 3. With different concentrations of β-CD (0.5, 1.0, 1.5, and 2.0%), cholesterol removal was in the range of 46.19% to 86.05%. Between 0.5 and 1.0% β-CD addition, a dramatic increase was found, however, above 1.0% addition did not show a marked increase (78.21% to 86.05%). Even though 1.5% addition showed a significantly higher rate, 1.0% of β-CD addition could be effective enough for cholesterol removal. The reason is that using a commercial β-CD is costly and the waste from the process may result in an environmental problem. Thus, 1.0% β-CD was selected as a cholesterol adsorbent for cholesterol-reduced Mozzarella cheese.

In our previous study, β-CD concentration (0.5, 1.0 and 2.0%) resulted in 92.2, 94.0, and 88.6% of cholesterol removal in commercial market milk, respectively (Lee et al., 1999). The difference of cholesterol removal between the two experiments may have resulted from the difference of homogenization pressure.

Yield

The effect of homogenization on the yield of Mozzarella cheese is shown in table 4. The yield was higher in all experimental cheeses than control, which was not homogenized. However, the cheese yield was

Table 2. Effect of various homogenization temperatures on cholesterol removal in milk[1,2]

Homogenization temperature	Cholesterol removal
(%)	(%)
40	71.75[c]
50	72.95[c]
60	75.71[b]
70	78.22[a]
SEM	0.41

[a,b] Means within a column with different superscript letter differ ($p<0.05$).

[1] Means of triplicate.

[2] Other experimental factors included homogenization pressure, 70 kg/cm^2; β-cyclodextrin added, 1%; mixing speed, 800 rpm; mixing temp., 10℃; mixing time, 10 min; centrifugal force, 72×g; and centrifugation time, 10 min.

Table 3. Effect of various β-cyclodextrin concentrations on cholesterol removal in milk[1,2]

β-CD concentration	Cholesterol removal
(%)	(%)
0.5	46.19[c]
1.0	78.21[b]
1.5	83.29[a]
2.0	86.05[a]
SEM	1.3

[a,b] Means within a column with different superscript letter differ ($p<0.05$).

[1] Means of triplicate.

[2] Other experimental factors included homogenization pressure, 70 kg/cm^2; homogenization temp., 70℃; mixing speed, 800 rpm; mixing temp., 10℃; mixing time, 10 min; centrifugal force, 72×g; and centrifugation time, 10 min.

Table 4. Effect of various homogenization pressures in treated milk with 1% β-CD on yield of Mozzarella cheese[1]

Homogenization pressure	Yield
(kg/cm^2)	(%)
0[2]	10.54[a]
52.5	12.53[b]
70	12.58[b]
91	12.59[b]

[a,b] Means within a column with different superscript letter differ ($p<0.05$).

[1] Means of triplicate.

[2] Mozzarella cheese made from unhomogenized milk (control).

not significantly different among homogenization pressures.

Jana and Upadhyay (1993a) reported that the yield increased in proportion to the homogenization pressure up to a certain homogenization pressure level. It could be explained by the fact that fat and protein recoveries were significantly higher in homogenized milk cheese due to reduced losses of fat, protein and total solid in whey or molding water (Jana and Upadhyay, 1993a).

Cholesterol removal

The composition was presented in table 5. Although the moisture content and moisture to protein ratio of the experimental cheese tended to be higher, no significant differences were detected in the levels of other components. The cholesterol content of the control cheese (23.80% milk fat) was 81.47 mg/100 g. The increase of homogenization pressure significantly enhanced the cholesterol removal in the Mozzarella cheese (table 6). The cholesterol reduction reached 68.43% with 91 kg/cm^2 pressure.

Meltability

The homogenization pressure significantly affected the meltability of the Mozzarella cheese at 0, 52.5 and 70 kg/cm^2, but meltability was not significantly different between 52.5 and 70 kg/cm^2 homogenization pressures (table 7). The control cheese showed 3.32 cm, which the highest among treatments.

Meltability decreased with homogenization (Tunick et al., 1995), which agreed with our result. It is well accepted that homogenization of milk breaks down the fat globule membrane: casein micelles or submicelles are then adsorbed onto the lipid droplets as pseudo-fat globule membranes, hindering the spread of the melted fat (Lelievre et al., 1990).

Stretchability

The homogenization pressure adversely influenced the stretchability of Mozzarella cheese (table 8). The stretchability of control made without β-CD addition was the highest. No difference was found among different pressures of homogenization. It was reported that homogenization milk resulted in poor curd stretching behavior in the manufacture of Mozzarella cheese (Lelievre et al., 1990). Lelievre et al. (1990) found that stretchability of Mozzarella cheese decreased with homogenization; they theorized that this was a result of the interaction of casein that had been adsorbed onto that fat globule.

Oiling-off

An increasing homogenization pressure markedly reduced the oiling-off properties (table 9). Our result is consistent with other studies (Rudan and Barbano, 1998; Tunick et al., 1993).

Rudan and Barbano (1998) reported that cheese

Table 5. Mean chemical composition of cholesterol-reduced Mozzarella cheese[1]

Component	Control cheese	Cholesterol-reduced cheese
Moisture,%	48.61^a	52.39^a
Fat, %	23.80^a	23.69^a
Protein, %	23.46^a	20.88^a
Moisture:Protein	2.07^a	2.51^b
Salt, %	0.92^a	0.93^a

^{a,b} Means within a column with different superscript letter differ ($p<0.05$).

[1] Means of triplicate.

[2] Other experimental factors included homogenization pressure, 70 kg/cm^2; homogenization temp., 70℃; mixing speed, 800 rpm; mixing temp., 10℃; mixing time, 10 min; centrifugal force, 72×g; and centrifugation time, 10 min.

Table 6. Effect of various homogenization pressures in treated milk with 1% β-CD on cholesterol removal from Mozzarella cheese[1]

Homogenization pressure	Cholesterol removal
(kg/cm^2)	(%)
52.5	51.19^a
70	63.92^b
91	68.43^c
SEM	0.88

^{a,b} Means within a column with different superscript letter differ ($p<0.05$).

[1] Means of triplicate.

[2] Other experimental factors included homogenization temp., 70℃; mixing speed, 800 rpm; mixing temp, 10℃; mixing time, 15 min; centrifugal force, 72×g; and centrifugation time, 10 min.

Table 7. Effect of various homogenization pressures in treated milk with 1% β-CD on meltability in Mozzarella cheese[1]

Homogenization pressure	Meltability
(kg/cm^2)	(cm)
0	3.32^a
52.5	2.82^b
70	2.37^c
91	2.25^c
SEM	0.04

^{a,b} Means within a column with different superscript letter differ ($p<0.05$).

[1] Means of triplicate.

[2] Mozzarella cheese made from unhomogenized milk (control).

made by homogenization expressed virtually no oiling-off, but the control cheese had about 3% oiling-off (as a percentage of fat in the cheese). In addition, Tunick et al. (1993) found that homogenization of milk used to make Mozzarella cheese (ca. 25% fat) significantly decreased that amount of oiling-off. They indicated that the reduction on fat particle size and the subsequent changes in the cheese structure were responsible for the change in oiling-off (Tunick et al., 1993).

The oiling-off test is important because an excess of oiling-off in the surface of a pizza after baking is a major quality defect for Mozzarella cheese manufactures (Kindstedt and Rippe, 1990). However, Rudan and Barbano (1998) demonstrated that lack of oiling-off in the critical event that limits shred melting and allows scorching of fat-free and lower fat Mozzarella cheese.

In our study, cholesterol-reduced Mozzarella cheese did not show any symptoms of scorching of the surface, excessive browning, or atypical burnt appearance with many dark brown intact shreds.

Texture

The cheese made by the homogenized milk and treated with 1% β-CD exhibited a significantly lower hardness, gumminess, and chewiness, but higher cohesiveness and elasticity values when compared with those of control cheese (table 10).

Tunick et al. (1993) compared the rheology of reduced fat Mozzarella cheese prepared from homogenized and unhomogenized milks. Homogenization at 10.3 MPa and higher resulted in Mozzarella cheese showing a greater hardness value than control made from unhomogenized milk. They hypothesized that this result was due to cross-linking (chemical bonding) of the casein on the newly formed fat globule in the cheese matrix.

Jana and Upadhyay (1993b) indicated that the cheese made from homogenized milk showed significantly lower hardness, cohesiveness, springiness, gumminess and chewiness values compared with those of control. Emmons et al. (1980) also found that homogenization of milk tended to decrease the hardness and elasticity of Cheddar cheese.

On the other hand, Schafer and Olson (1975) did not found any adverse effect on the rheological characteristics of Mozzarella cheese, when made from

Table 8. Effect of various homogenization pressures in treated milk with 1% β-CD on stretchability in Mozzarella cheese[1]

Homogenization pressure (kg/cm²)	Stretchability
0[3]	5[a]
52.5	2[b]
70	2[b]
91	2[b]

[a,b] Means within a column with different superscript letter differ ($p<0.05$).
[1] Means of triplicate.
[2] Sretchability was scored using a 1-5 scale; 5, >30 cm; 4, 20-30 cm; 3, 10-20 cm; 2, 5-10 cm; 1, <5 cm.
[3] Mozzarella cheese made from unhomogenized milk (control).

Table 9. Effect of various homogenization pressures in treated milk with 1% β-CD on oiling-off in Mozzarella cheese[1]

Homogenization pressure (kg/cm²)	Oiling-off (% of cheese fat)
0[3]	2.46[a]
52.5	0.67[b]
70	0.37[cd]
91	0.30[d]
SEM	0.03

[a,b] Means within a column with different superscript letter differ ($p<0.05$).
[1] Means of triplicate.
[2] Mozzarella cheese made from unhomogenized milk (control).

Table 10. Effect of various homogenization pressures on textural properties of Mozzarella cheese made from milk treated with 1% β-cyclodextrin[1]

Homogenizatio pressure (kg/cm²)	Hardness (kg/cm²)	Cohesiveness	Elasticity (cm)	Gumminess (kg)	Chewiness (kg/cm²)
0[2]	5.46[a]	0.96[a]	0.93[a]	5.24[a]	4.87[a]
52.5	2.33[b]	1.04[b]	1.02[b]	2.42[b]	2.47[b]
70	2.20[b]	1.05[b]	1.02[b]	2.30b[b]	2.35[b]
91	2.10[b]	1.08[b]	1.03[b]	2.27b[b]	2.34[b]
SEM	0.07	0.02	0.02	0.12	0.12

[a,b] Means within a column with different superscript letter differ ($p<0.05$).
[1] Means of triplicate.
[2] Mozzarella cheese made from unhomogenized milk (control).

separately homogenized milk imparted with UHT heat treatment (Schafer and Olson, 1975). In addition, Rudan and Barbano (1998) indicated that no significant difference in hardness and springiness (measured at 10℃) from treatment was detected. The cohesiveness tended to be higher for the sample than for the control.

Sensory quality

The sensory attribute of Mozzarella cheese was studied in appearance, texture and flavor in table 11. The appearance was significantly lower in control cheese, compared with those of others. The appearance of the cheese was improved with an increase of homogenization pressure. The experimental cheese was observed to be whiter and possessed better surface sheen, while the control cheese had a white color with a yellowish tinge as reported by others (Oakenfull and Sihdu, 1991; Jana and Upadhyay, 1993a, b).

The major effect of homogenization is on the characteristics of physical distribution of the fat in cheese. The homogenization significantly reduced the fat globule size, which resulted in a change in the microstructure of the cheese. A reduction in the fat particle size made the unmelted cheese whiter and less yellow (Rudan and Barbano, 1998). Lemay et al. (1994) demonstrated that full fat Cheddar cheese made from microfluidized milk or microfluidized cream was whiter than the control (no microfluidization). They hypothesized that the decrease milk fat globules increased the light scattering of the cheese, leading to an increase in whiteness, which was consistent with our result.

The characteristic of flavor was slightly improved by increasing homogenization pressure, however, no significant difference was found among samples. Rao et al. (1985) found that mean flavor scores decreased as homogenization pressure increased in Cheddar cheese.

The texture attribute of the cheese was ranked significantly lower in control, but the increasing pressure did not show a significant difference. Other studies indicated that the experimental cheese was observed to be smooth, pliable and had a homogeneous body, but lacked the characteristic fibrous or chewy texture, while the control cheese had the characteristic fibrous and chewy texture (Jana and Upadhyay, 1993a, b). The improved body and texture of the cheese may by due to the increased fat globule surface area in milk produced by homogenization.

Table 11. Effect of various homogenization pressures on textural properties of Mozzarella cheese made from milk treated with 1% β-cyclodextrin[1]

Homogenization pressure	Oiling-off		
	Appearance	Flavor	Texture
(kg/cm^2)			
0[3]	4.00^a	4.00^a	4.00^a
52.5	4.89^b	4.25^a	1.78^b
70	5.11^{bc}	4.50^a	1.67^b
91	5.56^c	4.63^a	1.44^b
SEM	0.19	0.31	0.26

[a,b] Means within a column with different superscript letter differ ($p<0.05$).

[1] Means of triplicate.

[2] As the value from 1 to 7, the intensity of sensory characteristics increases. The score of the control was 4.

[3] Mozzarella cheese made from unhomogenized milk (control).

CONCLUSION

This study suggested that the optimum condition of homogenization and β-CD addition on cholesterol-reduced Mozzarella cheese manufacture were 70 kg/cm^2 of homogenization pressure, 70℃ of homogenization temperature and 1.0% addition of β-CD. Cholesterol-reduced Mozzarella cheese showed 63.92% cholesterol removal using the above conditions.

Compared with control, cholesterol-reduced Mozzarella cheese showed a decrease in stretchability and texture. This study showed a possibility in the manufacture of cholesterol-reduced by the application of β-CD.

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